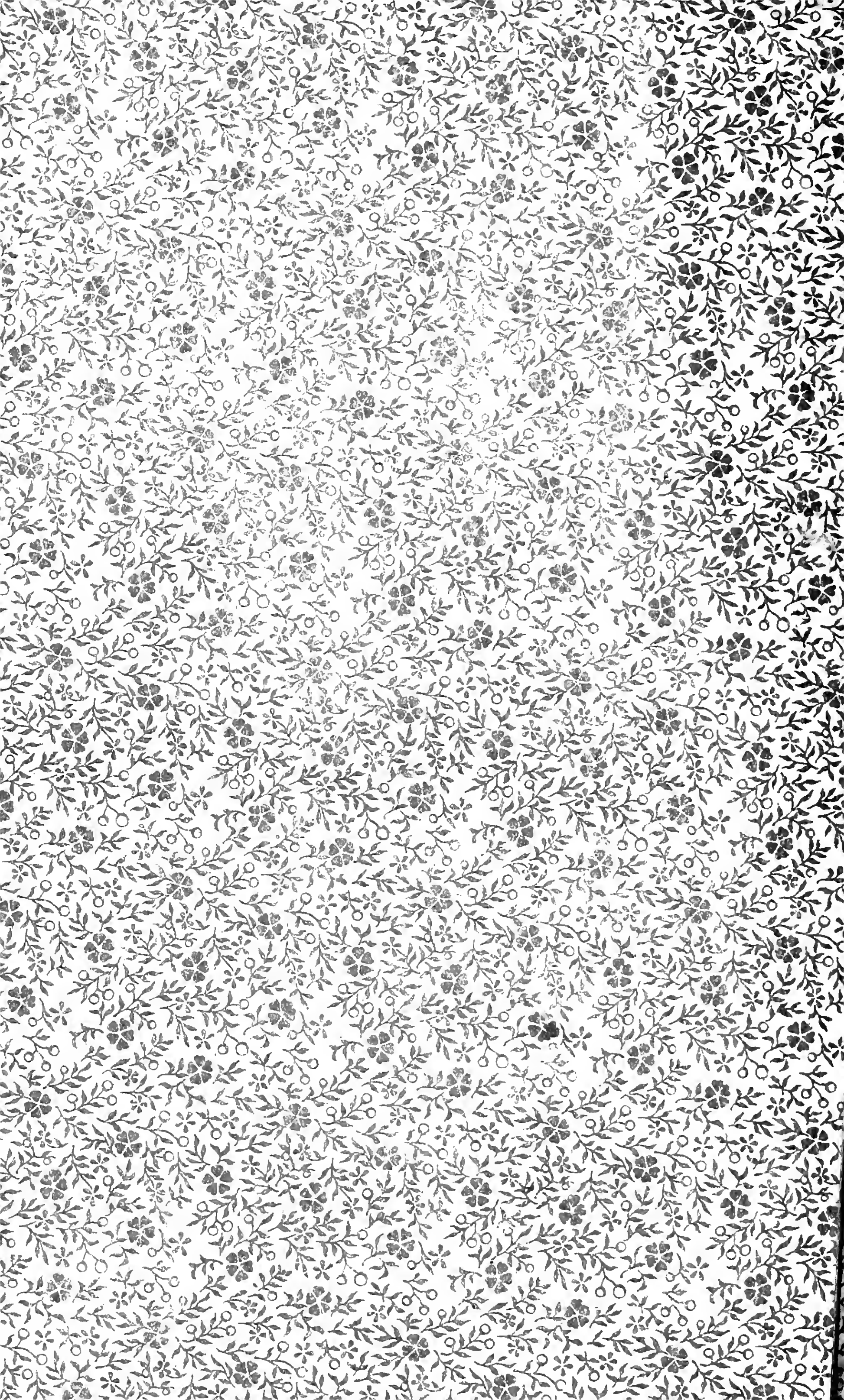

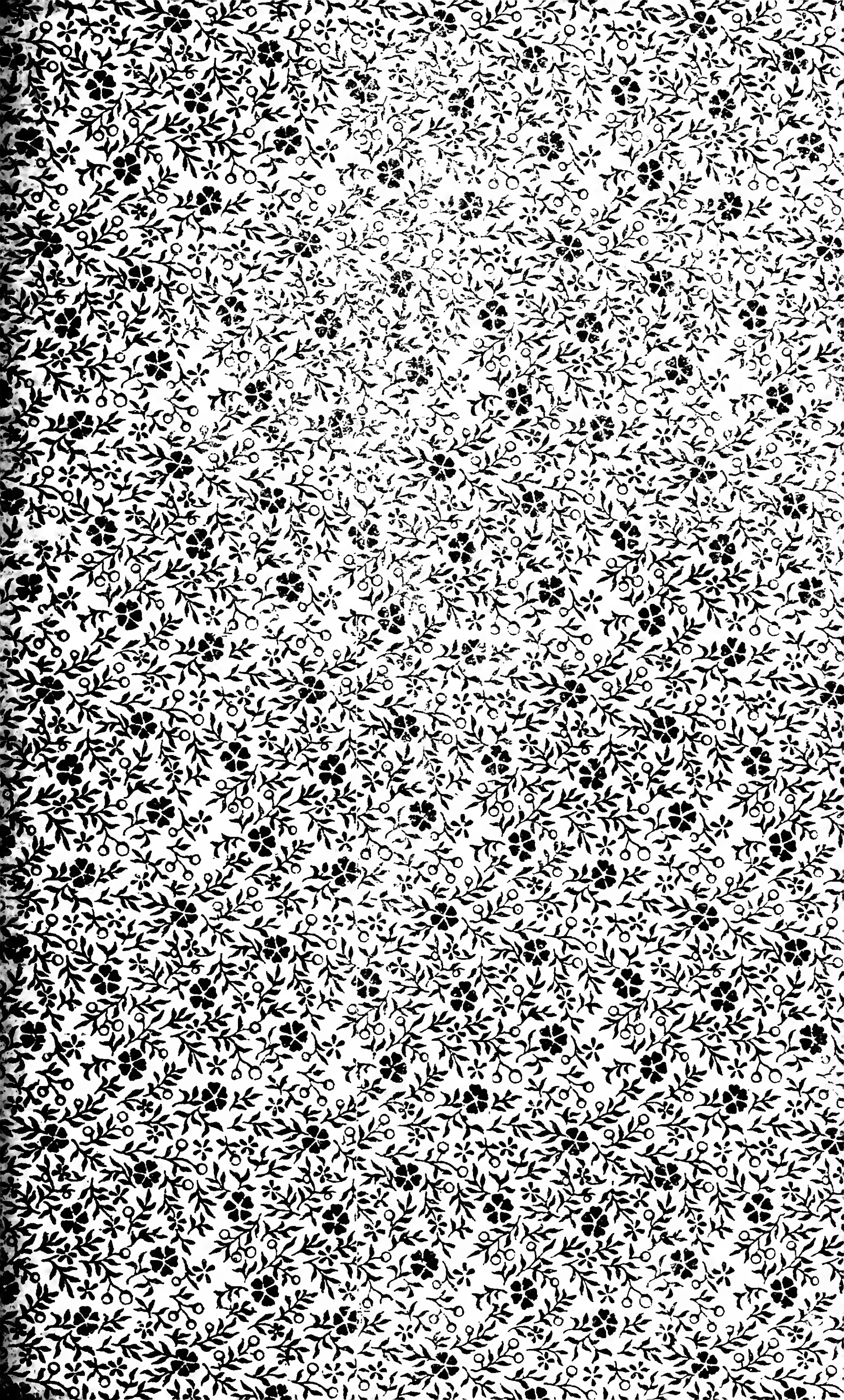

PROCEEDINGS

OF THE

SEVENTEENTH ANNUAL CONVENTION

OF THE

American Railway Engineering Association

HELD AT THE

CONGRESS HOTEL, CHICAGO, ILLINOIS

March 21, 22 and 23, 1916

VOLUME 17

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CONSTITUTION

CONSTITUTION.

REVISED AT THE FIFTH, EIGHTH AND TWELFTH ANNUAL CONVENTIONS.

ARTICLE I.

NAME, OBJECT AND LOCATION.

Name.

1. The name of this Association is the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

Object.

2. Its object is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

Means to be Used.

3. The means to be used for this purpose shall be as follows:

(a) Meetings for the reading and discussion of reports and papers and for social intercourse.

(b) The investigation of matters pertaining to the objects of this Association through Standing and Special Committees.

(c) The publication of papers, reports and discussions.

(d) The maintenance of a library.

Responsibility.

4. Its action shall be recommendatory, and not binding upon its members.

Location of Office.

5. Its permanent office shall be located in Chicago, Ill., and the annual convention shall be held in that city.

ARTICLE II.

MEMBERSHIP.

Membership Classes.

1. The membership of this Association shall be divided into three classes, viz.: Members, Honorary Members and Associates.

Membership Qualifications.

(2) A Member shall be:

(a) Either a Civil Engineer, a Mechanical Engineer, an Electrical Engineer, or an official of a railway corporation, who has had not less than five (5) years' experience in the location, construction, maintenance or operation of railways, and who, at the time of application for membership, is engaged in railway service in a responsible position in charge of work connected with the Location, Construction, Operation or Maintenance of a Railway; provided, that all persons who were Active Members prior to March 20, 1907, shall remain Members except as modified by Article II, Clause 9.

(b) A Professor of Engineering in a college of recognized standing.

Honorary Membership Qualifications.

3. An Honorary Member shall be a person of acknowledged eminence in railway engineering or management. The number of Honorary Members shall be limited to ten.

Associate Membership Qualifications.

4. An Associate shall be a person not eligible as a Member, but whose pursuits, scientific acquirements or practical experience qualify him to co-operate with Members in the advancement of professional knowledge, such as Consulting, Inspecting, Contracting, Government or other Engineers, Instructors of Engineering in Colleges of recognized standing, and Engineers of Industrial Corporations when their duties are purely technical.

Membership Rights.

5. (a) Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights of Members, except that of holding office, and shall be exempt from the payment of dues.

(c) Associates shall have all the rights of Members, except those of voting and holding office.

Age Requirement.

6. An applicant to be eligible for membership in any class shall not be less than twenty-five (25) years of age.

"Railway" Defined.

7. The word "railway" in this Constitution means one operated by steam or electricity as a common carrier, dependent upon transportation for its revenue. Engineers of street railway systems and of railways which are used primarily to transport the material or product of an industry or industries to and from a point on a railway which is a common carrier, or those which are merely adjuncts to such industries, are eligible only as Associates.

Changes in Classes.

8. A Member, elected after March 20, 1907, who shall leave the railway service, shall cease to be a Member, but may retain membership in the Association as an Associate, subject to the provisions of Article II, Clause 9; provided, however, if he re-enters the railway service, he shall be restored to the class of Members.

Supply Men.

9. Persons whose principal duties require them to be engaged in the sale or promotion of railway patents, appliances or supplies, shall not be eligible for, nor retain membership in any class in this Association, except that those who were Active Members prior to March 20, 1907, may retain membership as Associates; provided, however, that anyone having held membership in the Association and subsequently having become subject to the operation of this clause, shall, if he again becomes eligible, be permitted to re-enter the Association, without the payment of a second entrance fee.

Transfers.

10. The Board of Direction shall transfer members from one class to another, or remove a member from the membership list, under the provisions of this Article.

ARTICLE III.

ADMISSIONS AND EXPULSIONS.

Charter Membership.

1. The Charter Membership consists of all persons who were elected before March 15, 1900.

Application for Membership.

2. The Charter Membership having been completed, any person desirous of becoming a member shall make application upon the form

prescribed by the Board of Direction, setting forth in a concise statement his name, age, residence, technical education and practical experience. He shall refer to at least three members to whom he is personally known, each of whom shall be requested by the Secretary to certify to a personal knowledge of the candidate and his fitness for membership.

Election to Membership

3. Upon receipt of an application properly endorsed, the Board of Direction, through its Secretary, or a Membership Committee selected from its own members, shall make such investigation of the candidate's fitness as may be deemed necessary. The Secretary will furnish copies of the information obtained and of the application to each member of the Board of Direction. At any time, not less than thirty days after the filing of the application, the admission of the applicant shall be canvassed by letter-ballot among the members of the Board, and affirmative votes by two-thirds of its members shall elect the candidate; provided, however, that should an applicant for membership be personally unknown to three members of the Association, due to residence in a foreign country, or in such a portion of the United States as precludes him from a sufficient acquaintance with its members, he may refer to well-known men engaged in railway or allied professional work, upon the form above described, and such application shall be considered by the Board of Direction in the manner above set forth, and the applicant may be elected to membership by a unanimous vote of the Board.

Subscription to Constitution.

4. All persons, after due notice from the Secretary of their election, shall subscribe to the Constitution on the form prescribed by the Board of Direction. If this provision be not complied with within six months of said notice, the election shall be considered null and void.

Reinstatement.

5. Any person having been a member of this Association, and having, while in good standing, resigned such membership, may be reinstated without the payment of a second entrance fee; provided his application for reinstatement is signed by five members certifying to his fitness for same, and such application is passed by a two-thirds majority of the Board of Direction.

Honorary Membership.

6. Proposals for Honorary Membership shall be submitted by ten or more Members. Each member of the Board of Direction shall be furnished with a copy of the proposal, and if, after thirty days, the nominee shall receive the unanimous vote of said Board, he shall be declared an Honorary Member.

Expulsions.

7. When charges are preferred against a Member in writing by ten or more Members, the Member complained of shall be served with a copy of such charges, and he shall be called upon to show cause to the Board of Direction why he should not be expelled from the Association. Not less than thirty days thereafter a vote shall be taken on his expulsion, and he shall be expelled upon a two-thirds vote of the Board of Direction.

Resignations.

8. The Board of Direction shall accept the resignation, tendered in writing, of any Member whose dues are fully paid up.

ARTICLE IV.

DUES.

Entrance Fee.

1. An entrance fee of $10.00 shall be payable to the Association through its Secretary with each application for membership; and this sum shall be returned to the applicant if not elected.

Annual Dues.

2. *The annual dues are $10.00, payable during the first three months of the calendar year.

Arrears.

3. Any person whose dues are not paid before April 1st of the current year shall be notified of same by the Secretary. Should the dues not be paid prior to July 1st, the delinquent Member shall lose his right to vote. Should the dues remain unpaid October 1st, he shall be notified on the form prescribed by the Board of Direction, and he shall no longer receive the publications of the Association. If the dues are not paid by December 31st, he shall forfeit his membership without further action or notice, except as provided for in Clause 4 of this Article.

Remission of Dues.

4. The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, who, from ill-health, advanced age or other good reasons, is unable to pay them.

ARTICLE V.

OFFICERS.

Officers.

1. The officers of the Association shall be Members and shall consist of:

A President,
A First Vice-President,
A Second Vice-President,
A Treasurer,
A Secretary,
Nine Directors,

who, together with the five latest living Past-Presidents who are Members, shall constitute the Board of Direction in which the government of the Association shall be vested, and who shall act as Trustees, and have the custody of all property belonging to the Association.

Vice-Presidents' Priority.

2. The offices of First and Second Vice-Presidents shall be determined by the priority of their respective dates of election.

Terms of Office.

3. The terms of office of the several officers shall be as follows:

President, one year.
Vice-Presidents, two years.
Treasurer, one year.
Secretary, one year.
Directors, three years.

Officers Elected Annually.

4. (a) There shall be elected at each Annual Convention:

A President,
One Vice-President,
A Treasurer,
A Secretary,
Three Directors.

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*The annual payment of $10.00 made by each member is to be subdivided and credited on the books of the Association, as follows: To member's subscription to the Bulletin, $5.00; annual dues, $5.00.

(b) The candidates for President and for Vice-President shall be selected from the members of the Board of Direction.

Conditions of Re-election of Officers.

5. The office of President shall not be held twice by the same person. A person who shall have held the office of Vice-President or Director shall not be eligible for re-election to the same office until at least one full term shall have elapsed after the expiration of his previous term of office.

Term of Officers.

6. The term of each officer shall begin with his election and continue until his successor is elected.

Vacancies in Offices.

7. (a) A vacancy in the office of President shall be filled by the First Vice-President.

(b) A vacancy in the office of either of the Vice-Presidents shall be filled by the Board of Direction by election from the Directors. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) Any other vacancies for the unexpired term in the membership of the Board of Direction shall be filled by the Board.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office he is holding; provided, however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provision of Article V, Clause 5.

Vacation of Office.

8. When an officer ceases to be a Member of the Association, as provided in Article II, his office shall be vacated, and be filled as provided in Article V, Clause 7.

Disability or Neglect.

9. In case of the disability or neglect in the performance of his duty, of an officer, the Board of Direction, by a two-thirds majority vote of the entire Board, shall have power to declare the office vacant, and fill it as provided in Article V, Clause 7.

ARTICLE VI.

NOMINATION AND ELECTION OF OFFICERS.

Nominating Committee.

1. (a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members, and five Members not officers.

(b) The five Members shall be elected annually when the officers of the Association are elected.

Number of Candidates.

2. It shall be the duty of this committee to nominate candidates to fill the offices named in Article V, and vacancies in the Nominating Committee caused by expiration of term of service, for the ensuing year, as follows:

Office to be Filled.	Number of Candidates to be named by Nominating Committee.	Number of Candidates to be elected at Annual Election of Officers.
President	1	1
Vice-President	1	1
Treasurer	1	1
Secretary	1	1
Directors	9	3
Nominating Committee	10	5

Chairman.

3. The Senior Past-President shall act as permanent chairman of the committee, and will issue the call for meetings. In his absence from meetings, the Past-President next in age of service shall act as Chairman pro tem. at the meeting.

Meeting of Committee.

4. Prior to December 1st, each year, the Chairman shall call a meeting of the committee at a convenient place and, at this meeting, nominees for office shall be agreed upon.

Announcement of Names of Nominees.

5. The names of the nominees shall be announced by the permanent Chairman to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the Members of the Association on a printed slip not later than January 1st following.

Additional Nominations by Members.

6. At any time between January 1st and February 1st, any ten or more Members may send to the Secretary additional nominations for the ensuing year signed by such Members.

Vacancies in List of Nominees.

7. If any person so nominated shall be found by the Board of Direction to be ineligible for the office for which he is nominated, or should a nominee decline such nomination, his name shall be removed and the Board may substitute another one therefor; and may also fill any vacancies that may occur in this list of nominees up to the time the ballots are sent out.

Ballots Issued.

8. Not less than thirty days prior to each Annual Convention, the Secretary shall issue ballots to each voting member of record in good standing, with a list of the several candidates to be voted upon, with the names arranged in alphabetical order when there is more than one name for any office.

Substitution of Names.

9. Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

Ballots.

10. (a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw his ballot, and may substitute another, at any time before the polls close.

Invalid Ballots.

11. Ballots not endorsed or from persons not qualified to vote shall not be opened; and any others not complying with the above provisions shall not be counted.

Closure of Polls.

12. The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by three tellers appointed by the Presiding Officer. The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

Requirements for Election.

13. The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

Tie Vote.

14. In case of a tie between two or more candidates for the same office, the members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

15. The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article. Announcement.

16. Except as to the Past-Presidents, the first Nominating Committee and the three additional Directors provided for shall be appointed by the Board of Direction, one of the Directors for one year, one for two years, and one for three years. First Nominating Committee.

ARTICLE VII.

MANAGEMENT.

1. (a) The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio member of all Committees, except the Nominating Committee. Duties of President.

(b) The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and discharge his duties in case of a vacancy in his office.

2. The Treasurer shall receive all moneys and deposit same in the name of the Association, and shall receipt to the Secretary therefor. He shall invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. He shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction. Duties of Treasurer.

3. The Secretary shall be, under the direction of the President and Board of Direction, the Executive Officer of the Association. He shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. He shall see that the moneys due the Association are collected and without loss transferred to the custody of the Treasurer. He shall personally certify to the accuracy of all bills or vouchers on which money is to be paid. He is to conduct the correspondence of the Association and keep proper record thereof, and perform such other duties as the Board of Direction may prescribe. Duties of Secretary.

4. The accounts of the Treasurer and Secretary shall be audited annually by a public accountant, under the direction of the Finance Committee of the Board. Auditing of Accounts.

5. The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution. Duties of Board.

6. The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board. Board Meetings.

7. Seven members of the Board shall constitute a quorum. Board Quorum.

8. At the first meeting of the Board after the Annual Convention, the following committees from its members shall be appointed by the President, and shall report to and perform their duties under the supervision of the Board of Direction: Board Committees.

a. Finance Committee of three members.
b. Publication Committee of three members.
c. Library Committee of three members.
d. Outline of Work of Standing Committees of five members.

Duties of Finance Committee.

9. The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of moneys and as to other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by previous action and authority of the Board of Direction.

Duties of Publication Committee.

10. The Publication Committee shall have general supervision of the publications of the Association.

Duties of Library Committee.

11. The Library Committee shall have general supervision of the Library, the property therein, and the quarters occupied by the Secretary; shall make recommendations to the Board with reference thereto, and shall direct the expenditure for books and other articles of permanent value, from such sums as may be appropriated for these purposes.

Duties of Committee on Outline of Work of Standing Committees.

12. The Committee on Outline of Work of Standing Committees shall present a list of subjects for committee work during the ensuing year at the first meeting of the Board of Direction after the Annual Convention.

Standing Committees.

13. The Board of Direction may appoint such Standing Committees as it may deem best, to investigate, consider and report upon questions pertaining to railway location, construction or maintenance.

Special Committees.

14. Special Committees to examine into and report upon any subject connected with the objects of this Association may be appointed from time to time by the Board of Direction.

Discussion by Non-Members.

15. The Board of Direction may invite discussions of reports from persons not members of the Association.

Sanction of Acts of Board.

16. An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next Annual Convention of the Association shall be deemed to be the act of the Association, and shall not afterwards be impeached by any Member.

ARTICLE VIII.

MEETINGS.

Annual Convention.

1. The Annual Convention shall begin upon the third Tuesday in March of each year, and shall be held at such place in the City of Chicago as the Board of Direction may select.

Special Meetings.

2. Special meetings of the Association may be called by the Board of Direction, and special meetings shall be so called by the Board upon request of thirty Members, which request shall state the purpose of such meeting. The call for such meeting shall be issued not less than ten

days in advance, and shall state the purpose and place thereof, and no other business shall be taken up at such meeting.

Notification of Annual Convention.

3. The Secretary shall notify all members of the time and place of the Annual Convention of the Association at least thirty days in advance thereof.

Association Quorum.

4. Twenty-five Members shall constitute a quorum at all meetings of the Association.

Order of Business.

5. (a) The order of business at annual conventions of the Association shall be as follows:

Reading of minutes of last meeting.
Address of the President.
Reports of the Secretary and Treasurer.
Reports of Standing Committees.
Reports of Special Committees.
Unfinished business.
New business.
Election of officers.
Adjournment.

(b) This order of business, however, may be changed by a majority vote of members present.

Rules of Order.

6. The proceedings shall be governed by "Robert's Rules of Order," except as otherwise herein provided.

Discussion.

7. Discussion shall be limited to members and to those invited by the presiding officer to speak.

ARTICLE IX.

AMENDMENTS.

Amendments

1. Proposed amendments to this Constitution shall be made in writing and signed by not less than ten Members, and shall be acted upon in the following manner:

The amendments shall be presented to the Secretary, who shall send a copy of same to each member of the Board of Direction as soon as received. If at the next meeting of the Board of Direction a majority of the entire Board are in favor of considering the proposed amendments, the matter shall then be submitted to the Association for letter-ballot, and the result announced by the Secretary at the next Annual Convention. In case two-thirds of the votes received are affirmative, the amendments shall be declared adopted and become immediately effective.

GENERAL INFORMATION.

(Subject to change from time to time by Board of Direction.)

GENERAL RULES FOR THE PREPARATION, PUBLICATION AND CONSIDERATION OF COMMITTEE REPORTS.

(A) APPOINTMENT OF COMMITTEES AND OUTLINE OF WORK.

Standing Committees.

1. The following are standing committees:

- I. Roadway.
- II. Ballast.
- III. Ties.
- IV. Rail.
- V. Track.
- VI. Buildings.
- VII. Wooden Bridges and Trestles.
- VIII. Masonry.
- IX. Signs, Fences and Crossings.
- X. Signals and Interlocking.
- XI. Records and Accounts
- XII. Rules and Organization.
- XIII. Water Service.
- XIV. Yards and Terminals.
- XV. Iron and Steel Structures.
- XVI. Economics of Railway Location.
- XVII. Wood Preservation.
- XVIII. Electricity.
- XIX. Conservation of Natural Resources.

Special Committees.

2. Special Committees will be appointed from time to time, as may be deemed expedient, in the manner prescribed by Article VII, Clause 14, of the Constitution.

Personnel of Committees.

3. The personnel of all Committees will continue from year to year, except when changes are announced by the Board of Direction. Ten per cent. of the membership of each committee shall be changed each year.

Members of committees who do not attend meetings of committees during the year or render service by correspondence will be relieved and the vacancies filled by the Board at the succeeding annual convention.

Outline of Work.

4. As soon as practicable after each annual convention the Board of Direction will assign to each Committee the important questions which, in its judgment, should preferably be considered during the current year. Committees are privileged to present the results of any special study or investigation they may be engaged upon or that may be considered of sufficient importance to warrant presentation.

(B) PREPARATION OF COMMITTEE REPORTS.

General.

5. The collection and compilation of data and subsequent analysis in the form of arguments and criticism is a necessary and valuable preliminary element of committee work.

Collection of Data. 6. Committees are privileged to obtain data or information in any proper way. If desired, the Secretary will issue circulars of inquiry, which should be brief and concise. The questions asked should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. They should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blue-print.

Plan of Reports. 7. Committee reports should be prepared as far as practicable to conform to the following general plan:

(a) It is extremely important that every Committee should examine its own subject-matter in the "Manual" prior to each annual convention, and revise and supplement it, if deemed desirable, giving the necessary notice of any recommended changes in accordance with Clause 6 (a) of the General Rules for the Publication of the "Manual." If no changes are recommended, statement should be made accordingly.

(b) When deemed necessary, the previous report should be reviewed.

(c) Subjects presented in previous reports on which no action was taken should be resubmitted, stating concisely the action desired. It may not be necessary to repeat the original text in the report, reference to former publication being sufficient, unless changes in the previously published version are extensive. Minor changes can be explained in the text of the report.

Definitions. (d) Technical terms used in the report, the meaning of which is not clearly established, should be defined, but defined only from the standpoint of railway engineering.

History. (e) If necessary, a brief history of the subject-matter under discussion, with an outline of its origin and development, should be given.

Analysis. (f) An analysis of the most important elements of the subject-matter should be given.

Argument. (g) The advantages and disadvantages of the present and recommended practices should be set forth.

Illustrations. (h) Illustrations accompanying reports should be prepared so that they can be reproduced on one page. The use of folders should be avoided as much as possible, on account of the increased expense and inconvenience in referring to them. Plans showing current practice, or necessary for illustration, are admissible, but those showing proposed definite design or practice should be excluded. Recommendations should be confined to governing principles.

Illustrations should be made on tracing cloth with heavy black lines and figures, so as to stand a two-thirds reduction; for example: To come within a type page (4 inches by 7 inches), the illustration should be made three times the above size.

To insure uniformity, the one-stroke, inclined Gothic lettering is recommended.

Photographs should be clear and distinct silver prints.

Conclusions. (i) The conclusions of the Committee which are recommended for publication in the Manual should be stated in concise language, logical sequence, and grouped together, setting forth the principles, specifications, definitions, forms, tables and formulæ included in the recommendation. Portions of the text of the report which are essential to a clear interpretation and understanding of the conclusions, should be included as an integral part thereof.

(C) PUBLICATION OF COMMITTEE REPORTS.

Reports Required. 8. (a) Reports will be required from each of the Standing and Special Committees each year.

(b) Although several subjects may be assigned to each Committee by the Board of Direction, a full report on only one subject is expected at each annual convention, but the preliminary work on some of the remaining subjects should be in progress, and, when deemed advisable, partial reports of progress should also be presented. This method allows time for their proper preparation and consideration.

Date of Filing Reports. 9. Committee reports to come before the succeeding convention for discussion should be filed with the Secretary not later than November 30 of each year.

10. Committees engaged upon subjects involving an extended investigation and study are privileged to present progress reports, giving a brief statement of the work accomplished, and, if deemed expedient, a forecast of the final report to be presented.

Publication of Reports. 11. Committee reports will be published in the Bulletin in such sequence as the Board of Direction may determine, for consideration at the succeeding convention. Reports will be published in the form presented by the respective Committees. Alterations ordered by the convention will be printed as an appendix to the report.

Written Discussions. 12. Committees should endeavor to secure written discussions of published reports. Written discussions will be transmitted to the respective Committees, and if deemed desirable by the Committee, the discussions will be published prior to the convention and be considered in connection with the report.

Verbal Discussions. 13. Each speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

(D) CONSIDERATION OF COMMITTEE REPORTS.

Sequence. 14. The sequence in which Committee reports will be considered by the convention will be determined by the Board of Direction.

15. The method of consideration of Committee reports will be one of the following: **Method.**

(a) Reading by title.

(b) Reading, discussing and acting upon each conclusion separately.

(c) By majority vote, discussion will be had on each item. Clauses not objected to when read will be considered as voted upon and adopted.

16. Action by the convention on Committee reports will be one of the following, after discussion is closed: **Final Action**

(a) Receiving as information.

(b) Receiving as a progress report.

(c) Adoption of a part complete in itself and referring remainder back to Committee.

(d) Adoption as a whole.

(e) Recommittal with or without instructions.

(f) Adoption as a whole.

(g) Recommendation to publish in the Manual.

NOTE.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the Committee considers affected.

The Chair will decline to entertain amendments which in his opinion lie entirely within the duties of the Editor.

(E) PUBLICATION BY TECHNICAL JOURNALS.

The following rules will govern the releasing of matter for publication in technical journals:

Committee reports, requiring action by the Association at the annual convention, will not be released until after presentation to the convention; special articles, contributed by members and others, on which no action by the Association is necessary, are to be released for publication by the technical journals after issuance in the Bulletin; provided application therefor is made in writing and proper credit be given the Association, authors or Committees presenting such material.

GENERAL RULES FOR THE PUBLICATION OF THE "MANUAL"

Title.

1. The title of the volume will be "Manual of the American Railway Engineering Association."

2. The Board of Direction shall edit the Manual and shall have authority to withhold from publication any matter which it shall consider as not desirable to publish, or as not being in proper shape, or as not having received proper study and consideration.

Adoption of Reports Not Binding.

3. Matters adopted by the Association and subsequently published in the Manual shall be considered in the direction of good practice, but shall not be binding on the members.

Contents.

4. The Manual will only include conclusions relating to definitions, specifications and principles of practice as have been made the subject of a special study by a Standing or Special Committee and embodied in a committee report, published not less than thirty days prior to the annual convention, and submitted by the Committee to the annual convention, and which, after due consideration and discussion, shall have been voted on and formally adopted by the Association. Subjects which, in the opinion of the Board of Direction, should be reviewed by the American Railway Association, may be referred to that Association before being published in the Manual.

5. All conclusions included in the Manual must be in concise and proper shape for publication, as the Manual will consist only of a summary record of the definitions, specifications and principles of practice adopted by the Association, with a brief reference to the published Proceedings of the Association for the context of the Committee report and subsequent discussion and the final action of the Association.

Revision.

6. Any matter published in the Manual may be amended or withdrawn by vote at any subsequent annual convention, provided such changes are proposed in time for publication not less than thirty days prior to the annual convention, and in the following manner: (a) Upon recommendation of the Committee in charge of the subject; (b) upon recommendation of the Board of Direction; (c) upon request of five members, made to the Board of Direction.

7. The Manual will be revised either by publishing a new edition or a supplemental pamphlet as promptly as possible after each annual convention.

BUSINESS SESSION

PROCEEDINGS

The object of this Association is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways. Its action is not binding upon its Members.

TUESDAY, MARCH 21, 1916.

MORNING SESSION.

The Seventeenth Annual Convention of the American Railway Engineering Association was called to order by the President, Mr. Robert Trimble, Chief Engineer Maintenance of Way, Northwest System, Pennsylvania Lines, at 9:30 a. m.

The President:—The Seventeenth Annual Convention of the American Railway Engineering Association will please come to order.

The first order of business is the reading of the Minutes of the last annual meeting. Inasmuch as these Minutes are very voluminous and have been printed and distributed to the members, their reading will be dispensed with, if there is no objection. Not hearing any objection to this plan, the Minutes are approved as they have been submitted to you.

We wish to extend the privileges of the floor to all visiting members of railways and others who are interested in the work of the Association. We will be very glad to have you take part in our discussions, and hope you will be interested and benefitted in being here with us.

The next order of business is the annual address of the President.

PRESIDENT'S ADDRESS.

The work of the past year has been carried on under unusual difficulties. In the first part of the season, poor business made it hard for the railways to do more than meet expenses. They are now taxed in handling a business largely due to the European war, which, therefore, must be of uncertain duration.

Eastern railways have been handicapped by the congestion at the seaboard, due to an inadequate supply of boats. After twenty months of war there is no immediate prospect of peace. Uncertainty as to conditions after the war is over makes it difficult for those in control of railway properties to make provision for the future. Uncertainty seems to be the prevailing condition in the railway world. Uncertainty as to prices and time of delivery of supplies, uncertainty as to wages and hours of service, uncertainty as to the effect of federal valuation and uncertainty as to federal and state legislation.

The President suggested in his message to Congress the appointment of a commission to examine into and report on the entire railroad situation. This work, if properly done by competent men on broad lines, should help towards a solution of the future of the railways.

MEMBERSHIP.

The American Railway Engineering Association has a membership of 1,336, a net increase of 100 members since the last convention. Our growth is steady. We are not as large as any of the four national engineering societies, but our influence compares favorably with any of them. Systematic effort should be made to increase our membership and thereby add to the Association's influence and revenue.

FINANCE.

At the end of the fiscal year for 1915 the surplus on hand was $13,880.40, which is $3,431.87 less than the preceding year. This reduction is caused by slowness of collections. This matter is receiving the attention of the Board. Our finances are in such condition that the many requests for appropriations to carry on special work cannot be complied with.

CO-OPERATION WITH OTHER SOCIETIES.

The American Railway Engineering Association is represented on joint committees co-operating with the American Society of Civil Engineers, American Society for Testing Materials, American Electric Railway Engineering Association, the National Electric Light Association, the Bureau of Standards of the government, and others.

The Association received invitations to be officially represented at the Pan-American Scientific Congress, which was held in Washington, December 27, 1915, to January 6, 1916, and at the sixth National Good Roads Congress, which was held in Pittsburgh, February 28 to March 3, 1916. These invitations were accepted and delegates were appointed.

MANUAL.

The 1915 edition of the Manual has been issued and is in your hands. The volume is a notable one, as it covers the work of the Association for a period of sixteen years. The American Railway Engineering Association is to be congratulated on this work. It has become the guide for practice in railway engineering and maintenance of way work and we believe that it will be indispensable in the railway operating officer's library. It will also be an important factor in unifying and standardizing methods of work in construction, maintenance and operation of railways in the United States and Canada.

The Secretary has advised me that the idea of publishing a Manual originated with Mr. A. W. Sullivan, a former Vice-President of this Association, but the real credit for its present form belongs to the late Walter G. Berg, a former President; he elaborated Mr. Sullivan's idea and worked out the details. The rules formulated by Mr. Berg have practically remained as submitted by him.

GENERAL INDEX.

The matter of preparing a General Index to the Proceedings has been in hand for several years. We are able to advise you that considerable progress has been made, and it is expected that the Index will be ready for distribution during the coming year.

MONOGRAPHS.

An unusual number of important monographs have been furnished by our members this year. There are three of especial interest; one on "Ballast Tampers for Railway Ties," one on "A System for Standardizing Maintenance of Way Work," and the other on "Rail Failures." These papers are timely, the first, because of the necessity of developing labor-saving devices for track work, the second, because we need a more economical application of labor in maintenance of way work, and the third because of the necessity of ascertaining the causes of rail failures and applying the proper remedy. We suggest that a sum of money be annually set aside to provide a suitable medal for the most valuable paper offered during the year, the medal to be awarded by a committee of disinterested persons.

IMPACT EXPERIMENTS ON ELECTRIFIED RAILWAYS.

The management of the Norfolk & Western Railway, through its Chief Engineer, Mr. J. E. Crawford, has tendered the Committee on Iron and Steel Structures the necessary facilities for making impact tests on bridges under electric locomotives on the electrified portion of that railway. It has also offered the sum of $1,000 to cover necessary expenses for making the tests. These tests should develop valuable information, and it is hoped that other railways, having electrified sections, will be sufficiently interested to have similar tests made by the Committee on their roads.

FEDERAL VALUATION OF RAILWAYS.

The federal valuation of railways is being actively prosecuted. At the present time, surveys have been completed on about fifty thousand miles of railways, leaving approximately two hundred thousand miles to be surveyed, which will require about four years.

FLOOD PROTECTION.

A number of places affected by floods have secured state legislation establishing conservancy districts to provide for protection against flood by rectification of streams or storage reservoirs or both. These projects are costly, and in many cases contemplate large expenditures on the part of the railroads.

COMMITTEE WORK.

In the past our committee work has been well done and a high standard has been set. To maintain or surpass this standard requires continued effort. We cannot afford to lose the prestige we have gained. On the other hand, we should always keep before us a high ideal.

A review of the year's work shows that in a number of cases committee work is incomplete and that much of the work is submitted as information. Care must be exercised in submitting reports as information; very often this causes duplication of reading matter later when the committee makes its final conclusions and recommendations, because the same information is repeated.

There appears to be a growing disposition on the part of the committees to accept the work of their sub-committees without review and unification. Such reports should be reviewed and revised so as to become an integral part of the final report of the committee. Our Proceedings and Bulletins will present a better appearance if we dispense with printing sub-committee names and apportionment of work.

If we are to be successful, we must not sacrifice the quality of our work at the expense of quantity. If a committee is unable, for good reasons, to make a finished report, it should have the courage to ask for more time.

CLEARANCES.

The American Railway Association assigned to us the subject of clearances. This is one of the most important subjects to be considered at this convention. The recommendations which we make to the American Railway Association should be of such character as to have a favorable influence on the legislation now pending before the national congress and the several state public utilities commissions. These recommendations must also be approved by the railway companies.

The subject of clearances is of vital importance to the railroads, and we urge the most careful consideration by our legislative bodies and railway executives, in order that the interests of the public be cared for, and the interests of the transportation system of the country conserved. If the railways are required to provide the clearances demanded by labor representatives from our legislative bodies, large and expensive properties must be either reconstructed at enormous expense or abandoned.

Every officer in the executive, operating and engineering departments of our railways will heartily approve of a program of legislation which will be beneficial to all, provided that the program be a reasonable one, and that the funds therefor can be furnished by the railways.

Those intimately acquainted with this subject believe that any new legislation should relate only to new construction and to radical reconstructions of existing facilities, such as grade separation work, but that it should not apply to other existing construction where the expenditure required to make a change is out of proportion to the benefits to be gained.

RAIL STUDY.

The railways of the United States normally require about three million tons of rail annually, costing in round numbers about ninety million dollars. This is one of the large items of maintenance expenditure, and proper specifications and inspection for this expenditure are of the greatest importance.

Our Association, through the Rail Committee and its engineer of tests, has performed a valuable service in this matter, but we have not reached the place where we can say that the specifications need no further revision or that the methods of inspection are satisfactory.

Since January, 1910, there has been expended for investigations under the supervision of the Rail Committee, $42,564.67, which amount was furnished by the American Railway Association. In order to place this work on a more stable basis, the American Railway Association has been requested to appropriate ten thousand dollars a year for the next five years.

The proper method of inspection of rails has not been satisfactorily worked out. One large system now provides that the chemical analysis shall be taken from the finished rail in preference to the analysis from a test ingot. Another large system, last year, purchased rails under the "nick and break" test for every ingot. This method of inspection developed fewer rejections than under previous methods, resulting in a direct financial benefit to the mill.

The manufacturers are not making any concessions to the railways, and a change from the manufacturer's standard specifications has generally resulted in a considerable increase in price. The method of accepting rails on the basis of the chemistry of a test ingot cannot be maintained much longer, and it is therefore the duty of the manufacturers and the railways to agree on some other more reliable method.

It is also necessary to prescribe uniform methods of determining the chemical constituents of the material in our rails, joints, bolts, etc. Laboratory methods now vary and the results obtained from different laboratories are not uniform. This is also true with reference to the "yield point" in making physical tests. The speed of the testing machine at the time of determining the "yield point" is an important factor in the results obtained and comparisons of tests of the same material made by commercial and private laboratories indicate wide variations. The American Society for Testing Materials is working on this subject. We should insist that specifications for uniform methods of testing be agreed upon speedily.

Some engineers are designing rail sections differing slightly from those in present use or from those that have been proposed. We hope that any railway officers considering a change to a heavier rail will give careful consideration to the sections of this Association, for we believe that sufficient merit will be found in them to warrant their adoption.

SMOKE ABATEMENT AND ELECTRIFICATION OF RAILWAY TERMINALS IN CHICAGO.

A notable report has been made by the Chicago Association of Commerce Committee on the results of its investigation on smoke abatement and electrification of railway terminals in Chicago. This report has been awaited for a long time with the expectation that it would prove to be an interesting study in this branch of engineering. It has justified the expectations. It recommends no constructive program and outlines no course of action for the future. It codifies the whole problem of atmospheric pollution and clearly defines the proper relation of electric motive power on the railroads to the question of municipal smoke abatement. This work has never been done before with such thoroughness, and its publication is a distinct service.

This report shows that steam locomotives are responsible for about 22 per cent. of the total visible smoke discharge within the Chicago city limits, and definitely indicates that the railways are not responsible for the smoke conditions in the larger cities, and that if all the smoke produced by the railways was to be eliminated, there would still be a large amount of smoke and dirt from other causes, unless electrification is extended to all other lines of industry.

EXTRAVAGANT RAILWAY TERMINALS.

Work on the new union station in Chicago has begun. The railroads are being criticized for their extravagant passenger terminals, and this one is no exception. A visitor from Australia recently speaking in Chicago commented on our extravagant terminals, especially the "gilt stairways and marble halls," and his tale has been taken up by the prominent newspapers and magazines all over the country. A great lack of knowledge is shown by the critics in regard to the amount of money being spent for the beautification of a large railway terminal.

Take the new Chicago Union Station as an example, estimated to cost, in round numbers, fifty million dollars. Nearly thirty-five millions represents land. The figure cannot possibly change, no matter what kind of structures are placed upon it, unless a location in the heart of the city, which is the place where the traveling public wants to land, is abandoned or smaller facilities accepted. About five millions are for changing streets, rebuilding viaducts and bridges and reconstructing public utilities, and this cannot be escaped because the necessary enlargement of the station to take care of a growing business requires the reconstruction of these bridges and streets. About five millions are for tracks, signals, interlockings, platforms, train sheds, power plant and the necessary appurtenances of the station. This leaves five million dollars for the headhouse and concourse, the only part of the station where there can be any real question as to extravagance.

If a strictly utilitarian headhouse and concourse, the part that the public thinks of as the station, were to be constructed, the total cost might be reduced two million dollars. This figure represents what the railroad companies are paying for an advertisement, for the comfort and pleasure of its patrons, and the beautification of the city. The interest on this amount is one hundred thousand dollars per annum. How much yearly advertising would the newspapers, read by the patrons of the station, furnish the four or five railroads using it for one hundred thousand dollars per year, and would it be as effective as that provided by the railroad companies in furnishing a beautiful as well as a utilitarian structure? An analysis of the cost of other named extravagant terminals would disclose similar results. It must also be borne in mind that this construction is to provide for the next thirty years or more.

An editor in South Bend, Ind., has really approached this subject in a broader spirit than those of some of our great newspapers. He says: "It is true that much more money has been spent in those terminals than the efficiency of getting to trains requires. But when Mr. Gordon warns us that we ought to be satisfied with structures built purely for efficiency, sacrificing architectural beauty to revenue-producing, it is not plain that he is taking the right stand.

"In the middle ages, communities built magnificent cathedrals—and paid for them—and who questions the ennobling effects of these rich and spacious structures on all beholders? They satisfied and glorified the lives not only of those who built them, but also of their descendants. The genius of the American people runs to transportation and to business. Why not express through those mediums the artistic soul of the nation? Who that ever stood before the massive pillars of the Northwestern in Chicago, who that ever walked the floor of the 'wasteful' concourse in the Pennsylvania station in New York with its noble space and simplicity, its astonishing and grateful silence, can ever think of them without a thrill?"

ELECTRIFICATION.

Three notable pieces of steam railway electrification have been placed in operation during the year. The first is on the Norfolk & Western Railway, where an electric service for heavy coal freight traffic has been inaugurated between Bluefield and Vivian, W. Va.

The second important installation is on the Pennsylvania Railroad main line between Paoli and Broad Street station, Philadelphia, where the suburban passenger service is operated electrically. The work involves twenty miles of four-track railroad, in places complicated by additional tracks and intricate yard work.

The third piece of work is on the Chicago, Milwaukee & St. Paul Railway. One hundred and thirteen miles of main line between Three Forks and Deer Lodge, Mont., were placed in operation, and the electrification is to be extended as rapidly as possible over four hundred and forty miles of road from Harlowton to Avery, Idaho.

RAILWAY CONSTRUCTION.

The most important piece of railway construction of the past year, the Clark's Summit-Hallstead cut-off of the Delaware, Lackawanna & Western Railroad, was put into service November 7, 1915. The largest concrete bridge in the world, the Tunkhannock viaduct, is on this work. It is 2,375 feet long, with ten spans of 180 feet each and two spans of 100 feet each, with a height of 240 feet above the surface of the stream and 300 feet from bed rock.

One of the few pieces of heavy railroad construction in progress at the present time is the Chesapeake & Ohio Northern Railway, a line from Edington, Ky., to Waverly, Ohio. A bridge over the Ohio River at Sciotoville forms an important feature of the project. The notable feature of this bridge is the superstructure for the two channel spans, 775 feet each. This superstructure consists of a single symmetrical truss structure, 1,550 feet long, continuous over three supports. It will be unusual also for the fact that the trusses are said to be the longest and heaviest riveted trusses ever built in America.

BRIDGE WORK.

The construction of the Quebec bridge, containing the world's longest span, 1,800 feet, has progressed during the year. At the end of the working season of 1915 about 44,000 tons of a total of 63,000 tons had been erected.

Another notable piece of railroad bridge work is that of 977½ feet Hell Gate arch on the New York Connecting Railroad, where the closure was successfully accomplished on October 1, 1915, or four months after work on the main arches begun. During that period 13,000 tons of material was placed.

The moving of three 240-foot double-track spans on the P. C. C. & St. L. Railway proved an interesting feat in bridge construction. The new bridge was erected beside the old bridge, and after all arrangements had been perfected and the last train had crossed the bridge, in its temporary position, the tracks were broken and in seven minutes the bridge was in the new position, having moved a distance of forty-seven feet, the time during which the tracks were disconnected being ten minutes and seventeen seconds.

The channel and approach spans of the Ohio Connecting Railway bridge over the Ohio River, at Pittsburgh, were reconstructed for double track. Traffic was maintained on the original single-track bridge, and the new bridge was erected outside of and enveloping the old structure. The cantilever method was used without placing false work or staging in the river for the channel span.

IN CONCLUSION.

It is my painful duty to mention, among others, the death of General Grenville M. Dodge, an honorary member of the Association, who died at his home, Council Bluffs, Iowa, January 3, 1916. General Dodge was prominently connected with surveys and construction of some of the early railroads, notably the Union Pacific Railroad. He also rendered eminent service to his country.

In conclusion I wish to thank the members of the Association and committees for their continued interest, the members of the Board for their hearty support, and the efficient Secretary for his great assistance.

(Applause.)

The President:—The next order of business is the report of the Secretary and of the Treasurer.

REPORT OF SECRETARY.

To the Members of the American Railway Engineering Association:

Your Association has made decided progress in the year just passed in "the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways."

In addition to the usual Bulletins and Proceedings issued during the year, the new Manual has been placed in your hands. The Manual will add materially to the prestige of your Association.

The membership is increasing steadily, the net gain for the year being one hundred members.

Owing to the depressed business conditions prevailing during the year 1915 and the slowness of collections, the receipts have been reduced, resulting in an excess of disbursements over receipts of $3,431.87. This decrease, it is believed, will be more than offset during the present year by the proceeds from the new Manual and increased collection of dues, etc.

The Association has sustained the loss of the following members by death during the year:

W. M. Hughes, Consulting Bridge Engineer.

F. W. Scarborough, Consulting Engineer.

H. W. Cowan, Chief Engineer, Colorado & Southern Railway.

C. C. Schneider, Consulting Engineer.

William Hunter, Chief Engineer, Philadelphia & Reading Railway.

A. L. Bowman, Consulting Bridge Engineer.

C. C. Wentworth, Principal Assistant Engineer, Norfolk & Western Railway.

G. W. Merrell, Assistant to General Manager, Norfolk & Western Railway.

Ward Crosby, Chief Engineer, Carolina, Clinchfield & Ohio Railway.

J. W. Eber, General Manager, Toronto, Hamilton & Buffalo Railway.

C. A. Stephens, Chief Engineer, Texas City Terminal Railway.
Edward Gray, Contracting Engineer.
General Grenville M. Dodge (Honorary Member).

MEMBERSHIP.

Number members last annual report			1236
Admitted during the year		131	
Deceased members	13		
Resigned	9		
Dropped	9		
	31	31	
Net gain during year		100	100
Total membership			1336

FINANCIAL STATEMENT.

Balance on hand January 1, 1915	$17,312.27

Receipts during the year:

From Entrance Fees	$ 1,000.00
“ Dues	5,185.00
“ Subscriptions to Bulletin	5,342.35
“ Binding Proceedings and Manual	496.50
“ Sale of Proceedings	3,319.48
“ Sale of Manual	138.61
“ Sale of Bulletins	497.57
“ Sale of Specifications	136.45
“ Sale of Leaflets	334.35
“ Advertising	125.10
“ Interest on Bank Balance	123.85
“ Interest on Investments	275.73
“ Sale of Badges	42.00
“ Sale of Dinner Tickets	1,277.50
“ Miscellaneous	32.15
“ American Ry. Assn. (Rail Committee)	5,792.03
Total Receipts	$24,118.67

Disbursements during the year:

For Stationery and Printing	$ 557.90
“ Proceedings	3,967.23
“ Bulletins	5,921.35
“ Manual	32.26
“ Salaries	5,600.00
“ Officers' Expenses	21.95
“ Postage	859.38
“ Telephone and Telegrams	133.84
“ Committee Expenses	103.55
“ Supplies	346.47
“ Rents	1,064.96
“ Expressage	480.07
“ Light	29.20
“ Annual Meeting Expenses	1,700.75
“ Equipment	8.30

For Exchange	49.80	
" Miscellaneous	102.95	
" Compiling General Index	550.00	
" Contribution to Electricity Committee	225.00	
" Rail Committee	5,795.58	
Total Disbursements	$27,550.54	
Excess of Disbursements over Receipts		3,431.87
Balance on hand December 31, 1915		$13,880.40

STRESSES IN TRACK FUND.

Balance on hand January 1, 1915		$ 9,767.30
Received from Interest in 1915		278.85
		$10,046.15
Expenditures during 1915:		
Committee Expenses	$ 70.46	
Salaries	2,343.47	
Transportation	19.83	
Hotels and Meals	7.95	
Supplies	423.52	
Stationery and Printing	6.50	
Postage	10.00	
Expressage	16.41	
Telegrams	1.30	
Equipment	69.15	
Sundries	12.23	
Total Disbursements		$ 2,980.87
Balance of fund on hand, December 31, 1915		$ 7,065.28

Respectfully submitted,

E. H. FRITCH, Secretary.

REPORT OF THE TREASURER.

To the Members of the American Railway Engineering Association:

I have the honor to present the following report for the calendar year ending December 31, 1915:

Balance on hand January 1, 1915		$17,312.27
Receipts during 1915	$24,118.67	
Paid out on audited vouchers	27,550.54	
Excess of Disbursements over Receipts	$ 3,431.87	3,431.87
Balance on hand December 31, 1915		$13,880.40

Consisting of	
Six Railway bonds, at cost	$ 5,206.06
Four N. W. Park Dist. bonds, at cost	4,062.00
Cash in Standard Trust and Savings Bank	4,612.34
	$13,880.40

STRESSES IN TRACK FUND.

Balance on hand January 1, 1915	$ 9,767.30
Received from Interest in 1915	278.85
	$10,046.15
Paid out on audited vouchers in 1915	2,980.87
Balance of fund on hand December 31, 1915	$ 7,065.28

The securities listed above are in a safety deposit box in the vaults of the Merchants' Loan and Trust Company, Chicago.

Respectfully submitted,
GEO. H. BREMNER, Treasurer.

On motion, the reports of the Secretary and of the Treasurer were accepted.

The President:—Before taking up the regular order of business, there are one or two announcements to be made at this time. There is a report on the subject of Clearances, Bulletin 184. The Chair has been advised that some members did not know of this report, did not know that the Committee to which this subject had been assigned was the one to look for such a report. This is one of the most important reports that we have and we can waste a great deal of time by approaching this in an improper way. I have this suggestion to make: We feel that there are a number of you who will want to make amendments or suggest changes in this report, when it comes before you. We hope that anyone who wishes to make changes in the report will have his amendments written out so that he can hand them to the Secretary or the Chairman, and thereby we can gain time in the discussion of this report. If you try to frame changes in the report on the floor we will waste a great deal of time. Anyone who wishes to make changes in the report will please come with motions right to the point. I also wish to call attention to the fact that we have a long program and we want to confine ourselves strictly to the subjects before us. Sometimes the wording of the report is not just exactly what some of you would like to have it. There may be some grammatical errors, but we have not time in the convention to discuss those matters. We have a Committee whose business it is to edit these reports and such matters will be referred to that Committee. If any of you have any suggestions to make in regard to such matters, you will kindly write them out and hand them to the Secretary.

Mr. A. S. Baldwin (Illinois Central):—Before proceeding with the regular order of business I would like to bring the matter of the General Index to the attention of the members. It has been found that the preparation of this Index involves a considerable cost, amounting to over $2,000. The financial condition of the Society is such that it cannot take on this additional burden without having a deficit, and in consequence it has been decided by the Board that a motion should be made before the house that a reasonable charge be made to the members for this book. This volume is a General Index—detail indexes have been furnished with all the volumes. I therefore offer the following resolution:

"*Resolved,* That on account of the cost of production and publication, the General Index now being prepared shall not be presented to members free, but that a reasonable charge shall be made to cover the expense of the volume, to be furnished at the following prices: To Members: Paper, $1.00; cloth, $1.50; half-morocco, $2.00. To Non-members: Paper, $2.00; cloth, $2.50; half-morocco, $3.00."

This is really a very valuable engineering index, and it is being offered at less cost than indexes of this character which are published are ordinarily furnished.

(The resolution was adopted.)

The President:—The Chair would request each member who rises to speak to announce his name very clearly, together with the road with which he is connected, so that the names can be heard by the reporter. I have to make a confession to you that, while many of your faces are very familiar to me, I have considerable difficulty in naming you instantly, so I hope you will announce your names when you speak.

The first Committee to present a report is that of the Committee on Signals and Interlocking. The Committee will please come forward and take their places on the platform.

The report of the Committee on Signals and Interlocking will be presented by the Chairman, Mr. C. C. Anthony.

(See report, pp. 65-75; discussion, pp. 783-785.)

The President:—The report of the Committee on Signs, Fences and Crossings will be presented by Mr. W. F. Strouse.

(See report, pp. 77-88; discussion, pp. 786-791.)

The President:—The next report is that of the Committee on Water Service, Mr. A. F. Dorley, Chairman.

(See report, pp. 89-97; discussion, pp. 792-795.)

AFTERNOON SESSION.

The President:—The first report to be considered this afternoon is that of the Committee on Iron and Steel Structures, Mr. A. J. Himes, the Chairman of the Committee, will present the report.

(See report, pp. 99-140; discussion, pp. 796-806.)

The President:—The next report which we will take up is that of the Committee on Wooden Bridges and Trestles, and Mr. E. A. Frink, the Chairman of the Committee, will present the report.

(See report, pp. 185-212; discussion, pp. 807, 808.)

The President:—The report of the Committee on Masonry will be presented by the Vice-Chairman, Mr. F. L. Thompson, in the absence of the Chairman, Mr. Schall.

(See report, pp. 213-232; discussion, pp. 809-824.)

EVENING SESSION.

The meeting was called to order by President Trimble at 7:40 o'clock.

Capt. Robert W. Hunt presented a paper, entitled "The Nick and Break Test in the Inspection of Steel Rails," and commented on the lantern slides, illustrating the paper.

(See pp. 751-776; discussion, pp. 825-835.)

Mr. Earl Stimson presented his paper on "A System for Standardizing Maintenance of Way Work," and commented on the lantern slides, illustrating the paper.

(See Part 2, pp. 247-263; discussion, pp. 836-839.)

WEDNESDAY, MARCH 22, 1916.

MORNING SESSION.

The meeting was called to order by the President at 9:30 a. m.

The President:—The first report this morning will be that of the Committee on Ties, and it will be presented by the Chairman, Mr. L. A. Downs.

(See report, pp. 233-270; discussion, pp. 840-846.)

The President:—The next report is that of the Committee on Conservation of Natural Resources, Mr. R. C. Young, Chairman.

(See report, pp. 271-278; discussion, pp. 847-849.)

The President:—The report of the Committee on Yards and Terminals will be presented by the Chairman, Mr. E. B. Temple.

(See report, pp. 279-298; discussion, pp. 850-853.)

The President:—The report of the Committee on Uniform General Contract Forms will be presented by the Chairman, Mr. E. H. Lee.

(See report, pp. 299-307; discussion, 854-860.)

The President:—Prof. A. N. Talbot will present the report of the Committee on Stresses in Railroad Track.

(See report, pp. 309, 310; discussion, pp. 861-863.)

AFTERNOON SESSION.

The first report this afternoon will be that of the Committee on Rules and Organization. It will be presented by the Chairman, Mr. G. D. Brooke.

(See report, pp. 423-445; discussion, pp. 864-889.)

The President:—The Tellers are ready to make their report, and the Secretary will read it.

Secretary Fritch then read the following report:

REPORT OF TELLERS.

Total Votes Cast	685
Not Endorsed and Not Counted	25
Total Counted	660
President:	
A. S. Baldwin	659
Vice-President:	
C. A. Morse	657
W. H. Courtenay	2
A. H. Stead	1
Treasurer:	
Geo. H. Bremner	656
E. A. Hadley	2
C. H. Cartlidge	1
C. G. Delo	1
Secretary:	
E. H. Fritch	659
Directors:	
R. N. Begien	263
C. E. Lindsay	242
W. D. Pence	240
L. A. Downs	227
J. E. Willoughby	220
J. V. Hanna	217
F. E. Turneaure	213
W. M. Dawley	182
A. J. Himes	139
F. Merritt	2
E. R. Lewis	1
E. A. Hadley	1
C. P. Howard	1

Nominating Committee:

A. M. Burt	450
A. F. Robinson	389
E. B. Temple	388
M. A. Long	358
W. K. Hatt	320
V. K. Hendricks	280
O. E. Selby	272
A. R. Raymer	263
A. F. Dorley	249
A. Montzheimer	201
Scattering	12

(Signed) W. T. Dorrance,
W. T. Eaton,
T. S. Stevens,
C. H. Fake,
O. Rickert,
A. M. Van Auken,
W. F. Ogle,
Tellers.

THURSDAY, MARCH 23, 1916.

MORNING SESSION.

The President:—The first report to be taken up this morning is that of the Committee on Roadway, Mr. W. M. Dawley, Chairman.

(See report, pp. 311-322; discussion, pp. 890, 891.)

The President:—The next report is that of the Committee on Ballast, and it will be presented by the Chairman, Mr. H. E. Hale.

(See report, pp. 323-368; discussion, pp. 892-901.)

The President:—The report of the Committee on Track will be submitted by Mr. J. B. Jenkins, Chairman.

(See report, pp. 369-392; discussion, p. 902.)

The President:—Mr. M. A. Long, Chairman of the Committee on Buildings, will present the report of that Committee.

(See report, pp. 393-398; discussion, pp. 912,913.)

The President:—In the absence of the Chairman and Vice-Chairman of the Committee on Electricity, the report will be presented by Mr. C. E. Lindsay.

(See report, pp. 399-406; discussion, page 914.)

The President:—Dr. Hermann von Schrenk, Chairman of the Committee on Grading of Lumber, will present the report.

(See report, pp. 407-411; discussion, pp. 915-917.)

The President:—The report of the Committee on Records and Accounts will be submitted by the Chairman, Mr. W. A. Christian.

(See report, pp. 413-421; discussion, page 918.)

The President:—Mr. Earl Stimson, Chairman of the Committee on Wood Preservation, will present the report of that Committee.

(See report, pp. 447-482; discussion, page 807.)

The President:—The report of the Committee on Economics of Railway Location will be submitted by the Chairman, Mr. John G. Sullivan.

(See report, pp. 779, 780; discussion, page 924.)

The President:—The last report to be considered is that of the Rail Committee. Mr. J. A. Atwood, Chairman, will present the report.

(See report, pp. 483-776; discussion, page 920.)

The President:—The next is new business. Are there any resolutions to be offered?

Secretary Fritch:—I desire to offer the following resolutions:

Resolved, By the members of the American Railway Engineering Association, in convention assembled, that we place on record our hearty thanks and appreciation to—

Dr. John A. Brashear,
Hon. Rodolphe Lemieux,
Arnold W. Brunner, Esq., and the
Rev. Allen A. Stockdale,

for their admirable and instructive addresses at the annual dinner on the evening of March 22d.

To the National Railway Appliances Association for the comprehensive and instructive exhibit of railway appliances.

To the technical press for their daily reports of this convention, and for the useful information made available to the members.

To the official reporters, Messrs. T. E. Crossman and G. W. Burgoyne, for their accurate and painstaking reports of this convention.

To the Tellers, Messrs. W. T. Dorrance, W. T. Eaton, A. M. Van Auken, Thos. S. Stevens, W. F. Ogle, C. H. Fake, O. Rickert, for their arduous labors in counting and tabulating the ballots cast for officers.

To the Committee on Arrangements for the highly successful arrangements made for the comfort and entertainment of the members and guests attending this convention.

(The resolutions were adopted.)

The President:—Are there any further resolutions?

Mr. William McNab (Grand Trunk):—I hold in my hand a resolution which it would give me great pleasure to elaborate, but such action will be unnecessary:

Resolved, That this Association, in convention assembled, places on record an expression of its appreciation of the able manner in which the retiring President, Mr. Robert Trimble, has performed the duties of President during the year, and also for the efficient manner in which he has presided over the deliberations of this convention.

(President-Elect Baldwin put the resolution to vote and it was adopted by a rising vote.)

The President:—I thank you for your kind testimonial. I feel that the success of the Association is entirely in your hands. You have helped to make this convention a successful one, and the credit is yours, not mine. Some of our members have been kind enough to remark that this convention has reached a high-water mark in the history of our Association. My recommendation to you is to put the high-water mark a little higher and build up to it during the next year.

The next business is the installation of officers. The Chair will appoint Mr. Storey and Mr. McNab to conduct the President-Elect to the platform.

The President:—Mr. Baldwin, it is with a great deal of pleasure that I hand over to you this symbol of your authority as the President of this Association. I am quite sure that the Association has made no mistake in its selection of you as President and its work will be well taken care of. I want to advise you of the great assistance the Secretary has been to the retiring President and you will find him of great help to you. (Applause.)

President-Elect Baldwin:—Mr. Trimble and Gentlemen: I think I need not undertake to tell you that I appreciate the honor you have conferred upon me. When I think of the galaxy of men who have preceded me in this office, of their professional attainments, of their character and of their earnestness in their work, I feel, indeed, that the honor is a high one.

I can but promise you that to the very best of my ability I will strive with the assistance that I know will be so cordially rendered to me by my predecessor to see that the high-water mark next year is at least not lower than the years of those that have gone before.

I thank you, gentlemen. (Applause.)

The President:—If there is no further business, the convention will stand adjourned.

The Eighteenth Annual Convention of the American Railway Engineering Association will be held at the Congress Hotel, Chicago, March 20, 21, 22, 1917.

E. H. Fritch,
Secretary.

AMENDMENTS TO COMMITTEE REPORTS.

REFERENCE TO AMENDMENTS MADE TO COMMITTEE REPORTS AT THE SEVENTEENTH ANNUAL CONVENTION.

TIES.

(For Report, see pp. 233-270; discussion, pp. 840-846.)

Amend paragraph 3, page 243, to read as follows:

"3. Cross-ties shall be cut from straight, sound, live trees, which are felled in the season when the sap is down. They shall be hewed or sawed to the specified dimensions and out of wind, with straight and parallel faces and with the ends cut at right angles to the axis of the tree. The minimum width of either face shall be not less than that given in the table of dimensions. They must be free from such score marks, shakes, loose or decayed knots, rot, splits or checks, or any other imperfections as may impair their strength or durability."

Amend paragraph 8, page 245, to read as follows:

"8. Treated ties shall be cross piled closely on well-drained ground to prevent checking, and piles shall be far enough apart to reduce fire risk."

RULES AND ORGANIZATION.

(For Report, see pp. 423-445; discussion, pp. 864-889.)

Amend the Proposed Clearance Diagram by making the distance from the center of track 7 ft. 6 in.

Amend paragraph 6, page 433, by substituting the words "new construction" for the words "reconstruction work" in the first line.

Amend the first paragraph on page 432 by eliminating the words "and reconstruction," in the second line.

Add to paragraph 14, page 433, the words: "Corrections should be made for curvature and superelevation of track."

COMMITTEE REPORTS

REPORT OF COMMITTEE X—ON SIGNALS AND INTERLOCKING.

C. C. Anthony, *Chairman;*
Azel Ames,
H. S. Balliet,
C. A. Christofferson,
C. E. Denney,
F. L. Dodgson,
C. A. Dunham,
W. J. Eck,
W. H. Elliott,
G. E. Ellis,
M. H. Hovey,
A. S. Ingalls,
J. A. Peabody, *Vice-Chairman;*
A. M. Keppel,
H. K. Lowry,
J. C. Mock,
F. P. Patenall,
D. W. Richards,
A. H. Rudd,
W. B. Scott,
A. G. Shaver,
Thos. S. Stevens,
W. M. Vandersluis,
Committee.

To the Members of the American Railway Engineering Association:

The following subjects were assigned:

1. *Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.*

2. *Continue the study of economics of labor in signal maintenance.*

3. *Study the problem of signaling single-track roads with reference to the effect of signaling and proper location of passing sidings on the capacity of the line.*

4. *Present, for approval, specifications adopted by the Railway Signal Association, which, in the judgment of the Committee, warrant consideration.*

5. *Requisites for switch indicators, conveying information on condition of the block to conductors and enginemen.*

(1) REVISION OF THE MANUAL.

No revisions of the Manual are recommended. Your Committee believes that revisions deemed necessary at this time have been made in the edition in course of preparation at the time of writing this report.

(2) ECONOMICS OF LABOR IN SIGNAL MAINTENANCE.

In 1914 your Committee submitted a preliminary report on this subject, which was received as a progress report. (See Proceedings, Vol. 15, 1914, pp. 71-73 and 1011-1012.) Since that time your Committee has given the subject further study and now submits a report embodying the conclusion at which the Committee has arrived. This report was submitted to the Railway Signal Association in 1915 by its Committee on Signaling Practice and accepted as information.

ECONOMICS OF SIGNAL MAINTENANCE.

In the preliminary report on this subject, 1914, it was stated that signal work draws men from every class of mechanics. Any of these different classes can be developed into general signal men, but, in the present state of the art, a training along electrical lines is almost universally essential.

With practically all classes of mechanics existing on a division, if it is determined to use them on signals as well as other work, the question arises as to how they shall be handled. The Superintendent need not necessarily be a signal expert to handle the business of the company satisfactorily; by using judiciously the knowledge acquired by the departments, with a proper consideration for costs, he can so arrange the expenditures on the division that the maximum net revenue will result. It can hardly be expected that he will have or retain sufficient knowledge of the details to enable him even to supervise the signal work. The heads of other well-recognized departments have spent their lives doing actual work or handling busy executive jobs along their own lines and studying sufficiently to keep up with the progress made. So that, if the signal work on any division is of sufficient importance to affect the company revenue materially, or if inadequate maintenance of the signaling would materially affect the efficiency of train service, it would appear that men specially trained in signal work should be used for its supervision.

In all branches of engineering activities there are found specialties which apply only to the one under consideration and which can only be learned by experience. The track circuit with its relay is one of these specialties in signal work which, while it involves no new principles generally, is a combination which is not found in any other activity and must be studied as a part of signal work. Because of the necessity for the display of correct signal indications, the circuits must be studied from an entirely different standpoint from those found in other branches of electrical engineering; and the demand generally for fool-proof apparatus and its maintenance in such condition, creates a demand for men especially educated in a practical way to think and act correctly in emergency in accordance with established standards and practices.

In civil engineering activities a laborer can drive stakes or hold level rods and only a very limited education is necessary to run levels and work out the simpler problems with a transit; but when the positions of Division or Chief Engineer are under consideration, either general education or long practical experience, which has included special education, are necessary to fit the man for the job.

As with civil engineering or other activities, so it is with signal work; many of the operations can be carried on by untrained men. A large share of the work involves very little knowledge; but if men are used for these duties in connection with others of the same general character in other activities, there seems no way by which they can progress or learn the things that will fit them properly to inspect and maintain the more complicated parts of the installations, except through the medium of practical experience which, in turn, must involve a general force devoting its entire time to signal work or closely allied activities.

CONCLUSION.

Because the main controlling power of signal apparatus is electrical and because the special training required is so different, we do not recommend, as a means of obtaining economy and efficiency in signal maintenance, a combination of signal and track forces. Occasionally, however, it will be found practicable and economical to combine forces engaged in maintaining various electrical features on a railroad, with those maintaining signals. But, as a general proposition, economy and efficiency will be produced to a higher degree by co-operation than by combination; and this rests entirely with the officer in charge, in the arrangement of the forces available.

ACTION RECOMMENDED.

Your Committee recommends that the above report on "Economics of Signal Maintenance" be accepted as information.

(3) CAPACITY OF SINGLE TRACK.

This subject was assigned at the outset to a Sub-Committee, consisting of Messrs. Peabody (Chairman), Ames, Denney, Eck and Patenall, to which Messrs. Dodgson, Ingalls and Scott have since been added. The same subject is assigned by the Railway Signal Association to its Committee on Signaling Practice and the work is carried on jointly by the two committees. The first work of the Sub-Committee was to prepare an outline or classified schedule of the various characteristics affecting the capacity of single track. This outline, after discussion and amendment at several meetings, has been accepted by the Committee as a guide in the study of the subject.

This year the Sub-Committee was fortunate in securing the co-operation of F. L. Dodgson, Consulting Engineer, General Railway Signal Company, who has given a good deal of study to both phases of the subject—the signaling of single track and the effect of the number and location of passing sidings. Mr. Dodgson has contributed an analysis of the effect of passing-siding location on the capacity of single track, in which are developed formulas for determining the theoretically correct locations of a given number of passing sidings on a given piece of single-track road to secure the maximum capacity in trains per day, and for determining the theoretical number of trains that can be moved with a given number and arrangement of sidings. Such factors as the time consumed in taking siding, stops for water and movement of trains in sections, are introduced and specific examples are given.

A portion of this analysis, developing the principal formulas, is submitted for the information of the members and to show the basis of the Committee's work on this part of the subject.

LOCATION OF PASSING SIDINGS ON SINGLE TRACK.

In considering the effect of passing-siding locations on the capacity of single-track railroad, it would seem to be the most logical thing to first determine, if possible, what rule or rules, if any, must be followed in order to so locate the sidings that the maximum capacity of the road will be obtained.

With this in view, let us first assume a piece of level railroad forty miles long over which we are to operate one class of trains only, these trains traveling at a uniform speed of twenty miles per hour. Fig. 1 is a train diagram of such a road with the distance the vertical lines and the time the horizontal lines. If there were no sidings on this road, two trains could be run (one in each direction) each four hours during the day. These two trains are shown on the diagram by the two heavy lines aW and aE. If, now, we assume that there is one passing siding on the road, it is quite evident that the maximum capacity would be reached with this siding located exactly in the center of the road. With this arrangement two additional trains could be run each four hours and they are shown on the diagram by the lines bE and bW. If we represent the time required for the westbound train to run from E to C (C being the siding location) by W1 and the time required for the same train to run from C to A by W2; likewise the time required by the eastbound train to run from A to C by E2, and the time required to run from C

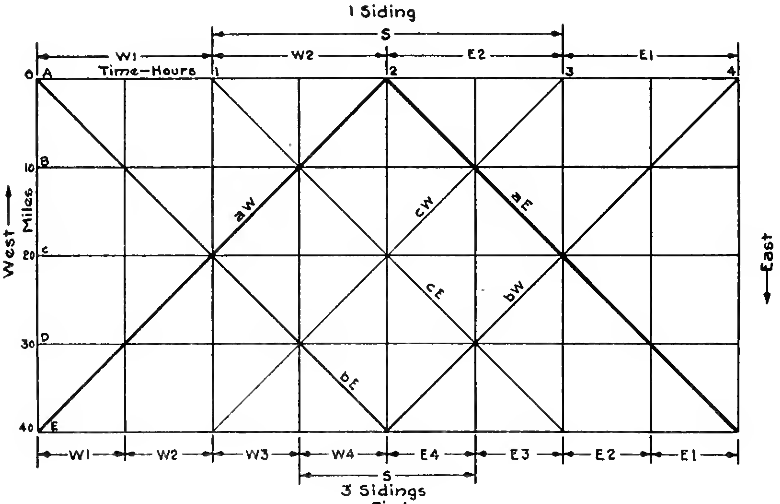


Fig. 1

to E by E_1; and represent by S the spacing in time between trains running in the same direction; we will find by inspecting the diagram that:

$$S = W_2 + E_2 \tag{1}$$

and

$$S = W_1 + E_1. \tag{2}$$

Therefore:

$$W_2 + E_2 = W_1 + E_1. \tag{3}$$

Or, if we state this last equation in words, it means that the sums of the running times of an eastbound and a westbound train between sidings are equal.

Now let us continue and add two more passing sidings to our railroad. Again it is quite obvious that the maximum capacity will be obtained if these two additional sidings are located exactly midway between A and C, and C and E. If, as before, we represent the running time of the westbound train from E to D by W_1, D to C by W_2, C to B by W_3, and B to A by W_4 (B and D being the locations of the two new sidings); and also the running time of the eastbound train from A to B by E_4, B to C by E_3, C to D by E_2, and D to E by E_1; and as before make S the time spacing between trains in the same direction; we will find from the diagram that:

$$S = W_1 + E_1 \tag{4}$$

and

$$S = W_2 + E_2 \tag{5}$$

and

$$S = W_3 + E_3 \tag{6}$$

and

$$S = W_4 + E_4. \tag{7}$$

Therefore:

$$W_1 + E_1 = W_2 + E_2 = W_3 + E_3 = W_4 + E_4.$$

Again this last equation stated in words means that the sums of the running times of trains in opposite directions between passing sidings are all equal.

From this simple diagram, Fig. 1, it will appear, therefore, that the maximum capacity of the railroad, with a given number of passing sidings, would be reached when the sums of the running times of the east and westbound trains between passing sidings were all equal.

We can determine the value of S quite readily as follows: By adding equations 1 and 2 we have:

$$2S = W_1 + W_2 + E_1 + E_2 \tag{8}$$

or, representing $W_1 + W_2$ by W, the total running time of the westbound train, and, similarly, $E_1 + E_2$ by E,

$$S = \frac{W + E}{2} \tag{9}$$

which is the value of S when there is only one passing siding.

Again, if we add equations 4, 5, 6 and 7, we have:

$$4S = W_1 + W_2 + W_3 + W_4 + E_1 + E_2 + E_3 + E_4 \tag{10}$$

or

$$S = \frac{W + E}{4}. \tag{11}$$

If we let N equal the number of passing sidings, then, in equation 9, $2 = N + 1$, and, in equation 11, $4 = N + 1$. Therefore, by substituting in equations 9 and 11, N for the number of sidings, we obtain the formula:

$$S = \frac{W + E}{N + 1}.$$

In deriving the above formula we have assumed uniform and equal speeds of trains. In order to show an application of this formula and also to prove its correctness, let us assume varying and unequal speeds of trains over our section of forty miles. Let us assume the running times to be as follows:

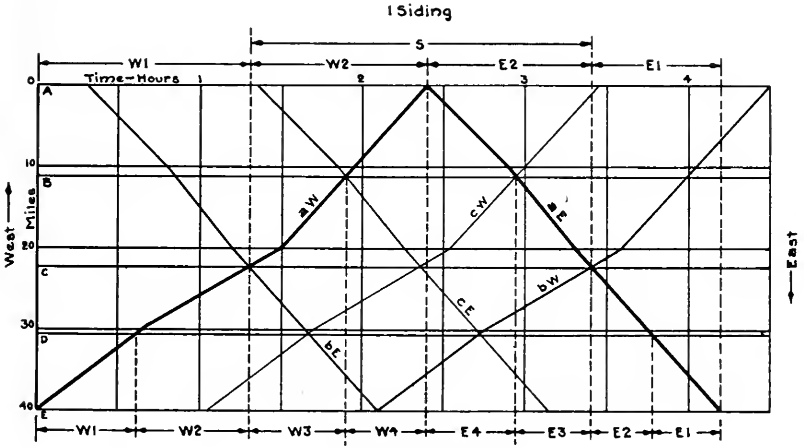
Distance	Westbound	Eastbound
0 to 10	27 minutes	30 minutes
10 to 20	27 "	24 "
20 to 30	51 "	27 "
30 to 40	39 "	27 "
Totals,	144 "	108 "

Now in Fig. 2, plot the line aW, using the time for westbound trains shown in the above table and from the point where this line crosses line A plot the line aE, using the time shown for eastbound trains in the same table. First, let us assume one passing siding. Then in our formula, $S = \frac{W + E}{N + 1}$, $W = 144$, $E = 108$ and $N = 1$, which gives the value, $S = \frac{144 + 108}{2} = \frac{252}{2} = 126$ minutes. Now, in Fig. 2, we will plot the line bW 126 minutes from aW and parallel with it and also plot the line bE 126 minutes from aE and parallel with it. If our plotting has been correct, aE will cross bW and aW will cross bE on the same horizontal line, because the two triangle-like figures formed on the line E as a base by the lines aW and bE, and bW and aE, have the same length of base and their other corresponding sides parallel with each other, and must, therefore, be the same in height. If the passing siding is located at the line C, it is quite evident that we will again have the maximum capacity of this piece of road under the conditions given; and it is also true that the sum of the running times between A and C of the west and eastbound trains is equal to the sum of the running times of the same trains between C and E.

Now let us suppose that we add two more passing sidings, making three in all. From our formula we find that under these conditions $S = \frac{144 + 108}{4} = \frac{252}{4} = 63$. Now, if on Fig. 2 we plot the line cW parallel with and 63 minutes from aW and the line cE parallel with and 63 minutes from aE, we will establish the positions of the passing sidings B and D at the points where these two lines intersect the lines bE ard aE, aW and bW. It will be apparent here, as before, that this arrangement would give the maximum capacity and also that the sum of the running times between A and B is equal to the sum of the running times between B and C, etc. The rule, therefore, which we first laid down seems to hold true when the running times are unequal and speeds not uniform.

While the method just pointed out in Fig. 2 will answer admirably as a graphic method of determining the locations of passing sidings for maximum capacity, it will not, however, answer for determining the capacity of the railroad, because we have not taken into account the time lost by a train which takes a siding to meet another train; neither have we taken into account the time required for water stops.

Starting again with a uniform speed of 20 m. p. h., let us assume on our forty-mile stretch that there is a water stop at mile post 15,



3 Sidings
Fig. 2

and further let us assume the total time lost in taking water by each train to be twelve minutes. The total running time, therefore, of each train would be two hours and twelve minutes. Further, let us assume that the time lost by a train taking a passing siding for another train to pass is nine minutes and that one-half of this time is consumed in entering the siding and one-half in leaving, and let us also assume that the eastbound train takes the siding. Fig. 3 shows the train diagram for such an arrangement with one passing siding.

If we let S equal the spacing between trains in the same direction, it is quite obvious that the number of trains per day, which we will represent by T, will be $T = \frac{1440 \times 2}{S}$ (1440 being minutes in a day and S being expressed in minutes), or $T = \frac{2880}{S}$.

We may determine the value of S as follows: Assuming that W_2 represents the time of the westbound train running between the passing siding and 0, and W_1 the time running between the passing siding and 40, and E_2 the time consumed by the eastbound train in running between 0 and the passing siding, and E_1 the time between the passing siding and 40, and also letting a represent the time consumed by a train taking the passing siding to meet another train, we have from the diagram:

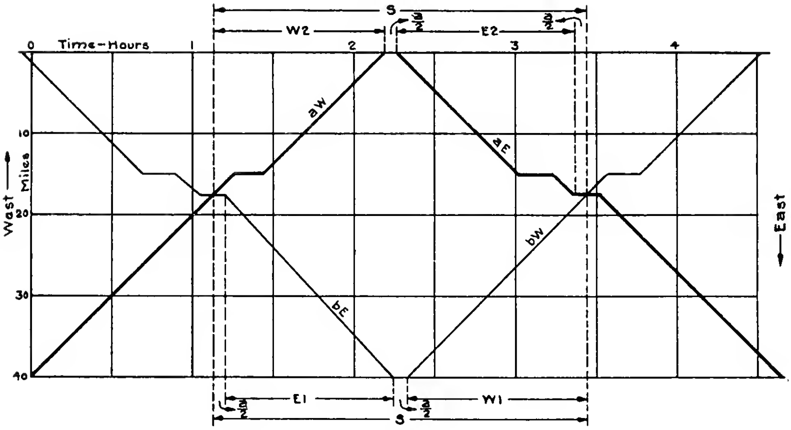


Fig. 3

$$S = W_1 + E_1 + \frac{a}{2} + \frac{a}{2};$$

also

$$S = W_2 + E_2 + \frac{a}{2} + \frac{a}{2};$$

or

$$2S = W_1 + W_2 + E_1 + E_2 + a + a$$

or

$$S = \frac{W + E + 2a}{2}.$$

If N equals the number of passing sidings, then substituting in the last equation N + 1 for 2 we have:

$$S = \frac{W + E + (N + 1)a}{N + 1}.$$

Substituting this value of S in

$$T = \frac{2880}{S}$$

we have

$$T = \frac{2880\ (N + 1)}{W + E + (N + 1)a}.$$

In other words the maximum number of trains of one class that can be run in twenty-four hours over a piece of railroad equals 2880 times the number of passing sidings plus 1, divided by the sum of the running times of an east and westbound train over the road, plus the number of sidings plus 1 multiplied by the delay caused by a train taking the passing siding.

FURTHER WORK ON THIS RRANCH OF THE SUBJECT.

It will be seen that, up to this point, there have been developed methods of finding the proper locations of passing sidings for trains of one kind and determining the capacity of a given piece of single-track road in trains of one kind. It is expected that formulas or methods will be developed for determining capacity in trains of one kind as affected by the movement of a given number of trains of other kinds run on definite schedules. Then the various formulas will be applied and tested in the analysis of actual pieces of road with their actual movement of scheduled trains.

ACTION RECOMMENDED.

Your Committee recommends that the above matter on Capacity of Single Track be accepted as a progress report.

(4) SPECIFICATIONS OF THE RAILWAY SIGNAL ASSOCIATION.

Your Committee submits the following list of matters acted upon by the Railway Signal Association at its convention in 1915 and adopted by letter-ballot in 1916, including certain revised titles:

LIST OF THE FINDINGS, CONCLUSIONS, STANDARDS AND SPECIFICATIONS ADDED TO THE MANUAL OF THE RAILWAY SIGNAL ASSOCIATION IN 1916.

Text.

Battery, Primary:
    Caustic-soda, Instructions for Maintenance.
    Dry, Instructions for Testing and Maintaining.
    Gravity, Instructions for Maintenance.
Battery, Storage:
    Lead-type, Description of—Eliminated.
    Nickel-iron alkaline, Specifications.
    Stationary Lead-type (not of the Pure-lead type), Specifications.
Choke Coils for Signaling, Requisites.
Indicator, Take-siding.
Lamps, Incandescent Electric, Specifications.
Lightning Arresters for Signaling:
    Requisites.
    Vacuum-gap, for Voltage Ranges 1 and 2 (175 volts or less), Specifications.
    Reactors for Line and Track Circuits, Specifications.

DRAWINGS.

Bracket Posts:	
Crank Brackets for	1198
Guides for Vertical Connections on	1196
Clamps, Brackets and Caps	1020
Ladders for	1028
Parts	1027
Clamps and Stays	1029
Pipe, Crank Bracket Fittings for	1024 and 1025
Cranks, Adjusting, for Signals	1361
Jaws for One-inch Pipe:	
Screw, for Ground-mast Signals	1360
Lamps, Incandescent Electric	1329
Machine, Two-lever Wall	1197 and 1397
Masts, Signal:	
Guides for Vertical Connections on	1023
Clamps	1021
Supports and Caps	1023
Ladders:	
Parts	1027
Clamps and Stays	1029
Bracket-post:	
Ladders for	1028
Ground	
Adjusting Cranks for	1361
Tang Ends with Screw Jaws for	1360
Signals:	
One-arm Mechanical Ground	1043
Two-arm Mechanical Ground	1044
Three-arm Mechanical Ground	1045
Tang Ends for One-inch Pipe:	
With Screw Jaws for Ground-mast Signals	1360

ACTION RECOMMENDED.

Your Committee recommends that this list of Railway Signal Association specifications and standards be published in the Manual, as supplementary to the list previously inserted, for the information of the members.

(5) REQUISITES FOR SWITCH INDICATORS.

Your Committee has continued the study of this subject with the purpose of adapting to single-track conditions the requisites, etc., previously submitted (see Proceedings, Vol. 16, 1915, pp. 75-76), but has not yet devised a satisfactory form, and therefore reports progress.

RECOMMENDATIONS FOR NEXT YEAR'S WORK.

Since Committee X and the Committee on Signaling Practice, of the Railway Signal Association, have nearly the same members and always meet jointly, it is convenient to have the same subjects assigned to these two committees. Your Committee therefore submits the subjects assigned to the latter committee with the recommendation that they, or such of them as the Board of Direction may choose, be assigned for next year.

2. Report on applications of aspect for instructions to trains to take siding at a non-interlocked switch.

3. Formulate and submit requisites for switch indicators, including method of conveying information as to the condition of the block to the conductor and engineman.

4. Investigate automatic train control.

5. Study the problem of signaling single-track roads with reference to the effect of signaling and proper location of passing sidings on the capacity of the line.

6. Analyze the signal schemes which have been presented to the Association. State specifically for what purpose each aspect and indication shall be used, and what action is required of the engineman.

7. Investigate the various methods of giving signal indications other than by means of the semaphore.

8. Recommend aspect for highway crossing signals.

To these should be added as a standing instruction:

Present the specifications, standards, etc., adopted by the Railway Signal Association during the year.

Your Committee further recommends that the subject, "Adaptation of design of movable bridges to signal and interlocking appliances required," be assigned jointly to Committee XV—on Iron and Steel Structures, and Committee X.

Respectfully submitted.

COMMITTEE ON SIGNALS AND INTERLOCKING.

REPORT OF COMMITTEE IX—ON SIGNS, FENCES AND CROSSINGS.

W. F. Strouse, *Chairman;*	G. E. Boyd, *Vice-Chairman;*
R. B. Abbott,	Maro Johnson,
H. E. Billman,	L. C. Lawton,
E. T. Brown,	G. L. Moore,
A. C. Copland,	W. F. Purdy,
Arthur Crumpton,	Thomas Quigley,
J. T. Frame,	C. H. Splitstone,
L. E. Haislip,	*Committee.*

To the Members of the American Railway Engineering Association:

The Board of Direction assigned your Committee the following outline of work:

(1) Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.

(2) Report on the principles governing the use of railway signs.

(3) Continue the study of Concrete Fence Posts.

(1) REVISION OF MANUAL.

Last year your Committee devoted a great deal of time to and made a very exhaustive study of the subject-matter in the Manual. A number of new definitions were added, a number of the old ones were improved as to diction, while a number of others were recommended for elimination on account of them defining objects so familiar to the membership of this Association as to make them seem superfluous. All changes recommended by the Committee were accepted by the Association, with some minor alterations or revisions. At the same time the convention was advised that the proposed revisions of the Manual submitted by the various Committees would be reviewed by a Special Committee appointed for the purpose.

Your Committee, therefore, makes no recommendations for changes this year in any portion of the Manual, upon which it reported last year. No changes, however, were recommended in the conclusions adopted by the Association three years ago, relative to "Track Construction and Flangeways at Paved Street Crossings and in Paved Streets."

This subject had been carefully considered by the Committee at that time, and without a thorough review of the information from which the conclusions were drawn, it was considered unwise to suggest changes.

When the above conclusions, however, were recommended for inclusion in the reprint of Manual without revision, rather strong opposition developed, which seemed to center particularly about paragraph 3, recommending the use of 141-lb. 9-inch girder rail. After a somewhat detailed discussion of the various phases of the subject, the Committee requested it be referred back for further study, feeling it might be able to secure additional information from which to draw conclusions or recommend changes in the conclusions already submitted. Further investigation of the matter and a careful study of the report and discussions has led your Committee to believe that some of the criticisms offered last year were due to a misunderstanding of the scope of the subject. Two distinct conditions are implied in the subject as assigned; namely, a style of construction suitable for use at paved street crossings, and one suitable for tracks laid in paved streets. A study of the report from which the above conclusions were deduced would seem to indicate that they were intended to be more especially applicable to the construction of tracks in paved streets than at paved street crossings, although there is no essential difference in the principle involved, but only in scope. Your Committee, therefore, believes that separate conclusions are necessary to cover each condition as implied in the outline.

It would undoubtedly be most objectionable to the railroads to be compelled to use special rail with compromise joints at a few isolated street or road crossings, even though they might be of more or less importance.

Indeed, it has been in comparatively recent years that this subject has been so strongly urged upon the railroads and then frequently by Municipal Engineers who do not appreciate the difficulties of maintaining the kind of construction required by them.

In many cities, however, the railroads have either commercial sidings or main tracks located in paved streets for varying distances occasionally miles in length.

If the vehicular traffic on these streets is heavy and they are paved with standard granite blocks of an average depth of 6 inches, the ordinary T rail is not deep enough to provide a proper sand cushion over the ties. This has brought about the very general use of the 141-lb. 9-inch girder rail with flangeway, although a slightly shallower rail might prove just as satisfactory. On the other hand, if the vehicular traffic is light and other conditions are favorable to the use of sheet asphalt, asphalt, wood or vitrified blocks, the regular T rail construction is not only possible but preferable.

During the past few years the Baltimore & Ohio Railroad Company has relaid considerable track located in paved streets in Baltimore and Washington with girder rail. In Washington a 60-lb. T rail on a chair was superseded by a 141-lb. 9-inch girder rail. In Baltimore various rails, including a form of grooved rail on longitudinal sleepers, has finally been replaced by the girder rail. Little attention, however, has as yet been given the matter of street crossing construction, the crossings usually being planked.

With a view of ascertaining what the railroads are doing along the lines above referred to in other cities, your Committee secured plans from a number of railroads showing the construction in use by such roads. An examination of these plans will show that in some cases considerable attention has been paid to drainage, while in others no provisions whatever have been made. As a general proposition this is a very important feature and should not be neglected.

There are a number of factors, however, which should be carefully considered in planning such construction; for example, the character of material upon which the tracks are laid, whether supported on ballast or a concrete base, style of paving, etc.

If the subgrade is perfectly dry and thoroughly drained naturally and the street is paved with sheet asphalt or grouted blocks on a substantial concrete base, the matter of drainage is not so important, as conditions tend to improve with age.

If, however, the subgrade is naturally wet, the question of drainage, regardless of the character of the construction above, is most important. Each case should, therefore, receive attention as the surrounding conditions would seem to dictate.

In the discussion of this subject before the last convention, objection was made to paragraph 5 of the conclusions on above subject, relative to having paving conform to municipal requirements. As the use of public streets can only be acquired by ordinance or other legislative act, the railroads can generally rest assured that such occupation will be conditioned on their compliance with municipal requirements, which generally are construed to cover the best and most improved construction in the respective cities. Almost invariably this will be of much better type than that in use when occupation was granted. Nor does it always rest at that, but frequently is conditioned on the railroads doing additional work as part of the franchise.

In growing cities and towns, especially in the West, the demands for carrying the standard street pavement across tracks at street intersections have become so frequent and insistent that it is of great importance to the railroads. In many cases the municipalities require a concrete base under and between the ties. This form of construction has not always proven satisfactory under heavy railroad traffic; hence the results have not warranted the expense. The use of ballast under high-speed tracks seems to be more satisfactory from every standpoint because of its elastic qualities, the concrete base being too rigid.

In Kansas City a few years ago an ordinance was passed requiring the use of a concrete base and paving material to correspond to that of the street adjacent. Following the passage of this ordinance, a Committee composed of railroad and city officials was appointed to investigate and submit a plan for a type of the construction which would be mutually satisfactory. The result of the Committee's deliberations was a type of construction unquestionably better adapted to general conditions than that required by the ordinance.

The former ordinance was then repealed and another enacted, making the styles of crossings shown in Plate A standard for the city. Since the enactment of the latter ordinance all renewals are required to be in accordance with these plans.

The fundamental principle underlying the design is that the street paving adjacent should in no way be connected to or be dependent upon the track, thus giving it a chance to slightly change its position vertically without disturbing the surface of the crossing or that of the adjacent street paving.

The construction consists essentially of the standard track construction of the several railroads on stone ballast with proper provision for taking care of the drainage. The street paving is separated from the track construction, and held in position by a 3 by 12 inch timber curb supported on substantial posts located at intervals of about 4 feet just outside the ends of the ties. The track space is covered by a single or double plank floor, as may be required to meet traffic conditions. The flangeways are provided by the use of a relaying rail of lighter section than the running rail, laid on its side.

This general type of construction has been adopted by the Chicago, Rock Island & Pacific Railway, and it is said to be giving satisfactory service where it has been used.

The Atchison, Topeka & Santa Fe has used two types of construction at paved street crossings, which are said to have given satisfaction where used. In one case it consists of the standard track construction imbedded in concrete from a point 12 inches below to the tops of the ties. Upon this is placed a sand cushion and vitrified brick paving. In the other case, the construction is similar, except that provision is made for a bed of ballast between the concrete base and the ties, the thickness depending on the character of the traffic, 6 inches being used for high-speed service and nothing for yard service.

For flangeways they have used rails of a lighter section set upright on blocks to provide proper elevation and bolted to the running rail at intervals of 6 feet, the proper flangeway being maintained by the use of fillers or separators. This style of flangeway is claimed to be more satisfactory than that where the rails are laid upon their sides, in that there are no sharp edges exposed to damage automobile tires.

The Illinois Central Railroad has used several different types of construction in paved streets and at paved street crossings. These types have generally consisted of a 6-inch concrete base under the ties, with the space between filled to the tops of the ties. On this base the various forms of paving have been laid, the rail in each case being the standard T rail of the company. The flangeways have been formed by fitting the paving blocks against the web of the rail by beveling the blocks and by the use of rails laid upon their sides. No suggestion is made on the plans as to drainage, this feature being left open to be treated as occasion required. The Pennsylvania Lines West of Pittsburgh use their standard track construction with rail flangeways and plank crossing.

In the report of this Committee three years ago attention was called to the fact that street car companies seemed to pay more attention to the details of construction of their tracks in paved streets than had been done by steam roads. Your Committee is still of this opinion, and in support of the same, wishes to call attention to drawing in this report illustrating details of construction of tracks by the Montreal Tramways Company. This drawing illustrates both girder and T rail construction. The matter of drainage is also apparently very carefully considered. While this drawing illustrates the style of construction for trolley companies, the same general details are used in the construction of steam railways at intersection points with tramways company's tracks.

During the past year the city of Baltimore has laid in the center of a new thoroughfare, along the south side of the harbor, known as the "Key Highway," an industrial track which is to form part of a "Belt Line." This track is of girder rail construction and laid in a wide street paved with granite blocks on concrete base, all grouted together, and is designed to provide rail accommodations to industries located along and near the waterfront by running spurs into properties desiring them. This line is connected with the railroad lines in that territory and will some day handle a heavy vehicular traffic.

After a careful study of the plans received and of construction with which the membership of the Committee is familiar, it has reached the conclusion that two distinct conditions are to be met and that three distinct forms of construction are desirable.

For paved street crossings, where the general direction of traffic is at right angles to the track, the regular standard track construction of the several railroads should be used, and the space occupied by the track or tracks planked over. The flangeway should be formed by using a rail laid upon its side and properly secured to the ties or set upright and bolted to the running rail, the flangeway being maintained by a continuous iron or steel filler, made in short sections to permit its use when necessary on curved tracks. Where the flangeway rail is set upright the side of the head of the rail adjacent to the flangeway should be beveled to an angle of about 45 degrees to prevent horses' feet from getting trapped.

For tracks located in paved streets, subject to heavy traffic, requiring granite block paving, the construction should consist of stone or gravel ballast not less than 12 inches deep, treated ties and 141-lb. 9-inch girder rail, the paving within the track limits to comply with municipal requirements as to depth of base, thickness of sand cushion, sealing of joints, etc.

For tracks located in streets subjected to light traffic only, the construction should consist of standard track construction, using treated ties, stone or gravel ballast, the space occupied by tracks to be paved to meet municipal requirements.

FLANGEWAYS.

In the course of its investigations your Committee found quite a number of schemes in use for providing flangeways at road and street crossings and in paved streets. A form in very general use is that provided by laying a rail upon its side with the head resting against the web of the running rail and the base against the edge of the adjacent planking or other paving material used between the rails. Objection to this style of flangeway has been made in some quarters because the base of the rail has been known to work up above the adjacent paving and cut or damage automobile tires.

This objection could no doubt be eliminated by securing the rail to the ties by the use of lag screws or spikes, as is done by some roads. The expense of drilling the rail at intervals of about 4 feet would be somewhat objectionable, but would even then be much cheaper than the commercial flangeways now on the market.

Another and more serious objection, however, to this style of flangeway is the fact that it cannot be used at joints in the running rail without cutting out the head opposite the angle bar or eliminating the flangeway entirely at the joints, which is frequently done.

Another form of flangeway quite common in plank crossings is either to leave sufficient space between the gage line and the adjacent planks or to bevel them to fit. This form is objectionable in that the opening is deep and horses are liable to get their feet caught in the opening. In case two thicknesses of plank is used the depth of flangeway can be diminished by fitting the lower plank over the base of the rail. The wear and tear from passing wheels on this form of flangeway is usually rapid, requiring rather frequent renewals of the planks.

Another method is to fit one of the various forms of paving blocks against the web of the rail between the head and base. This form of flangeway would probably prove satisfactory in tracks where the speed of trains is low, but could not be recommended for use in high-speed tracks. The form of flangeway which most nearly meets all requirements, and at a moderate cost, is that provided by the girder rail now extensively used in the construction of tracks in paved streets, and to which attention has already been called in this and previous reports.

There are some forms of proprietary flangeways on the market which have good points in their favor, among which may be mentioned the simplicity of installation, low cost of maintenance, safety to horses or other animals using the crossings and freedom from sharp edges, which would cut or otherwise damage automobile tires. The first cost, however, may delay their general adoption, although it is believed the above-mentioned advantages will in time warrant their use in all important crossings.

A study of the cost per linear foot of track of the various forms or combinations used to provide flangeways, based on the use of new steel rails in the track at one and one-half cents per pound and relaying rail for flangeways at one cent per pound, results as follows:

100-lb. T Rail,	$1.00;	labor fitting planks,	$0.10	$1.10
100-lb. T Rail,	1.00;	labor fitting paving blocks,	.20	1.20
100-lb. T Rail,	1.00;	75-lb. flange rail,	.50	1.50
100-lb. T Rail,	1.00;	metal flangeway,	1.00	2.00
141-lb. girder rail with flangeway				1.40

In the above statement showing cost data no allowance has been made for cost of labor laying the track rail, it being assumed to be in place. The cost of putting down the planks, laying adjacent paving blocks, placing flangeway rails and installing proprietary flangeways would vary so little as to make no appreciable difference in cost per unit after the track is constructed.

It should be stated in passing that with the exception of the form first mentioned all the above flangeways can be used in paved street crossings, should this style of construction be required.

From the above it will be noted that the cheapest flangeway is that furnished by dressing and placing the crossing planks a sufficient distance from the gage of the rails to provide the necessary space. This form is unsatisfactory because the feet of horses or other animals are easily trapped and because of the expense incurred in making frequent renewals on account of the wheels cutting or wearing the timbers away.

The use of paving blocks fitted to the webs of the rails and either grouted or filled with paving pitch, is somewhat more expensive and not so well-suited to high-speed traffic as the other forms, but very satisfactory for use in commercial tracks laid in paved streets.

For important street crossings, where the depth of paving will permit the use of the regular T rail, or where the crossings are planked, the most desirable flangeway from the railroad company's standpoint is that formed by the use of relaying rail properly secured to the ties with lag screws or other satisfactory form of fastening. With this style of flangeway it is highly desirable that the track, where practicable, be laid so as to avoid joints in the crossings. In the case of wide crossings this condition, of course, cannot be realized without the use of extra-length rails.

In the matter of flangeways for tracks laid in paved streets, your Committee feels that the most satisfactory construction is that obtained by the use of the 141-lb. 9-inch girder rail with flangeway. This construction is cheaper in first cost than where a relaying T rail is used with the main rail to form the flangeway. It will permit the use of any kind of paving; provides a flangeway for the wheels; leaves no openings in which animals can get trapped; provides a shoulder against which to place the paving and requires no maintenance as long as the rail lasts.

(2) PRINCIPLES GOVERNING THE USE OF RAILWAY SIGNS.

Railway signs naturally fall under two divisions or classes: One applying to the general public, the other to the employés of the railroad companies.

Of the former, the principal signs are public and private road crossings and trespass signs. Under the latter may be mentioned whistle and ring boards, clearance and mile posts, right-of-way monuments, bridge and trestle numbers, etc.

The signs of the first class are pretty fully covered by the laws and rulings or decrees of the Public Utility or Railway Commissions of the various States, while those of the second class are the results of expedients adopted from time to time to aid in the solution of operation problems and insure greater safety.

In the report submitted by this Committee two years ago, and which may be found in Volume 15 of the Proceedings of the Association, is given the text of the laws in 32 States and the Dominion of Canada relating to the maintenance of signs at public highway crossings. For quick reference, synopses of these laws, as well as the decrees and rulings of the Public Utility or Railway Commissions of Connecticut, Indiana, New Jersey and Rhode Island are given in the body of the report, with the statement that there are no laws in effect in Colorado, Louisiana, Nebraska or Oregon respecting the installation or maintenance of highway crossing signs. This statement, however, does not imply that the railroads do not use crossing signs in these States, but they are in no way restricted as to design, wording of inscription or size of letters.

In the same report may be found the text of laws in force in 28 States and the Dominion of Canada relating to trespassing on railroad or other private property.

Synopses of laws, relative to the installation and maintenance of highway crossing signs, in force in California, Idaho, Montana, Nevada, Utah, Vermont and Wyoming, received too late for inclusion in the report of 1914, were given in the body of last year's report. Synopses of laws respecting trespassing, in force in California, Idaho, Montana, Nevada, New Hampshire, Utah and Wyoming, received too late to appear in the 1914 report, will be found in the body of last year's report.

The laws of about 75 per cent. of the States reported state more or less specifically what shall constitute a legal highway crossing sign, that is, the general design, the wording of the inscription, size of letters, etc. In no case, however, do the laws respecting trespassing state what inscription shall appear on trespass signs. In some States posting is required, but no suggestion of the wording to be used is made.

In most cases, certain illegal acts are specified, but no style of warning is suggested, it being left to the civil authorities to make arrests and inflict such punishment as the laws of the various States provide, usually fines or imprisonment, or both fine and imprisonment, at the discretion of the court. Your Committee has, therefore, not been able to secure any new information to submit on this class of signs this year.

It has, however, made a study of the laws relating to the second class of signs, viz., those applying to the employés of the railroad companies, and finds the only signs covered by laws, and that only by implication, are whistle and ring boards. These signs are covered by a quite common provision in the laws of the different States and summed up by Mr. Stimson in his treatise on American Statute Law, Section No. 8822, as follows:

Every Railroad Corporation shall cause a bell (except in Kansas) of 30 or 35 lbs. in weight and a steam whistle to be placed on each locomotive engine passing upon its road, and such bell shall be rung or whistle sounded (three blasts in Massachusetts) at the distance of at least 300 yards or 80 rods from the place where the road crosses upon the same level any highway. This provision or a slight variation of it has been adopted by Alabama, Arkansas, Illlinois, Indiana, Iowa, Kansas, Maine, Massachusetts, Nebraska, Nevada, New Hampshire, New Jersey, New York, New Mexico, Ohio, Oklahoma, Rhode Island, South Carolina, Texas, Utah, Vermont, West Virginia and Wisconsin.

While the above statute does not contain any specific provision as to the installation of or style of whistle or ring boards, the railroads have been allowed to establish such signs at their discretion for the purpose of calling the trainmen's attention to the need of warning the public of the approach of their trains.

With this precaution taken by the trainmen and the further warning given by the highway crossing signs, accidents are only possible when the warnings are not heeded. There are, of course, cases where the crossing signs are not visible a sufficient distance from the crossing to furnish the proper degree of safety, and other cases where the view of the railroad for a proper distance is obstructed by buildings or the natural contour of the country. In such cases an additional warning is usually provided by placing signs along the highway at some stated distance from the crossing notifying the public of the proximity of the railroad. The introduction of the automobile with its attending train of reckless handling, tendencies to take risks and failure to obey regulations, has greatly increased the element of danger of accident at grade crossings and many catastrophes are traceable to its influence.

We have all no doubt at some time wondered what prompted or inspired the wording on the various signs and warnings which have from time to time been brought to our notice. In some States the highway crossing sign has the inscription "Look Out for the Engine," in others "Look Out for the Locomotive," while in the majority of the States the public is warned to "Look Out for the Cars." As the locomotive usually precedes the cars in the train the natural inference would be that either the first or second style of warning would be generally adopted. The facts, however, contradict this assumption, as will be seen by referring to the report of two years ago.

Various stories have gone the rounds respecting the origin of the warning "Stop, Look, Listen," in use in Pennsylvania and Rhode Island, who originated it, compensation received, etc. In its investigation your Committee received some information regarding this inscription, which is authenic and may be interesting to some. Just when and where it was first used we are not advised, but it was adopted by the Philadelphia & Reading Railway July 23, 1891.

About that time this company acquired the Gettysburg & Harrisburg Railroad, and on an inspection trip over that road several officials of the Philadelphia & Reading Railway noticed that sign at a number of crossings.

As it was especially adapted to circumstancese covering the rule of law governing travelers on public highways when approaching railroad crossings at grade, the Philadelphia & Reading Railway adopted the sign for use at grade crossings on its lines of railroad in Pennsylvania. The use of this particular inscription is not covered by any laws in force in Pennsylvania.

(3) CONTINUE THE STUDY OF CONCRETE FENCE POSTS.

As concrete fence posts had been so fully investigated during the past four years, your Committee felt somewhat at a loss to know what feature of the subject could be studied with profit this year. The idea of making a general review of the entire subject suggested itself and your Chairman secured from the Secretary of the American Society of Civil Engineers two searches—one dated November 15, 1907, covering articles on concrete fence posts and telegraph poles, published in the various Engineering Journals 1905-1907, the other dated November 13, 1914, being a continuation of the above, covering articles published 1908-1914.

All articles bearing on concrete fence posts, which were available in the libraries of Baltimore, were read, and your Committee considers a number of these well worth reading by the members of the Association interested in this subject. The feature which appealed especially to your Chairman while making these investigations was the change in sentiment which has developed in regard to the manufacture of concrete fence posts during the past ten or twelve years.

An abstract of a paper read before the Association of Cement Users by J. A. Mitchell, a manufacturer of concrete posts, appearing in the Engineering News of January 26, 1905, in which some statements were made, which at this time sounds little short of startling. He advocated the use of wood forms of two compartments, galvanized reinforcement, dry mixture, and stated that two men could turn out 100 posts per day, or three men could turn out 175 or 200 posts per day, at a cost of 11 to 12½ cents each, and that he had never known a post to be broken after it had been set in the ground.

He advocated the use of wooden forms because he considered metal forms too heavy and expensive. Since then a great change has taken place in the matter of forms. Metal has now almost wholly supplemented wood, except in experimental cases and where odd sizes of posts are desired. Instead of the wooden forms of two compartments, they are now made of metal in nests of 5 to 10, supported on convenient frames and equipped with facilities for compacting the concrete. Galvanized reinforcing material was advocated because the thin shell of concrete outside the reinforcement of a post was not considered adequate protection to plain iron or steel rods. Recent experience indicates that bright galvanized rods, unless deformed, would not develop proper strength in the concrete, and that slightly rusted rods are a decided advantage as a reinforcing material. It is also a pretty fully established fact that concrete, even in a thin layer, does arrest corrosion in iron and steel imbedded in it. Either round or corrugated rods are more satisfactory than the flat bar type sometimes used, although this form is advocated by some because of the greater area presented to the concrete.

The use of dry mixture was advocated because the best looking posts were made from concrete of that consistency, although more time was required in the manufacture. The use of dry mixture is now questioned because it is not always dense enough to prevent water from penetrating it and causing injury in freezing weather. Furthermore, where tamping is necessary it is impossible to maintain the reinforcement in its proper location nor will the dry mixture bond with the steel as ridigly as will the wetter mixture.

In regard to the speed with which posts could be turned out by two or three men, it developed that they were of such size as to permit the manufacture of 40 posts from a cubic yard of concrete, which is about 50 per cent. in excess of the present practice. In the matter of breakage, we find few cases where some posts are not sooner or later broken after being set. This appears to be true especially where posts of the smaller dimensions are used. The Engineering News of January 18, 1906, contains a two-page abstract of an article by Philip L. Wormsley, Jr., Testing Engineer, Office of Public Roads, Department of Agriculture, Washington, D. C., which was published in full in the Farmers Bulletin, No. 235. In this article he lays down three principles or conditions which must be fulfilled by a thoroughly satisfactory fence post, as follows: (1) It must be obtained at a reasonable cost. (2) It must have sufficient strength to meet the demands of general farm use. (3) It must not be subject to decay and must be able to withstand successfully the effects of water, frost and fire.

He then describes in detail the various forms of reinforcement, and its location in the post, the mixture and size of aggregate, consistency of the mixture, various kinds of molds, method of securing fencing to the post, chamfering or rounding of edges to avoid damage by chipping, cost data, and gives the results of a long series of tests conducted by the department.

Your Chairman considers it one of the best expositions of the subject he has been able to find and strongly recommends it to anyone interested.

RECOMMENDATIONS.

(1) In view of the variety of flangeways found by your Committee in its investigations this year, it recommends that a further study be made with a view of determining the proper flangeway opening through crossing frogs where steam railroad tracks are crossed by trolley tracks at street crossings.

(2) Investigate the matter of reduction of the number of roadway signs and the adoption of a standard sign for general use as far as possible. Also consider the location of signs, having in mind the matter of safety for employés obliged to use the roadway.

(3) Investigate the legal requirements relative to fencing right-of-way and providing stock guards.

(4) The adoption and inclusion in the Manual of plan of Street Crossing shown on Plate B.

Respectfully submitted,

COMMITTEE ON SIGNS, FENCES AND CROSSINGS.

REPORT OF COMMITTEE XIII—ON WATER SERVICE.

A. F. Dorley, *Chairman;*
J. T. Andrews,
C. A. Ashbaugh,
F. T. Beckett,
M. C. Blanchard,
C. C. Cook,
J. L. Campbell, *Vice-Chairman;*
R. H. Gaines,
W. C. Harvey,
E. G. Lane,
W. A. Parker,
R. W. Willis,
Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Water Service presents below its report to the seventeenth annual convention. The following subjects were assigned the Committee by the Board of Direction:

(a) *Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.*

(1) *Report on cost of pumping water by various methods.*

(2) *Report on protection for water stations against freezing.*

The following Sub-Committees were appointed to deal with the several subjects assigned:

Sub-Committee A.

J. L. Campbell, *Chairman;*
C. A. Ashbaugh,
F. T. Beckett,
M. C. Blanchard,
R. H. Gaines.

Sub-Committee B.

W. C. Harvey, *Chairman;*
C. C. Cook,
J. T. Andrews,
A. F. Dorley,
E. G. Lane,
W. A. Parker,
R. W. Willis.

(a) REVISION OF MANUAL.

In its report to the sixteenth annual convention in March, 1915, your Committee submitted for approval a number of important changes in the subject-matter embodied in the Manual under the heading of "Water Service." Your Committee assumes that its recommendations of last year have received the favorable consideration of the Board of Direction, and at this time it has no additional revisions to recommend.

(1) COST OF PUMPING WATER BY VARIOUS METHODS.

The Committee formulated and the Secretary of the Association sent to the railroads the questionnaire appearing in the last column of the appended tables, the answers thereto being stated in detail on the tables.

These tables embody all of the results of the inquiry and they are submitted as information only. On account of lack of uniformity and incompleteness of the replies received, it would not be wise to attempt general or specific deductions from the data given. In some instances it was necessary to reduce the replies to a form that would admit of entry on the tables under the classification of the questionnaire and this introduces another element of some uncertainty and unreliability as a basis for conclusions.

The inquiry has undoubtedly brought together considerable information of some value or at least some interest, but the Committee raises the question whether or not an investigation of this kind results in any general substantial advance in the state of the art of the subject investigated, especially when it involves so many diverse conditions having no general application such as are found in pumping the water supplies of American railways.

Those who have given some attention to the details of the subject generally agree that the cost of pumping water at a water station frequently has little relation to the cost of pumping at another station and gives no basis on which the cost of pumping at another station could be deduced even on the same railroad. It frequently happens that the quantity of water pumped is the factor that affects the cost more largely than the efficiency of the pumping machinery or the height to which the water is lifted. The wide variations in cost of pumping indicated on the tables are in many cases doubtless the result of conditions other than the character and efficiency of the pumping apparatus and substantially unamenable to correction. This applies to the roads individually as well as collectively, many of the roads individually showing wide variations in unit costs.

The only basis on which reliable deductions could be drawn in the investigation of the efficiency of different kinds of pumps and pumping would involve the application of different kinds of pumping apparatus to the same case and all of its conditions, or to cases strictly comparable throughout, all the conditions of which would be fully known. It is needless to say that such comparisons are unattainable in any general investigation such as was assigned to this Committee in the absence of specific comparative pumping tests under strictly comparative conditions indicated.

The Committee is of the opinion that the principal value of an investigation of this kind is its direction of the attention of the roads individually to what they are individually doing and doubtless such investigations of the different phases of the general transportation problem do result in more or less improvement in operating conditions. The benefit derived depends primarily on the extent to which the roads individually are induced to go into a detailed analysis of their individual problems.

Of the sources of water supply reported, about 30 per cent. are deep wells of small diameter. The roads are, therefore, securing a large part of their water supply under the most adverse conditions for economical pumping. On Table 3 will be found some information covering the cost of pumping from such wells by the use of deep well centrifugal pumps having lifts slightly over 100 feet and capable of lifting 200 feet. A good deep well centrifugal pump offers some important advantages over the old deep well working barrel in the matter of maintenance, capacity of well and cost of pumping. Additional information will also be found on the tables relative to centrifugal lifts up to a maximum of 300 feet.

(2) ON PROTECTION FOR WATER STATIONS AGAINST FREEZING.

Your Committee on the above subject formulated a set of thirty or more questions, which were sent to forty-four railroads in the United States and Canada, requesting information concerning the practice on the various lines, the troubles encountered due to freezing of the water stations and the remedies employed to correct their troubles. These questions pertained to pipe lines, pump houses and machinery, tanks and water columns. Answers were received from forty roads, and as it is not practicable to place the information received in tabulated form, the answers have been thoroughly reviewed and analyzed, and in the following report we give the general practice, the remedies and our conclusions.

The minimum temperatures to which the water stations are exposed vary from about 18 degrees above zero in the Gulf States to 50 degrees below zero at some Canadian stations. Some of the mountain roads in the United States report temperature conditions fully as troublesome as the Canadian roads, and roads in the Southern States report low temperatures of short duration, which do not justify the same precautions against freezing that is necessary with the same minimum temperature of long duration at other points.

The penetration of frost is reported as one inch in Louisiana and three inches, six inches and ten inches in some of the other Southern States. In the Central and Plains States, it is reported variously from two feet to six feet. In Canada it varies from three feet in southern Ontario to six feet in Manitoba. Some of the mountain roads in the United States report six, seven and even eight feet as the depth of frost. The depth of the frost does not always vary directly with the temperature. Earth well covered with snow freezes to a much less depth than when the snow covering does not exist or is very light. Frost penetrates to a greater depth in gravel or loose rock than in clay; therefore, in the laying of pipe lines, the local conditions must be considered as well as the temperature.

Pipe lines may be laid on the surface without cover in the extreme Southern States. In the central districts the minimum cover is variously reported as being from two feet to seven feet. Three feet of cover is sufficient in the southern parts of Canada, and at other Canadian stations 7 feet 6 inches is reported as the practice. The size of pipe, amount of water discharged and local conditions will have a bearing on the minimum depth of cover and no inflexible rules can be made governing this depth. Of the forty roads reporting, four report trouble with the pipe cover in use. In Dakota a pipe line froze with a 5 feet 4 inches cover. One mountain road had trouble in rocky soil. Another mountain road had trouble when the cover was less than 4 feet.

When pipe lines cannot be drained, or on account of construction difficulties must be left above ground, protection is provided in various ways. Sometimes the circulation of the water in the pipe is sufficient, or the pipe may be wrapped with hair felt covered with tarred paper and then boxed. The number of layers of hair felt, paper and boxing will depend on the length and size of pipe, temperature, etc. When steam is available a steam pipe may be enclosed with the water pipe. A common method is to enclose the pipe in a wooden box and pack the box with sawdust. This method should only be used in the more moderate temperatures. A favorite method, used where the cold is more extreme, is air-space insulation—two or more air spaces being built around the pipe and lined with building paper. One road in Canada uses a four-foot square box with four thicknesses of lumber, four thicknesses of 10-ounce felt and four air-spaces. It is important that all boxes of pipe coverings be as air-tight as practicable, and waterproof.

For long lengths of exposed pipe, alternate layers of hair felt and tar paper protected by an outer layer of metal or heavy roofing paper may be used. Four layers each of hair felt and tar paper are used by one road exposed to a temperature of twenty degrees. Heavy canvas, painted, is also used for the outer covering without boxing.

Valves should be located below frost line where possible. Large valves may be buried and valve stem protected by cast-iron valve box extending to surface of the ground. Valves frequently used require more frequent inspection and may be placed in pits, which, in the colder climates, must be provided with double cover. If the covers are air-tight, or nearly so, the air space between them forms an excellent insulation, otherwise the space should be filled with sawdust, manure or other good insulating material. When the frost penetration is deep, it is not ordinarily possible to place the lower cover below the frost line, and in some instances the side walls of the pits are built with air space between outer and inner walls.

Some roads avoid freezing of discharge line by extending the pipe to the top of the tank and then draining all pipes and valves after pumping.

Where water is pumped directly from shallow streams or reservoirs, and it is not possible to place the suction pipe below the frost line, it may be protected by carrying it out to deep water beneath an earth dike covered with sod. The better practice is to construct an intake well fed by gravity from the stream, the end of the suction pipe being installed in the well. Suction pipes subject to freezing should be arranged so that they will drain after using. The use of intake wells is generally recommended. The warmth of the earth is a factor in preventing the freezing of the water in the wells, and it is generally only necessary to place a single wooden cover over the wells. In colder climates, double covers are resorted to, with air space between, or else a single cover is used and covered with snow, which forms a first-class protection.

Anything done to exclude the cold from the wells will prevent lowering of the temperature of the water, thereby decreasing the liability of trouble from freezing in the tank or water columns.

PUMP HOUSES.

The necessity for special construction of pump houses in order to prevent the freezing of the machinery and piping will depend on the power used for pumping and whether the plant is operated frequently or infrequently.

Where steam is used for power, and night and day pumping is done and circulation of water is constant, the heat from the boiler will ordinarily be sufficient to keep all piping and machinery from freezing without special frost protection. In the colder climates, however, the construction of pump houses must provide better protection against cold than further south.

Three roads in the Southern States report that they do not use any ceiling or sheathing on the inside of studding on frame pump houses. Elsewhere in the United States and Canada more or less protection of this kind is generally used. The protection consists sometimes of one layer of matched boards—sometimes two layers. The Canadian lines ceil their houses on the inside and double-sheath them on the outside, using building paper between the two layers of sheathing. It would seem to be generally good practice to ceil up pump houses on interior with one or more layers when the minimum temperature encountered is 20 degrees or less.

Double doors and storm windows may be used to good advantage where the temperatures go to zero or below. Pump houses of brick, hollow tile and hollow concrete blocks may be used without ceiling protection.

The freezing of water jackets and piping on internal combustion engines is experienced by a number of the roads, because they are not properly drained by the attendant and it is either necessary to avoid carelessness or neglect at these places or else see that heat is provided at all times. The radiation from the exhaust pipe and muffler and circulating tank of internal combustion engines is used by some roads to a limited extent to warm the pump house, but as the pumping is generally intermittent, it cannot be depended on for frost protection. The use of stoves is general at such stations, but on account of the presence of gasoline and other oils, which increase the fire hazard, it is generally conceded that steam heat or hot water heat is preferable and should be used if available. It is essential that the water jackets of internal combustion engines be always drained after pumping and all pumps and pipes in pump houses should be so arranged that they can be drained. There are devices which automatically drain the engines when the pumps stop, but it is safer to give the valves personal attention.

When pumps of any kind are not in use and will not be used for a considerable length of time, the pumps should generally be drained as a precaution against freezing. The necessity for this will depend on the weather, temperature of water, construction of pump house and time pump will be out of service, etc.

Few roads have any printed rules regarding the care of water stations to prevent freezing. Several roads have instructions printed in the Maintenance of Way Book of Rules. Generally the pumper receives his instructions orally from water service supervisor and also by letter, thirty to sixty days before the arrival of freezing weather.

It would seem desirable that rules for the care of water stations be incorporated in Maintenance of Way Book of Rules and that each person handling water service be supplied with a copy, and that, in addition, each individual pumper be given verbal and written instructions regarding the particular plant handled by him.

TANKS.

Tanks infrequently used are subject to more trouble from freezing than those in frequent service. Tanks supplied from ice-cold streams will cause more trouble than those supplied with the warmer ground waters from wells. The troubles due to freezing are generally as follows:

(a) The rods operating the outlet valve become inoperative due to the ice forming in top of tank and holding the rod and tank valve shut.

(b) After the rods become inoperative as above, and the pumps are started, the sheet of ice in top of tank acts as a float and raises the rods, thus opening the tank valve, allowing the water to drain out of tank and flood track and vicinity.

(c) Outlet valves freeze in shut position. This is frequently due to leaky condition of the valve. It is also due to the location of valve. Valves in tank bottoms flush with the floor and not immediately above frost box, give more trouble than those elevated above the floor of tank and above the frost box. Leaky valves result in filling the outlet spout with ice.

Some roads arrange for systematic thawing of the spouts and valves by means of steam hose on way-freight engines. Others thaw them by torches or burning oily waste and one or two roads report special metal boxes under valves in which a lamp with iron chimney is kept burning at all hours. Others use metal baskets with fire in them.

(d) An accumulation of ice on the walls of the tank sometimes results in the ice falling into the tank when nearly empty, breaking piping and valve rods or pulling down the ladder.

On roads in the extreme Southern States, no frost boxes to protect riser pipes are used. In the latitude of Atlanta, Birmingham and points with similar temperatures, simple boxes of one layer of two-inch plank around the riser pipe filled with sawdust are used. From these points northward, frost boxes are almost universally used under wooden tanks and consist of layers of D. & M. material, building paper and air spaces. The number of air spaces required vary with the temperatures encountered. It is important that the frost-box extend into the ground well below the frost line. The part of the box below ground is usually concrete. The central air space should be carried down inside the pit in order to prevent frost entering through the side walls. The joint at top of foundation and at junction with tank should be made as air-tight as possible.

In the Gulf States and in some of the Southwestern States, the use of roofs over tank is not generally necessary to prevent freezing. In colder climates a roof of sheathing laid tight and covered with prepared roofing is common and in still colder climates the formation of ice on the surface of the water in the tank and the prevention of the valve rods freezing up will be largely overcome if a frostproof floor of matched lumber and paper is built at the level of the top of staves. Cornice should be tight so as to exclude all air.

Canadian roads find it necessary to entirely surround their wooden tanks with a separate house, built of 2 inch by 6 inch studs, tarred felt being applied to both sides of studs and covered on one side by shiplap and on the other with drop siding. The floor over top of tub consists of joist with the underside ceiled with shiplap, the upper side being ceiled with two layers of shiplap with tarred paper between.

A stove is used for heating this house and the smokestack passes through the tank.

Other northern roads do not build an entirely separate house, but ceil up the entire substructure or tower of tank from the lower end of staves to the ground and keep up fires in stove, smokestack extending through tank near valve rod.

STEEL TANKS.

The freezing trouble in steel tanks is found to be practically the same as in wood tanks. That is, the rods operating the valve are held by the ice forming in top of tank, the valves freeze when used infrequently and ice forms more quickly if ice cold water from streams is pumped into tank.

While wood is a better non-conductor than steel, and the ice accumulation is somewhat greater in steel tanks than in wood, it is not apparent that steel tanks cause any more trouble than wood.

Ice itself is a fair non-conductor, and when a coating of ice has accumulated on the walls of the tank it forms a fair insulation. Inlet and outlet pipes should enter the tanks well away from the side walls. Steel tanks are preferably used where the consumption of water is heavy.

On some Canadian roads steam or hot water coils are used in the bottom of the down leg or mud drum of the steel tanks. A more successful method consists of a stove beneath the mud drum with stovepipe extending up through mud drum and tank near inlet and outlet pipe. No trouble is reported when this was done.

One road in northern climate builds a house of hollow brick around down leg or mud drum of steel tanks and places a stove inside with stovepipe passing through tank near outlet valve.

Keeping tanks full, or nearly so, at all times during winter will result in less accumulation of ice.

WATER COLUMNS.

Most roads in territory subject to freezing report trouble with water columns. The operating rods and other operating parts freeze, due to accumulation of ice. The valve rods stick where they pass through the stuffing boxes or where they pass through the flange of the lower upright. The valves and pits freeze, due to insufficient protection.

To remedy the above conditions, burning coal oil or kerosene lamps are sometimes placed in the pits or the frozen parts are thawed by means of steam hose where available or by building a fire of oily waste, or thawing by hot water or turning exhaust steam into pit.

All columns may be drained. The usual arrangement is a valve at base of column which may be so turned in warm weather that the column will not drain. In cold weather this valve should be turned so that the column will drain into the pit. The pit itself should be provided with drain to sewer or depression. In cold climates a single cover is not sufficient protection for the pit. Where weather conditions warrant, a second cover consisting of layers of wood and tarred paper should be installed below the upper one with air space between the two. This cover is frequently placed a foot or more below the top and space filled with burlap, manure or other insulation. This may not entirely eliminate the danger from freezing, for it is generally impracticable to get the second cover below the frost-line, and the frost may come through the side walls of the pit.

The device generally used under the spout of water column to catch the drip consists of wood, brick or concrete catch basins with iron grating. They are useful in carrying away the greater part of the drip from water column and overflow from tender and preventing an accumulation of ice. Ice accumulates to some extent, however, and it is occasionally necessary to remove it. These basins should not drain to the water column pits, as the drain forms a passage by which the cold will enter the pit.

SUGGESTED SUBJECTS FOR NEXT YEAR'S STUDY AND REPORT.

(1) Report on methods for rejuvenating driven wells; cost and success, as compared with driving new wells.

(2) Report on various types of well strainers in use and the service secured from each type.

(3) Report on best methods for complying with new Federal quarantine regulations in regard to purity of drinking water supplied to the public and employes on interstate trains.

ATER SUPPLY

27	28	29	30	31	32	33	34	35	REMARKS
1.75	$0.07	$0.03	$0.04						
087	0.015	0.01	0.03	$1.67					$0.085 per 1000 gals
0.87	0.015	0.016	0.66	1.00					0.083 " 1000 "
.24	0.022	0.05	0.14						0024 " 1000 "
375	0.007	0.01	0.14	0.25					0.035 " 1000 "
41	0.04	0.05	0.14	0.25					0.028 " 1000 "
87	0.01	1.67	0.04	0.83					0.156 " 1000 "
	0.02	0.02	0.167						0.011 " 1000 "
58	0.01	0.02	0.08	0.83					0.076 " 1000 "
29	0.015	0.016	0.069	1.33					0.054 " 1000 "
61	0.05	0.03	0.069						"
	0.075	0.03	1.67						
	0.041	0.03	0.03						
25	0.02	0.003	0.03	0.07	0.25				0.041 " 1000 "
25	0.02	0.003	0.097	0.25					0.045 " 1000 "
16	0.01	0.017	0.07	0.67					0.085 " 1000 "
375	0.06	0.003	0.07	0.25					0.150 " 1000 "
58	0.01	0.013	0.055	0.33					0.115 " 1000 "
08	0.01	0.08	0.055	0.83					0.224 " 1000 "
58	0.02	.007	0.055	0.83					0.148 " 1000 "
55	0.10		0.500				$2.00	$5.15	0.043 " HP hour-theoretical
20	0.20		0.150	2.00				3.55	0.099 " HP hour
76	0.20		0.30	2.00				10.26	0.098 " " "
20	0.10		0.25	2.00				3.55	0.237
74	0.15		0.56	2.50				3.94	0.03
72								0.726	0.0152 " 1000 gals
9.00	2.38	0.17	3.00	27.50				64.55	
108.00	2.24	1.71	6.00	60.00				187.95	
98.00	1.12	0.64	6.00	108.00				322.11	
46.15	9.00		7.16	600.00				862.31	
38.00	8.70	10.20	60.00	600.00			27.00	993.90	
30.76	3.96		30.00	48.00				762.72	
54.44	10.00	8.00	35.00	1464.00			5.00	1976.00	
8.20	0.24	1.50	9.00	50.00			2.00	84.50	
9.10	0.12	1.00	6.00	25.50			1.00	27.62	
8.20	0.24	3.00	7.00	57.25			3.00	86.69	
3.00	0.12	1.00	10.00	20.40			2.00	33.52	
9.10	0.12	1.00	9.00	25.00			2.00	37.12	
9.10	0.12	1.00	12.00	25.00			3.00	41.12	
8.40	12.96	1.20	20.00		192.48			265.08	
4.13	2.31	1.50	11.25	100.00				139.19	
.70	1.10	0.60	3.33		64.00			81.73	
04	1.18		2.50					11.72	
3.02	0.96		3.33			16.20		53.51	
.19	0.96	0.35	1.67		144.00			270.17	
	1.36	0.50	7.50	22.50				48.71	
	0.60	0.50	3.33	90.80				130.78	
	6.00	5.10	16.67	95.00				265.91	
	0.60	0.50	8.33	55.00				87.98	
	0.60	0.50	8.33	50.00				82.98	
	0.60	0.50	5.00	44.90				74.55	
	0.60	0.50	5.00	95.30				125.95	
.60	0.75	0.50	5.00	128.00				194.25	
35	0.50	0.50	5.00	51.00				97.50	
.00	0.75	0.50	5.00	102.00				148.25	
00	0.50	0.50	5.00	51.00				78.00	
5.00	0.50	1.50	5.00	102.00				135.00	
00	0.75	0.50	5.00	51.00				97.75	
00	0.50	0.50	5.00	65.00				92.00	
.70	1.00	0.75	10.00	120.00				212.75	
20	15.00	20.00	50.00	45.00				104.55	
09	0.91	13.50	165.55		865.50			1826.55	
6.58	25.50	79.19	421.42		2289.60	360.00		5722.29	
11	2.34	24.67	87.64		1384.80			1911.56	
7.24	1.17	2.49	57.28		698.00			1126.18	
8.32	5.80	87.10	281.21		2289.60			4552.03	
1.68	2.60	20.21	249.59		1384.80			2398.88	
.48	26.21	73.61	267.03		2416.80			6465.13	
.05	1.04	8.12	342.46		1384.80			2204.47	
.56	1.56	1.49	77.51		692.40			1159.52	
23	1.56	8.52	85.57		1444.31			1997.19	
.40		0.30	10.00	77.70					
.00	3.75	2.50	4.54	15.08	22.59		0.48		
.75		0.55	25.00	115.40					
40		0.30	10.00	77.70					
.50		0.30	10.00	77.70					
40		0.30	10.00	77.70					
60		0.30	8.00	57.70					
00	0.38	0.42	1.50		14.40				

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REPORT OF KIND AND COST OF PUMPING RAILWAY WATER SUPPLY

AMERICAN RAILWAY ENGINEERING ASSOCIATION

1	2	3	4	5	6	7	8
Morgan's Louisiana & Texas R R & S S	Lafayette, La	Well 12 & 26	85	Thane, Deep Well Dean [illegible]	8 1/2 bore 18 stroke	Fairbanks Morse	20 HP
T & N O R R	[illegible]	Wells	23	Worthington Horizontal	[illegible]		
G H & S A R R	Rosenberg	Well	100	American Deep Well Pump [illegible] action	[illegible]	Fairbanks Morse	[illegible]
G H & S A R R	Valentine	Wells	150	Cook Steam Head	[illegible]	Air from Pump	[illegible]
H & T C R R	[illegible]	Lake	[illegible]	2 Stage Centrifugal	[illegible]	Fairbanks M[illegible]	[illegible]
G H & S A R R	[illegible]	Well	95	[illegible]	Layne [illegible]	Fairbanks [illegible]	32 HP
Houston East & West Texas R R	[illegible]	Caney Creek	475	[illegible]	6	[illegible]	[illegible]
Long Island R R	Amagansett	Artesian Well	50	[illegible]	[illegible]		
" "	Bridgehampton	Well	20	[illegible]			[illegible]
" "	Quogue	Artesian Well	20	Worthington Duplex [illegible]			[illegible]
" "	[illegible]	"	215	Worthington [illegible]			[illegible]
" "	Babylon	" "	20				[illegible]
" "	Greenport	Well	15	Smith & Vaile Duplex [illegible]			[illegible]
" "	Mattituck	Artesian Well	21	Blake Duplex [illegible]			[illegible]
" "	Riverhead	Well	25	[illegible]			[illegible]
" "	Manorville		24				[illegible]
" "	[illegible]	Artesian Well	60	[illegible]	[illegible]		[illegible]
" "	Wading River		30	[illegible]			[illegible]
" "	Smithtown	"	41				[illegible]
" "	Oyster Bay	" "	[illegible]	[illegible]	[illegible]		[illegible]
Chicago Milwaukee & St Paul R R	[illegible]		45	[illegible]	[illegible]	[illegible]	4
" "	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]
" "	[illegible]		43		[illegible]		[illegible]
" "	[illegible]		[illegible]		[illegible]		[illegible]
" "	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]
" "	[illegible]		24		[illegible]		[illegible]
" "	[illegible]		[illegible]	[illegible]	5 x 8		[illegible]
" "	[illegible]		14	[illegible]	6 x 8		[illegible]
" "	[illegible]		[illegible]		6 x 10		[illegible]
" "	[illegible]		[illegible]		[illegible]		[illegible]
" "	[illegible]		[illegible]		[illegible]		[illegible]
" "	[illegible]		40		[illegible] x 9		[illegible]
" "	[illegible]		44		[illegible] x 10"		[illegible]
" "	[illegible]		38		[illegible] x 12"		[illegible]
" "	[illegible]		58		[illegible] x 12"		10
" "	[illegible]		64		4 1/2 x 10"		[illegible]
" "	[illegible]		64				[illegible]
" "	[illegible]		[illegible]		5" x 10"		8
" "	[illegible]		[illegible]		8 1/2 x 12"		8
" "	[illegible]		[illegible]				[illegible]
" "	[illegible]		41		7 1/2 x 10"		4
" "	[illegible]		49		[illegible] x 9 1/2		[illegible]
" "	[illegible]		44	Triplex	8 x [illegible]		[illegible]
" "	Oxford Jct		58		[illegible]		[illegible]
" "	East Hastings		85		[illegible]		[illegible]
" "	Sewel		90		[illegible] x 10		[illegible]
" "	Madrid		125		[illegible]		[illegible]
" "	Roscoe		100	Triplex Air			[illegible]
" "	Bristol		250				[illegible]
" "	Morton Grove		56	Air			[illegible]
" "	Ortonville		34	Knowles	8 x 5 x 12		
" "	Columbus		34				
" "	Oshkosh		38				
" "	Minocqua		41				
" "	[illegible]		40	Knowles	8 x 5 x 12		
" "	[illegible]		46				
" "	[illegible]		50		8 1/2 x 6 1/2 x 10"		
" "	Keystone		60		[illegible]		
" "	[illegible]		56				
" "	[illegible]		6				
" "	[illegible]		62				
" "	[illegible]		65	Duplex	[illegible]		
" "	[illegible]		[illegible]	Duplex	[illegible]		
" "	[illegible]		[illegible]		7 1/2 x [illegible] x 10"		
" "	[illegible]		[illegible]	[illegible]	8 x 5" x 12"		
" "	[illegible]		[illegible]		[illegible] x 12"		
" "	[illegible]		[illegible]				
" "	Lennox		80				
" "	[illegible]		64				
" "	Algona		64				
" "	Reno		[illegible]				
" "	[illegible]		72				
" "	[illegible]		53				
" "	McGregor		455				
The Wabash R R	[illegible]	Well	112	Cook Steam Deep Well Pump	[illegible] x 36"	Steam Cylinder	
" "	[illegible]	Well	32	[illegible] Double Acting [illegible] Air pumps	[illegible] x 9"	Remington Vert Oil	15 HP
" "	[illegible]		78	Wheeler & Tappan Duplex	5 x 10	Steam Cylinders	10 x 10"
" "	[illegible]	Reservoir	129	[illegible] Triplex Double Acting	3" x [illegible]	Remington Vert Oil	15 HP
" "	[illegible]		160	Fairbanks Morse Simplex	[illegible] x [illegible]		25 HP
" "	[illegible]	Wells	[illegible]	Duplex	3" x 6"		[illegible] HP

1	11	12	13	14	15	17	21	22	23	24	25	26	27	28	29	30	31	35	Remarks
The Wabash R R		Hor Tubular	16" x 16	42"	80"	37#	3760-	13720				220 tons	177 91			13 60	650 00	844 43	21 216 000 gal pumped @ 0.0300 per 1000 gal
" "	Chain					66#	3250-	2908	.8000			4000 gal	93 50	84 4	0 84	403 62	366 20	948 30	45 200 000 " " " 0.0209 " "
" "	Direct	Hor return tub	36" x 10 1/2	[illegible]	80"	25#	250	4 30				41 tons	116 71	5 12		30 24	483 00	635 67	15 000 000 " " " 0.0424 " "
" "	"					51.5#	945	5.65	.0000			1250 gal	62 50	9 60	2 00	9 22	255 00	338 32	12 020 000 " " " 0.0281 " "
" "	"					65#	750	8925	.6000			2000	200 00	3 10	6 86	23 53	409 00	645 09	13 250 000 " " " 0.0487 " "
" "	"					21#	2234			[illegible]	4022	[illegible]	[illegible]	[illegible]	[illegible]	30 00	30 00	[illegible]	[illegible]

34	35	Remarks
[illegible]	[illegible]	
0.0042	.036	
0.0070	[illegible]	.1000
0.0072	[illegible]	.1000
0.0325	.000	.1000
0.0005	[illegible]	.1000
0.0032	[illegible]	.1000
0.0039	[illegible]	.1000
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
0.0024	0.0344	.1000
0.0026	0.0270	.1000
0.0027	0.0345	.1000
[illegible]	0.0242	.1000
0.0084	0.0224	.1000
[illegible]	0.0416	.1000
0.0044	0.0282	.1000
0.0300	[illegible]	.1000
0.0034	[illegible]	.1000
0.0094	0.0262	.1000
[illegible]	0.0506	.1000
[illegible]	0.0220	.1000
0.0032	0.0259	.1000
[illegible]	[illegible]	.1000
0.0030	[illegible]	.1000
0.0106	0.0432	.1000
0.0232	[illegible]	.1000
0.0124	[illegible]	.1000
[illegible]	0.0260	.1000
0.0153	0.0505	.1000
0.0463	0.1263	.1000
0.0167	0.0337	.1000
0.0135	0.0309	.1000
[illegible]	0.0252	.1000
0.0173	0.0370	.1000
0.0189	0.0456	.1000
0.0633	0.0799	.1000
0.0133	0.0230	.1000
0.0101	0.0239	.1000
0.0240	0.0407	.1000
0.0167	0.0315	.1000
0.0500	0.0725	.1000
0.0382	0.1004	.1000
0.0283	0.0449	.1000
0.0350	[illegible]	.1000
0.0084	0.0268	.1000
0.0340	0.0554	.1000
0.005	0.0456	.1000
0.0176	0.0329	.1000
0.0332	0.0455	.1000
0.0205	0.0357	.1000
0.0214	0.0440	.1000
0.0464	0.0874	.1000
0.0248	0.0037	.1000

NUMBERED ITEMS HAVE THE FOLLOWING SIGNIFICATION

11 [illegible]
12 Kind of steam boilers
13 Size
14 Water evaporated [illegible]
15 Mean steam pressure [illegible]
18 [illegible]
19 [illegible]
20 Cost of [illegible] gal of water pumped
21 Total pumping hours
22 Thereof [illegible] other hours
23 Total
24 Thereof [illegible]
25 Total
26 Total [illegible]
27 Cost of fuel or current
28 " " lubrication
29 " " other supplies
30 " " repairs
31 " " engineers
32 " " firemen
33 " " helpers
34 " " other labor
35 " " [illegible] operation including cost preceding [illegible] items

REPORT OF KIND AND COST OF PUMPING RAILWAY WATER SUPPLY

AMERICAN RAILWAY ENGINEERING ASSOCIATION

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	REMARKS
Chicago St Paul Minneapolis & Omaha	[illegible]	[illegible]		[illegible]	[illegible]						[illegible]			[illegible]	80	26				13 hrs					2650	$.175	$.002	$.003	$.004						
" "	[illegible]				[illegible]							3'×9'		[illegible]	50	20				6					03	.087	.0015	.001	.003	$.07					$.0085 [illegible]
" "	[illegible]	Creek		[illegible]	[illegible]							3'×9'		70	[illegible]	35				3					23	.087	.0015	.0016	.008	[illegible]					.0093 [illegible]
" "	[illegible]		80		[illegible]						Vertical	[illegible]		85	[illegible]	40				18					18	.124	.0022	.005	.014						.0074
" "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	FMS Gasoline	[illegible]			Direct										3					3.20	[illegible]	.002	.001	.013	.025					.0037
" "	[illegible]	[illegible]		[illegible]	[illegible]						Horizontal	[illegible]		90	[illegible]	90				10					085 tons	[illegible]	.004	.005	.014	[illegible]					.0128
" "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	9"		Vertical	[illegible]		[illegible]	[illegible]	21	[illegible]	[illegible]		3					53	[illegible]	.01	.007	.024	[illegible]					[illegible]
" "	[illegible]		[illegible]	[illegible]	[illegible]	[illegible] Compound Eng	10HP									21				5					33.22		.002	.002	.0167						[illegible]
" "	[illegible]		[illegible]	[illegible]	[illegible]	Crank Steam				Direct	Vertical	3×7		85	65	25				4					02 tons	.159	.001	.002	.015	.045					[illegible]
" "	[illegible]				[illegible]	Vert. engine Belt	[illegible]			Direct	Vertical Tubular	3×9		85	65	20				5					375	.19	.006	.0016	.0065	.53					[illegible]
" "	[illegible]				[illegible]						[illegible]			[illegible]	75	30				4					29	[illegible]	.005	.003	.0069						
" "	[illegible]			[illegible] steam	[illegible]	Smith Vaile								100	60	60				28							.0025	.004	.167						
" "	[illegible]	[illegible]		[illegible]	[illegible]	Electric Motor	1.5HP							100		30				6							.0041	.003	.003						
" "	[illegible]	[illegible]			[illegible]	Otto Gasoline Eng	[illegible]			Direct					20					2					222	0.25	.002	.0003	.003	[illegible]	[illegible]				[illegible]
" "	[illegible]				[illegible]		3HP									21				2					2 "	0.25	.002	.0003	.0097	0.25					0.045
" "	[illegible]			[illegible]	[illegible]						Vertical Tubular	2×12		15	15	20				4					34 tons	[illegible]	.001	.001	.007	0.27					.0385
" "	[illegible]			[illegible]	[illegible]	Otto Gasoline	3HP									21				3					3 gal	0.375	.006	.0003	.007	0.25					0.030 - .000
" "	[illegible]			Eclipse	[illegible]															2					02 tons	0.55	[illegible]	.0013	0.055	0.33					0.015 - .000
" "	[illegible]				[illegible]	[illegible]	6"×15"				Vertical one flue	3×7		85	[illegible]	20				1					375	[illegible]	[illegible]	[illegible]	0.055	0.83					0.224 - .000
" "	[illegible]	[illegible]	[illegible]	Air	[illegible]							3×7		80	[illegible]	20				2					02	.256	.002	[illegible]	0.055	0.83					2.40 - .000
" "	Stewart	[illegible] River	130	Steam [illegible] double acting	[illegible]						Horizontal type	35HP		100						5	.17				285	.255	.010		0.500				$1.00	$5.15	0.043 [illegible]
" "	Sydney	Small Creek	241	Fairbanks Morse single cylinder	[illegible]	FM [illegible]	20HP					30HP								3	31				25 gal	1.20	.020		0.150	2.00				3.53	0.099 [illegible]
" "	[illegible]	Well	205	Steam [illegible] double acting	[illegible]															15	.05				192 tons	[illegible]	0.20		0.30	2.00				10.26	0.098
" "	[illegible]	[illegible]			[illegible]						Horizontal type	50HP								3	5				03	1.20	.010		0.25	2.00				3.55	0.237
" "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] Producer & Engine	30HP													43	.10				45	0.74	0.15		0.56	2.50				3.94	.003
" "	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	60HP									58				25		508			595 gal	0.72								0.726	0.0152 [illegible]
Chicago Burlington & Quincy Ry	[illegible]			[illegible]	[illegible]	FM Gasoline	15HP			Direct						181.9				180					200 "	19.00	2.39	0.77	3.00	27.50				64.55	
Erie R R	[illegible]	[illegible]	[illegible]	Fairbanks Morse [illegible]	[illegible]			[illegible]	8×8×12		Old locomotive boiler	4'×12'	8"	90	60	152	65	[illegible]	1.15	360					60 tons	139.07	1.24	1.7	6.00	60.00				187.95	
" "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							[illegible]	9.9"	50	30	199				720					90 "	195.00	1.12	0.54	[illegible]	186.00				322.11	
" "	[illegible]	[illegible]	[illegible]	[illegible]	7×9	FMCo	6HP													4500					1895 gal	216.15	9.00		7.16	600.00				863.31	
" "	[illegible]	[illegible]	[illegible]	Buffalo Steam Pump	9×8×12						Horizontal return tube	20HP		100	45	28				3600					128 tons	288.00	8.70	10.20	60.00	600.00			27.00	995.90	
" "	[illegible]		[illegible]	American Well Works Centrifugal	5	Electric Motor	10HP			Direct						24							21024		21024 kw	660.78	3.96		30.00	48.00				762.72	
" "	[illegible]	[illegible]	40	[illegible]	26"×42"	[illegible]	26HP			Belt					[illegible]		50			8640					324 gal	414.44	10.00	8.00	35.00	454.00			5.00	1976.00	
Pennsylvania Lines	Fremont	[illegible]	12	Dean Bros single direct acting	10"×7"×12"						Upright vertical	3'×7½'		[illegible]		35				330					[illegible] ton	3.20	0.24	.50	9.00	30.00			2.00	84.50	
" "	Roseville	[illegible]	4		10"×7"×12"						" "	2'×5½'		55		20				180					7 "	7.10	0.12	1.00	6.00	25.50			1.00	27.62	
" "	McLuney	[illegible] Creek	18		10"×7"×12"						" "	4'×8½'		50		30				360					24 "	19.20	0.24	3.00	7.00	57.25			3.00	86.69	
" "	New Lexington	Creek	25		10"×7"×12"						" "	4'×8½'		50		30				105					10 "	15.00	0.12	1.00	10.00	20.40			2.00	33.52	
" "	Williamsport		12		10"×7"×12"						" "	4'×8½'		50		30				300					7 "	9.10	0.12	1.00	9.00	23.00			2.00	33.12	
" "	Crooksville				10"×7"×12"						" "	4'×8½'		50		25				300					" "	9.10	0.12	1.00	12.00	25.00			3.00	41.12	
" "	Watson	Well	26	Fairbanks Morse & Co	10½"×10"	Gas Engine	10HP			Direct						12				1040					[illegible]	19.40	12.96	1.20	20.00		192.49			285.08	
" "	Canal	Wells		Keystone Driller Co	6½×24 & 10×24					Direct	Vertical	40×10.5	6.67"	80	50	15				870					19 tons	24.15	2.31	1.50	11.25	100.00				139.19	
" "	[illegible]	[illegible]	26	Worthington duplex	7½×7½×10					Direct		3½×14½	6.77"	60	50	15				180	4.20				10 "	12.70	1.10	0.60	3.33		54.00			81.73	
" "	[illegible]	Creek	20'	Fairbanks Morse & Co	8½"×7½"	FMCo Gasoline	5HP			Direct										210					67 gal	6.04	1.18		2.50					11.72	
" "	Orrville	Well		Keystone Driller Co double acting	10"×24"					Direct	Horizontal			100	30	22				720					25 tons	35.02	0.96		3.33			16.20		55.51	
" "	South Akron	Well	27	Worthington duplex	7½×7"×10"					Direct			6.67	100	30	22				720					97 "	123.19	0.96	0.35	1.67		144.00			270.17	
" "	Toledo	Maumee River		FMCo 7.5H comb. gas engine & pump																100							1.33	0.50	1.50	22.50				28.71	
" "	Gibsonburg	Reservoir		Columbus Steam Pump	6×5×12						Upright	15HP		80						540					12 "		0.60	0.50	3.33	90.80				130.78	
" "	Tiffin	Well		Air	10×10½×12			Sargent [illegible]	8×10½×12		Tubular	30HP		80			65"	65"		540					50		6.00	5.10	6.67	95.00				265.91	
" "	St Stephens			Cook deep well	10×36"						Upright	23HP		80						360					8 "		0.60	0.50	8.33	55.00				87.98	
" "	Richland	Richland Cr		Knowles Duplex	12×7×12"							25HP		80						300					8 "		0.60	0.50	8.33	50.00				82.98	
" "	Waldo	Reservoir		Steam pump #8	9×10×15"							12HP		40						300					8 "		0.60	0.30	5.00	44.90				74.55	
" "	Chatfield	Creek		Steam pump #6	9×10×5							12HP		60						540					8 "		0.60	0.50	5.00	95.30				125.95	
" "	Mingo Jct	Creek	13'	Blake deep well	14×10×18"									70	70	28				600					45	0.60	0.75	0.50	5.00	128.00				194.25	
" "	Freemans	Ohio River	15	Hall deep well	8×8½×10"									70	70	22				300					30	1.35	0.50	0.50	5.00	51.00				97.50	
" "	Wheelock	Reservoir	6	Worthington double action	14×10½×10"									70	70	15				480					30	40.00	0.75	0.50	5.00	102.00				148.25	
" "	Zoarville	Creek	12'	" "	9×8½×10"									70	70	12				150					15	21.00	0.50	0.50	5.00	51.00				78.00	
" "	Bayard O	Creek	8	Fairbanks Morse Oil	7¾×5×12"	Oil	25HP									22				360					520 gal	26.00	0.50	1.50	5.00	102.00				135.00	
" "	Kensington	Well	5	Worthington double action	14×10½×10"						Upright			70	70	22				360					30 ton	40.00	0.75	0.50	5.00	51.00				97.75	
" "	Clarks Tank	Creek	8	" "	14×10½×10"									70	70	22				360					15 "	21.00	0.50	0.50	5.00	65.00				92.00	
" "	Wellsville Shop	River	18	Blake Deep Well	14×10×18"									80	80	35				720					60 "	2.70	1.00	0.75	10.00	120.00				212.75	
" "	Cambridge	Wills Creek	146½	Fairbanks Morse duplex	7"×10"	Steam	7"×10"				Vert single flue	22HP		80		22				260						9.20	15.00	20.00	30.00	45.00				104.55	
" "	Upper Sandusky	Sandusky River		Special Blake	12×10×15"						Upright	64.5HP		80						2933	9182				461 tons	361.09	0.91	13.50	165.55		665.50			1526.55	
" "	Dola	Well		" "	12×10×18"						Water tube boiler	134HP		100						2480	1151920				1142 "	1546.56	25.50	79.19	421.42		2239.60	360.00		5722.29	
" "	Plymouth	Yellow River		" "	12×10×18						Upright	64.5HP		60						5169	33540				212 "	472.11	2.34	24.67	87.64		1394.80			1911.56	
" "	[illegible]	[illegible] Creek		" "	10×8×12"									70						2981	19227				191 "	367.24	1.17	2.59	57.28		698.00			1126.16	
" "	Davis	Kankakee R		" "	12×10×18						Tubular	150HP		100						6075	91250				994 "	455.12	5.80	87.10	281.21		2239.60			4332.03	
" "	[illegible]	Well		Small	10×8×12"						Upright	64.5HP								6015	38797				390 "	741.68	2.60	20.21	249.59		1384.40			2398.89	
" "	Fort Wayne	St Marys River		2 Snow Hughes compound duplex							Tubular	80HP		100						8257	660360				1936 "	365.48	26.21	73.61	267.03		2416.80			6445.13	
" "	Wanatah	Stream		Special Blake	12×10×18"						Upright	64.5HP		70						4361	29418				252 "	486.03	1.28	8.12	342.46		1384.80			2204.47	
" "	[illegible] City	Blue River		Small Blake	10×8×12"							64.5HP		70						2936	1911				203 "	386.36	1.36	1.49	77.31		692.40			1133.57	
" "	Clarke	Grand Calumet R			10×8×12"						Boone Tubular	3HP		70						3297	42861				241 "	451.23	1.56	8.52	85.57		444.31			991.19	
" "	Thompson	River	18'	Camerons	No 10						Locomotive type	108HP		60						240					12 "	17.40		0.30	10.00	77.70					
" "	Lawrence Jct	Dug Well	22'	Centrifugal	5" Volute		20HP			Direct										720	7930	6120		6120		23.00	3.75	2.30	4.54	13.08	22.59		0.48		
" "	Niles	River	25'	Camerons	No 10						Hor Ret Tub	54HP		85						480					35	30.75		0.55	25.00	115.40					
" "	Van Wye	"	20'		" 10						" "	37.6HP		80						360					12	17.40		0.30	10.00	77.70					
" "	Oakfield	Well	18'		" 8						Vert Tubular	35HP		60						240					10	14.50		0.30	10.00	77.70					
" "	Austinburg	Creek	12'		" 10						Locomotive Type	12HP		60						300					12	17.40		0.30	10.00	77.70					
" "	Berlin Center	Reservoir	3'		" 10						Vert one flue	6HP		60						180					8	16.60		0.30	8.00	57.70					
" "	Dock Jct	Well	25'	Dean Steam	" 10						Hor Ret Tub	63HP		80						360					20	25.00	0.38	0.42	1.50		14.40				

NUMBERED ITEMS HAVE THE FOLLOWING SIGNIFICATION

1	Name of railway
2	" station
3	Source of supply
4	Total mean lift
5	Kind of pump
6	Size
7	Kind of engine or motor
8	Size
9	Kind of compressor
10	Size
11	Connection, direct or belted
12	Kind of steam boilers
13	Size
14	Water evaporation per lb or gal of fuel
15	Mean steam pressure on boilers
16	" " " " pump
17	" water " "
18	" air " compressors
19	" " " well
20	Cu ft of air per gallon of water pumped
21	Total pumping hours
22	" theoretical horse power hours
23	" actual " " "
24	" theoretical kilo watt hours
25	" actual " " "
26	Total fuel, [illegible] tons, gal or current
27	Cost of fuel or current
28	" " oil
29	" " other supplies
30	" " repairs
31	" " engineers
32	" " firemen
33	" " [illegible]
34	" " other labor
35	" [illegible] and [illegible] last preceding 9 items

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NUMBERED ITEMS HAVE THE FOLLOWING SIGNIFICATION

1	Name of railway
2	" station
3	Source of supply
4	Total mean lift
5	Kind of pump
6	Size "
7	Kind of engine or motor
8	Size "
9	Kind of compressor
10	Size
11	Connection, direct or belted
12	Kind of steam boilers
13	Size "
14	Water evaporation per lb or gal of fuel
15	Mean steam pressure on boilers
16	" pump
17	" water " "
18	" air " compressors
19	" wells
20	Cu ft of air per gallon of water pumped
21	Total pumping hours
22	" theoretical horse power hours
23	" actual "
24	" theoretical kilo watt hours
25	actual " "
26	Total fuel used tons gal or current
27	" cost of fuel or current
28	" " " lubrication
29	" " " other supplies
30	" " " repairs
31	" " " engineers
32	" " " firemen
33	" " " helpers
34	" " " other labor
35	" maintenance and operation including last preceding 9 items

7	28	29	30	31	32	33	34	35	REMARKS
				$25.00				$51.57	164,334 gals. pumped @
				35.00				64.89	1,266,180 " " "
				40.00				95.77	1,213,504 " " "
				50.00				128.47	1,830,392 " " "
				42.50				87.41	828,025 " " "
				35.00				53.27	470,420 " " "
				30.00				69.18	697,392 " " "
				35.00				38.96	184,000 " " "
				40.00				102.74	890,618 " " "
				40.00				44.78	172,000 " " "
				25.00				59.45	741,316 " " "
				40.00				74.03	1,019,288 " " "
				30.00				41.21	203,960 " " "
				30.00				118.29	1,633,000 " " "
									Cost 12¢ to 30¢ per 1000 gal
									" 3¢ " " "
									" 3¢ " " "
									" 3¢ " " "
									" 3¢ " " "
									" 3¢ " " "
									" 3¢ " " "
									" 4¢ " " "
									" 3¢ " " "
									Cost $45000 annually
									Supplied by main line pumping station
									Supplied by Red Bank pumping station
									Cost 5¢ per 1000 gal
									Cost 14¢ per 100 cu ft. up to 2000, 13¢ per 100 cu ft. f
									" 11¢ per 1000 gal
									" $0.064 per 1000 gal
.60	$6.01	$5.52	←— —	— —	— —	— —	$623.40	$835.53	14,240,000 gals. pumped @
									" 0.09 " " "
									" 0.05 " " "
									" 0.10 " " "
.60	0.97	2.57	←— —	— —	— —	— —	58.48	130.52	" 0.026 " " "
.80	2.30	10.80	←— —	— —	— —	— —	233.08	492.98	" 0.0359 " " "
.20	1.97	2.58	←— —	— —	— —	— —	469.94	844.69	" 0.0243 " " "
.83	24.23	4.38	←— —	— —	— —	— —	171.24	406.68	45,900,500 gals. pumped @
.77			←— —	— —	— —	— —	37.86	340.63	6,975,154 " " "
									Cost $0.14 per 1000 cu ft. up to 20000 cu ft.
									" 0.15 " 100 " " maximum (Graded rate
									" 0.14½ " 100 " "
									" 0.35 for 1st 1000 gal. 24¢ next 2000 & 18¢ fo
									" 0.30 per 1000 "
									" 0.125 " 100 cu ft.
									" 0.10 " 1000 gal.

REPORT OF KIND AND COST OF PUMPING RAILWAY WATER SUPPLY

AMERICAN RAILWAY ENGINEERING ASSOCIATION

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	REMARKS	
[illegible] Lines	[illegible]	Creek	23	[illegible]							[illegible]	28 HP		60#						[illegible]																
	[illegible]	River	4	[illegible]		[illegible]	6 HP													300																
	[illegible]		25	[illegible]		[illegible] Motor										60#				57		300														
	[illegible]		20	[illegible]						Direct	[illegible]			[illegible]						240																
	8th Street	[illegible]	31	[illegible]		Fairbanks Morse														2820																
	55th		4	[illegible]							[illegible]									25																
	[illegible]	Stream	45	[illegible] steam							[illegible]				50#					[illegible]																
	[illegible]	[illegible] water																																		
	[illegible]										[illegible]					20#				[illegible]																
	[illegible]	[illegible]	32																																	
	[illegible]	[illegible]																																		
	[illegible]	[illegible]																		483																
	[illegible]	Creek	14																	60		248														
	[illegible]															20#																				
	[illegible]															9#				270																
	[illegible]						[illegible]	5 HP																												
	[illegible]															20#				360	3708															
	[illegible]																				26.9															
	[illegible]																				3468															
El Paso & Southwestern [illegible]	[illegible]	We				[illegible]					[illegible]									600																
	[illegible]					[illegible] Eng				Belted																										
																					9778															
	[illegible]																																			
	[illegible]																																			
	[illegible]				4x35	[illegible] Eng																														
	[illegible]																																			
	[illegible]									Direct																										
	[illegible]																																			
Boston & Maine R.R.	[illegible]					[illegible]	[illegible] HP				[illegible]																									
	[illegible]																																			
	[illegible]		4			[illegible] Gasolene	5 HP			Direct																										
	[illegible]		45		5x8	Gasolene	[illegible] HP			Belted																										
	[illegible]		21		6x8																															
	[illegible]		14			Gasolene																														
	[illegible]	We	46		6x6						[illegible]	[illegible]				5#																				
	[illegible]		44		6x6x10																															
	[illegible]		47	[illegible]	5x6	[illegible] Elec	3 HP			Belted										250																
	[illegible]		43	[illegible]	9x[illegible]	[illegible]ene	4 HP			Direct										22																
	[illegible]	[illegible]		Steam																																
	[illegible] Bay	[illegible]		[illegible]		Gasolene	5 HP																													
	Exeter	[illegible]		[illegible]	[illegible]						Vertical	[illegible]		12#	[illegible]	4#																				
	[illegible]	We		[illegible]	6x8	Fairbanks Morse	6 HP									5#																				
	[illegible]	River		[illegible]	3x8	[illegible]										30#																				
	[illegible]	Cox		Centrifugal		[illegible]										20#																				
	[illegible]	River		[illegible]	Type 2 P S											40#																				
	[illegible]ington	We		Steam [illegible]	#4						[illegible]	32x7½				20#																				
	Springfield	[illegible]	21	[illegible]	9x12"	[illegible] steam	8½x12				Hor. tubular	[illegible]		100#	00#	20#				24					2 ton	55	.005	.002	.005	0.305	0.18		0.15	2.23	446,000 gal. pumped per [illegible]	.0001 per 100 gal.
	Northfield	[illegible]	88	Horizontal piston pattern	8½x12	Gasolene	6 HP									34#				12					1 gal	35	.010	.007	0.8	.5				2.85	35,000 " " "	.002 " " "
	[illegible]	River	30	[illegible] 2 stage	2"	A.C. Electric	7½ HP									22#				15					8¼ kw	.731	.0075	.001	.010	.025				1.695	115,500 " " "	.00307 " " "
	[illegible]		41	Horizontal piston pattern	8½x12"	Kerosene Oil	5 HP									5#				8					8 gal	.048	.012	.007	0.50	0.64				.8	20,000 " " "	.0066 " " "
	[illegible]		12		8½x12"	Gasolene	10 HP									26#				2					2	1.70	.013	.007	.00	.064				3.54	170,000 " " "	.00208 " " "
	[illegible]	Pond	11		8x12		6 HP									26#									8	.20	.005	.007	0.50	.025				2.07	68,000 " " "	.0034 " " "
	[illegible]	River	54	Vertical triplex pump	5x8"	Kerosene Oil	6 HP									9#				2					2	.011	.001	.001	.040	.075				.088	8000 " " "	.00206 " " "
	[illegible]		34½	Duplex piston pattern	7x10	Steam [illegible]	4x10				Hor. tubular	[illegible]		90#	60#	60#				9					½ ton	.280	.002	.005	.003	.040				1.31	15,000 " " "	.0018 " " "
	[illegible]	Lake	18	Horizontal piston [illegible]	5x8x12	Steam						[illegible]		40#	31#	8#				6					1	.103	.002	.002	.010		1.76			2.95	47,000 " " "	.0062 " " "
	Newport	"	4		8x10"	Gasolene	6 HP									4#				20					5 gal	.225	.018	.007	.050	.95				3.95	80,000 " " "	.0022 " " "
	Newport	"	32		6x10"		4 HP									2#				8					2	.060	.002	.007	.051	.153				2.53	48,000 " " "	.0053 " " "
	[illegible]	River	[illegible]		4x8"	Steam					Vert. tubular	42x96		40#	35#	3#				3					[illegible] ton	.031	.001	.0025	.010	.050				.045	10,000 " "	0.045 " " "
	[illegible]	Well	60	Duplex [illegible] pattern	5x6"	A.C. Electric										16#				5						0.66	.001	.001		.029				.0466	36,000	.0013 " "
	Dover	River		[illegible]												63#																				
[illegible] R.R.	[illegible]	Spring	223	Fairbanks Morse [illegible]	6¼"	F.M.Co kerosene	2½ HP									100#				300					450 gal	22.50	.25	.050	2.00	35.00				61.55		
	[illegible]	River	200	[illegible]	6½x10"						Vert. sub. tub.	3x9		75#	75#	100#				300					20 ton	50.00	2.00	1.00	3.00	30.00				87.00		
	[illegible]	Creek	100	Fairbanks Morse [illegible]	8"	F.M.Co Gasolene	10 HP			Direct						100#				300					200 gal	25.00	.30		2.00	25.00			.00	53.50		
	[illegible]	We	45	Worth[illegible] duplex	6x3¾x6"						Vert. sub tubular	30x93		70#	60#	22#				270					17 ton	55.00	.20	.040	5.35	30.00			0.50	105.9		
	[illegible]	River	57	Horizontal double [illegible]	6"	F.M.Co Gas comb				Direct						27#				240					137½ gal	15.12	.35	1.00	7.00	10.00			14.00	53.4[illegible]		
	[illegible]	Creek	128		8"	F.M.Co Oil										63#				270					500	30.00	2.20	.040	12.00	37.50			5.00	[illegible]		
	[illegible]		[illegible]	Worthington duplex	10x[illegible]x10"						Vertical	36x98		80#	80#	65#				240					20 ton	50.00	1.07	.030	1.25	25.00				[illegible]62		
Illinois Central R.R. Co	Carbondale	Big Muddy R	208	Duplex compound	[illegible]x12"						Return tubular	72x18	6.5	90#	90#	[illegible]				600	[illegible]3858	[illegible]			78	18.00	6.00	.30	2.30	20.10			8.00	24.00		
	Dyersburg	[illegible]	3	[illegible] power	[illegible]	Duplex [illegible] boiler feed	25 HP [illegible]			Bot						46#				193	3.84	4.245			325 gal	8.95	5.57	2.80		60.00				76.82		
	[illegible]	Des Moines R	6	Single acting	9x10"	220v [illegible] A.C. motor	30 HP									62#				390		6659		3.32		.0654	1.20	3.00	7.00	100.00			6.00	273.74		
	[illegible]	Well	653	Horiz [illegible]	6¾x5 2 cyl [illegible]			LDS 2 stage	[illegible]		Return tubular	[illegible]					90#	44#	0.40	660	683	9.6								175.37				175.37		
	[illegible]		6	Combined [illegible]	8x[illegible]	Gasolene eng	6 HP			Direct						20#				360	968	.291			565	17.51	.50	.070	2.90	50.00			6.00	78.61		
	[illegible]	Reservoir	64	Vertical [illegible]	9x10"	Crescent oil eng	20 HP			Direct						26#				609	308	4.26			781	24.3[illegible]	4.06	8.00	6.00	90.00			8.00	150.37		
	[illegible]	Wells	195	[illegible]	5¾x15"	[illegible]	10 HP									65#				2956		10393				266.52	3.03	9.00	38.00	100.00			20.00	436.52		
[illegible] R.R.	[illegible]	[illegible]		[illegible]	[illegible]x12"	Induction	[illegible] HP				[illegible]	[illegible]		[illegible]	18#	40#					442000		3.5000	1140	3500 kw											

NUMBERED ITEMS HAVE THE FOLLOWING SIGNIFICATION

REPORT OF KIND AND COST OF PUMPING RAILWAY WATER SUPPLY

AMERICAN RAILWAY ENGINEERING ASSOCIATION

26	27	28	29	31	34	35	REMARKS	
[illegible]				$25.00		$31.37	164,334 gals pumped @	[illegible]
[illegible]				35.00		64.39	1266180 "	[illegible]
[illegible]				40.00		[illegible]	[illegible] "	[illegible]
[illegible]				50.00		129.47	430343 "	[illegible]
[illegible]				42.50		[illegible]	428025 "	[illegible]
[illegible]				35.00		53.27	470420 "	[illegible]
[illegible]				30.00		69.18	697392 "	[illegible]
160 ton				35.00		38.95	[illegible] "	[illegible]
2055				40.00		[illegible]	[illegible] "	[illegible]
[illegible]				40.00		44.78	172000 "	[illegible]
[illegible]				25.00		59.45	741316 "	[illegible]
[illegible]				40.00		[illegible]	9228 "	[illegible]
[illegible]				30.00		[illegible]	205960 "	[illegible]
[illegible]				30.00		18.29	635000 "	[illegible]
							Cost 2½¢ to 30¢ per 1000 gal	
							Cost 14¢ per 100 cu ft up to 2000, [illegible] per 100 cu ft [illegible] per 40000 cu ft	
							" 11¢ per 1000 gal	
							$.2064 per 1000 gal	
[illegible]	$[illegible]	$[illegible]	$[illegible]		$623.40	$535.53	4,242,000 gals pumped @	$[illegible] per 1000 gal
							" 0.09 " " "	
							" 0.05 " " "	
							0.10 " " "	
583 gc	66.60	0.97	2.51		55.48	13.752	0.076 " " "	
234	246.80	2.50	10.60		213.09	492.98	0.0359 " " "	
2090	370.70	1.91	2.58		469.94	844.59	0.0243 " " "	
[illegible]	206.83	24.23	4.38		[illegible].24	426.66	45,903,500 gals pumped @	[illegible] per 1000 gal
3308 kwh	302.77				37.86	340.63	6,915,754 " " "	.00154 " " "
							Cost $0.14 per 1000 cu ft up to 20000 cu ft	
							" 0.15 " 100 " " maximum (graded rate)	
							0.14½ " 100 " "	
							0.35 for 1st 1000 gal 24¢ next [illegible] & 18¢ for next 1000 gal	
							" 0.50 per 1000 "	
							0.125 " 100 cu ft	
							0.10 " 1000 gal	

NUMBERED ITEMS HAVE THE FOLLOWING SIGNIFICATION	
1	Name of railway
2	" station
3	Source of supply
4	Total mean lift
5	Kind of pump
6	Size " "
7	Kind of engine or motor
8	Size " "
9	Kind of compressor
10	Size " "
11	Connection, direct or belted
12	Kind of steam boilers
13	Size " "
14	Water evaporation per lb or gal of fuel
15	Mean steam pressure on boilers
16	" " " " pump
17	" water " "
18	" air " " compressors
19	" " " " wells
20	Ft lift of one gallon of water pumped
21	Total pumping hours
22	" theoretical horse power hours
23	" actual " " "
24	" theoretical kilo watt hours
25	" actual " " "
26	" fuel used, tons, gal or current
27	" cost of fuel or current
28	" " " lubricants
29	" " " other supplies
30	" " " repairs
31	" " " engineers
32	" " " firemen
33	" " " helpers
34	" " " other labor
35	" " " maintenance and operation including cost preceding 9 items

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07021
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
26035
06019
07265
[illegible]
07.384

next 40000 cu ft

$.0659 per 1000 gal

.00309 per 1000 gal
.00254 " " "

next 1000 gal

NUMBERED ITEMS HAVE THE FOLLOWING SIGNIFICATION

1	Name of city
2	" station
3	Source of supply
4	Total mean lift
5	Kind of pump
6	Size
7	Kind of engine or motor
8	Size " "
9	Kind of compressor
10	Size
11	Connection, direct or belted
12	Kind of steam boilers
13	Size
14	Water evaporation per lb or gal of fuel
15	Mean steam pressure on boilers
16	" " " pump
17	" water
18	" air " compressors
19	" " wells
20	[illegible] water pumped
21	Total pumping hours
22	" theoretical horse power hours
23	" actual
24	" theoretical kilo watt hours
25	" actual
26	Fuel used, tons, gal or current
27	Cost of fuel or current
28	" " lubrication
29	" " other supplies
30	" repairs
31	" engineers
32	" firemen
33	" helpers
34	" other labor
35	" maintenance and [illegible]
	Cost preceding 9 items

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REPORT OF KIND AND COST OF PUMPING RAILWAY WATER SUPPLY.

REPORT OF KIND AND COST OF PUMPING RAILWAY WATER SUPPLY

AMERICAN RAILWAY ENGINEERING ASSOCIATION

REMARKS

$50.00 per year

cost 3¢ per 1000 gal up to 15000 gal and 0¢ above

3,256,000 gal pumped @ $.01040 per 1000 gal

NUMBERED ITEMS HAVE THE FOLLOWING SIGNIFICATION

23	ditto
25	ditto
26	Fuel used for ... or current
27	cost of fuel or current
28	lubrication
29	other supplies
30	repairs
31	engineers
32	firemen
33	helpers
34	other labor
35	maintenance and operation including cost preceding 9 items

(4) Report on the prevalence of pitting and corrosion in locomotive boilers and methods for their prevention.

(5) Report on impounding reservoirs for railway water supplies.

(6) Report on the relative merits of continuous and intermittent water softeners.

CONCLUSION.

Your Committee respectfully submits the above reports as information only, as their subject-matter is not suited for inclusion in the Manual.

Respectfully submitted,

COMMITTEE ON WATER SERVICE.

REPORT OF COMMITTEE XV—ON IRON AND STEEL STRUCTURES.

A. J. Himes, *Chairman;*
J. A. Bohland,
W. S. Bouton,
A. W. Carpenter,
Charles Chandler,
C. L. Crandall,
J. E. Crawford,
A. C. Irwin,
J. M. Johnson,
B. R. Leffler,
W. H. Moore,

O. E. Selby, *Vice-Chairman;*
P. B. Motley,
Albert Reichmann,
J. W. Reid,
A. F. Robinson,
H. B. Seaman,
C. E. Smith,
H. B. Stuart,
G. E. Tebbetts,
F. E. Turneaure,
L. F. Van Hagan,

Committee.

To the Members of the American Railway Engineering Association:

The subjects assigned to your Committee for investigation during the past year are:

(*1*) *Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.*

(*2*) *Continue the study of methods of protection of iron and steel structures against corrosion.*

(*3*) *Continue the study of the relative economy of various types of movable bridges.*

(*4*) *Continue the study on secondary stresses and impact.*

(*5*) *Continue the study of column tests.*

(*6*) *Continue the study of design, length and operation of turntables.*

Sub-Committees to handle these subjects were appointed as follows:

Sub-Committee A, Subject (2):

A. W. Carpenter, Chairman;
J. A. Bohland,
L. F. Van Hagan,
H. B. Stuart,
G. E. Tebbetts.

Sub-Committee B, Subject (5):

W. H. Moore, Chairman;
C. L. Crandall,
J. E. Crawford,
P. B. Motley,
H. B. Seaman.

Sub-Committee C, Subject (6):
O. E. Selby, Chairman;
W. S. Bouton,
Charles Chandler,
Albert Reichmann,
C. E. Smith.

Sub-Committee D, Subject (3):
B. R. Leffler, Chairman;
W. S. Bouton,
P. B. Motley,
J. W. Reid,
G. E. Tebbetts.

Sub-Committee E, Subject (4):
F. E. Turneaure, Chairman;
C. L. Crandall,
A. C. Irwin,
Albert Reichmann,
A. F. Robinson.

Sub-Committee J, Subject (1):
J. E. Crawford, Chairman;
A. C. Irwin,
J. M. Johnson,
B. R. Leffler,
H. B. Seaman.

Sub-Committee A submits a progress report on the Method of Protection of Iron and Steel Structures against Corrosion, in Appendix A. No recommendations are included.

Sub-Committee B submits a progress report on Column Tests in Appendix B. The Sub-Committee has no recommendations to make, but it is worth while to note that important progress is being made by the U. S. Bureau of Standards on the column tests outlined by this Sub-Committee. The importance of these tests cannot be too strongly emphasized.

Sub-Committee C submits a progress report on the Design, Length and Operation of Turntables, in Appendix C. No recommendations are included.

Sub-Committee D submits a progress report on the Relative Economy of Various Types of Movable Bridges, in Appendix D. No recommendations are made.

Sub-Committee E submits a progress report on Stresses and Impact, in Appendix E.

This report embodies certain practical deductions from the series of impact tests and analytical investigations of stresses carried on for several years by this Committee. These deductions are not presented for adoption by the Association at the present time. On the contrary, it is the purpose of the Committee in presenting the report to place it before the Association and the engineering profession for discussion and criticism.

The proposed changes in our bridge specifications affecting unit stresses and impact are of very far-reaching importance and should not be adopted hastily. It is earnestly hoped that these proposed changes will receive liberal discussion and that on the occasion of our next annual convention final conclusions may be presented for adoption.

Sub-Committee J does not submit a report of progress on the Examination of the Manual. A complete revision of the Specifications for Iron and Steel Structures has beeen under discussion in the Committee for some time. Such a revision is considered to be necessary, but time has not yet been found to give it the thorough attention which its importance demands.

The Requirements for the Protection of Traffic at Movable Bridges, which has been in the hands of the Committee for a couple of years, has been the subject of further consideration. A resumé of the subject has been published in Bulletin 178, and the Committee recommends for adoption the specifications printed on page 274 of that Bulletin. It also recommends for adoption three additional specifications submitted by the Chairman of Committee 2 of the Railway Signal Association, as follows:

1. The rails and attachments should be separated from the metallic structure so track circuits may be successfully operated the entire length of the bridge.

2. The various bridge devices should be so designed that Railway Signal Association interlocking apparatus may be used.

3. Electric and time locking are regarded as adjuncts.

In addition to the work above referred to and described in the Appendices, the interest of the Committee in the work of the Association is shown by the publication in the Bulletins throughout the year of the following articles:

Power Input of Tractor Operated Turntables, by B. R. Leffler.

Adaptation of Designs of Movable Bridges to Signal and Interlocking Appliances Required, by C. E. Smith.

Especial interest is attached to the paper by Mr. Leffler because it is a report of original investigation in a subject concerning which the available data is exceedingly limited. It is expected that the results of these investigations will be an important contribution to this branch of engineering.

The Committee recommends the continuation of the same subjects for further study during the ensuing year. It is believed that all of these subjects are worthy of much further investigation and it is impracticable to bring them to a conclusion without several continued years of discussion.

Respectfully submitted,

COMMITTEE ON IRON AND STEEL STRUCTURES.

Appendix A.

METHODS OF PROTECTION OF IRON AND STEEL STRUCTURES AGAINST CORROSION.

REPORT OF SUB-COMMITTEE A.

Sub-Committee A, on Methods of Protection of Iron and Steel Structures against Corrosion, is continuing its investigation of common practice in shop painting, on which it presented some information in last year's report. Further inspections of painting at shops, under varying weather conditions, are on the program. It is the idea of the Sub-Committee to obtain accurate information as to the common practice in shop painting and to use the same as a basis for recommendations to the Association.

During the year a new method for coating with metals has been called to the Sub-Committee's attention. This is the so-called Schoop Metal Spraying Process, by which surfaces may be coated with easily fusible metals such as lead, tin, zinc, aluminum, copper, brass, etc. The process involves an apparatus called a "pistol" which is a mechanism somewhat resembling a large pistol and which feeds wire, of the metal to be deposited, into a blast flame of combined oxygen, reducing gas and compressed air, which results in the issuance from the nozzle of the pistol of a spray of fused metal. This spray, when directed upon a proper surface, coats the latter with the metal. Iron and steel surfaces are readily coated after cleaning by the sand blast method. It is claimed that a coating of zinc or lead can be applied at a cost of only a few cents per square foot of surface coated, including the preliminary sand-blasting.

The Sub-Committee is also investigating the question of whether or not it is necessary or advisable to paint structural steel forms which are encased in concrete for protection.

Appendix B.

COLUMN TESTS.

REPORT OF SUB-COMMITTEE B.

The Sub-Committee on Columns has not, at present, very much information beyond what was published in the last report. In June, last, Mr. Moore forwarded to Director Stratton of the Bureau of Standards, drawings covering eight columns supplementary to the first series, these columns being variations of our column No. 1, series No. 1.

Word has just been received from Washington that the twenty-four columns for this series are all delivered and that the Bureau will be pleased to test any particular column which the Committee may desire to see tested at any time which may suit their convenience. In Mr. Moore's reply to Mr. Stratton it was stated that it was not believed that just at this time we could get many members of the Committee to visit Washington and he was asked to proceed with the tests as promptly as possible keeping him advised as to the progress. He was also asked particularly to advise if the Bureau, in making these tests, develop any further refinements or methods or whether it may be possible to obtain valuable information by taking any other measurements in addition to those which we had originally decided on.

It is doubtful if the results of the tests of this supplementary series will come to us in time to have them fully reported on next March, but that will depend on the progress in Washington.

The tests have been discussed quite a good deal with members of the American Society Committee and some apparent anomalies have arisen in the test results which, if verified by further tests, may be interesting to bring to the attention of the Committee.

Appendix C.

PHOSPHOR BRONZES FOR USE IN TURNTABLES AND MOVABLE BRIDGES.

Sub-Committee C, on the Design, Length and Operation of Turntables, submits the following report on phosphor bronzes, to be printed as information. The specifications accompanying the report are somewhat tentative for the reason that, while the manufacture of bronzes is old, the art of technical specifications for them is young, and extended use of the specifications proposed is desirable before their incorporation in the Manual.

A test of the hardness of the bronze is provided for in the specifications. Hardness, as distinguished from compressive strength, is one of the primary qualities, but the experimental knowledge of the hardness numbers of bronzes is not yet great enough to warrant setting limits in the specifications as a criterion for acceptance. It is expected that a systematic recording of the results of hardness tests on bronzes of the qualities here required will result in hardness limits which may be specified, perhaps to the exclusion of the compressive strength requirements. There are two methods of determining hardness in common use: the Shore's scleroscope and the Brinell ball method. The numbers of the two methods bear a fairly constant ratio for metals of the same kind. The scleroscope is really a measure of the resilience. The Brinell method consists in applying to a finished plane surface of the metal a hardened steel ball 10 mm. in diameter loaded with a weight varying from 500 to 3000 kg. for a period of 30 seconds. Dividing the applied weight by the area of the indentation gives the hardness number. In Appendix A is given a partial bibliography of hardness testing.

As valuable contributions to the knowledge of the subject, two papers are made parts of this report: one by Mr. George H. Tinker printed in Bulletin No. 180, and one by Mr. Clement E. Chase submitted herewith.

BRONZES FOR USE IN TURNTABLES AND MOVABLE BRIDGES.

1. Bearing metals are used for the purpose of reducing friction and wear between parts of machinery in sliding contact. It is well-known that the friction between surfaces of different metals is less than between surfaces of like metals. The same is true in a more marked degree of the tendency to heat and "seize" with motion under pressure. The simplest form of application of this principle of using different metals in contact is in the use of cast-iron bearings under rolled or forged wrought-iron or steel shafts. There is no tendency to heat and "seize" under moderate speeds; the friction is little, but, on account of the small differ-

ence between the metals, the wear is considerable and the use of such bearings is limited to the crudest kind of machinery. Cast-iron may then be said to be the primitive bearing metal.

In 1839 Isaac Babbitt discovered the alloy known as Babbitt's Metal which has become a standard bearing metal for use in machinery the world over. The composition is shown in Item 1 in the accompanying table. On account of its high tin contents, Babbitt Metal is high in price and frequently is adulterated by the addition of lead. Many other white bearing metals have been made having tin and lead bases and marketed under various names but all may be considered substitutes for Babbitt Metal.

Bronze and brass come next in order of development of bearing metals. Being harder than Babbitt Metal the friction and wear are less, but the fit of the bearings must be more nearly perfect. Bronze is an alloy of copper and tin; brass is an alloy of copper and zinc, the copper preponderating in both. Phosphor bronze is a bronze to which phosphorus has been added for the purpose of cleansing and deoxidizing the metal. Most of the phosphorus passes off with the impurities and little remains in the metal. Manganese bronze is a bronze in which manganese has been used for the same purpose. Aluminum, vanadium, titanium and such recently discovered elements have been used also in alloys with bronze. Their effect is to add to the strength, homogeniety and other good qualities of the metal, but their development may be said still to be in the proprietary stage.

The physical properties desired in bronze depend on the use to be made of it. For machinery bearings with low pressure and high speeds. under constant operation, the strength of the bronze is less important than its anti-friction and wearing qualities. For bearings of movable bridge trunnions and discs, turntable discs, and similar slow-moving parts operated infrequently and carrying heavy pressure, the bronze must be hard enough and strong enough in compression to reduce friction to a minimum and not to flow or distort under the pressure. For worms, gears, nuts, etc., the bronze must have tenacity and hardness as well as anti-friction and wear-resisting qualities. The differentiation of bronzes according to the uses mentioned is a matter of recent years; the earlier practice was to use one kind for all purposes.

The hardness and strength of bronze increase with the amount of tin. The introduction of lead improves the wearing qualities and softens the metal besides cheapening the product. Zinc increases the tensile strength but is injurious to the alloy for bearing purposes. It should not be used except in bronze for the third purpose mentioned above and then only in small quantities, as too much causes a segregation of the tin and the formation of hard "tin spots."

Until 1887 the standard bearing alloy was seven parts copper and one part tin, shown as Item 2 in the table. Sometime before 1887, Dicks of England patented the introduction of lead and phosphorus into the copper tin alloy and the resulting metal became known as the "S Brand," Item

3 in the table. This alloy was adopted by the Pennsylvania Railroad and as a result of tests made by L. W. Cloud, Engineer of Tests, the specification shown in Item 4 was adopted. This probably was the first specification for phosphor bronze, and as the following history will show, has been used widely and specified generally to this day.

About 1876, F. J. Clamer made and sold a metal known as Ajax Metal, containing more lead and less copper than the "S" Brand. This is shown as Item 5. It was used largely for engine bearings.

Dr. C. B. Dudley, of the Pennsylvania Railroad, began a series of experiments and tests which proved the beneficial influence of phosphorus and lead in bronze. He then made experiments in the direction of increasing the lead and decreasing the tin which resulted in his "Ex B Metal," Items 6 and 63. Increasing the lead developed difficulties due to the fact that the lead does not alloy with the copper and tin but is mechanically held in the copper tin alloy as a matrix. G. H. Clamer experimented with increasing amounts of lead and by decreasing the tin and using only pure metals produced successfully "Plastic Bronze," Item 7. This metal is suitable for light bearings and resists wear well but is too soft for bearings under heavy pressure.

Dr. Dudley made no experiments on the frictional effects of the lead. It appears that the introduction of lead decreases the wear but increases the friction. A table of experiments by Clamer, printed in "Lubrication and Lubricants," by Archbutt and Deeley, shows that while the wear decreases proportionately with the increase in lead, the friction in the cases of lead exceeding five per cent. was as high as forty per cent. greater than in cases having no lead. These results are said to have been confirmed by Spare in the Cornell laboratory. There are no definite experiments known which show lead to improve the anti-frictional qualities.

The "S Metal" formula, Items 3 and 4, and the "Ex B Metal," Item 6, appear substantially in the specifications and recommendations of numerous engineers, Item 8 repeats the Dudley formula, Item 6, in slightly different form and Items 9 to 23 inclusive are the "S Metal" formula with variations.

In Items 13 and 14 the elastic limit in compression 27,000 lbs., is too high to be attained with this composition, and the compression 1/16-in. under 100,000 lbs., is to small for this soft metal. Mr. Moore qualifies his recommendation in a way which subordinates the chemical composition to the physical requirements. An elastic limit in compression of from 15,000 to 20,000 lbs., and a permanent set of 0.25-inch maximum under 100,000 lbs., on a one-inch cube seem to be consistent requirements with this composition.

The necessity for a harder bearing metal for heavy pressures has developed a series of formulas containing upwards of 20 per cent. tin and no lead. The metal produced has an elastic limit in compression of from 24,000 to 40,000 lbs., and the permanent set is from 1/16-inch to 1/10-inch. Items 24 to 32 inclusive and 56 illustrate this class. The most prominent advocate is Mr. C. C. Schneider.

A considerable number of Engineers believe in specifying the physical properties only and leave the chemical composition to the maker. Others modify this course by stipulating certain control over the formula but making the physical requirements the criterion for acceptance. Items 33 to 48 inclusive and 53 illustrate this kind of specifications and give some results of experience with turntable discs secured under them.

The third class of bronze, that requiring high tensile strength, is best secured by the introduction of from one to two per cent. of zinc. This constitutes gun-metal and examples are given in Items 49 to 58 inclusive, except 53. For this purpose the ultimate tensile strength and percentage of elongation seem to be more proper physical requirements than the compression characteristics.

Items 59 to 62 inclusive give instructive failures of discs both too brittle and too soft. Item 61 is especially interesting as illustrating the failure of a local man's experiment in replacing a bronze disc by a steel one to turn between steel discs.

There are two ways of introducing the phosphorus into the copper-tin alloy: first, by adding it direct to the molten metal; second, by the use of phosphor-tin for a part of the tin content. The first method is dangerous and results in the loss of a considerable part of the phosphorus. The second method gives better results and probably makes for more uniform crystallization of the tin by the phosphorus. Mr. Schneider's formula emphasizes this method. In the table those formulas which contain phosphor-tin have the total tin content given in the tin column, the amount of phosphor-tin being given in addition. This permits of a more ready comparison.

The so-called Manganese Bronze, Items 38 and 64, being primarily a copper-zinc alloy, is not bronze but brass. The same is true of Tensilite Bronze, Item 58. These alloys are designed for tensile strength and not for bearing metals, although they are so used.. Manganese bronze is considered unsuitable for high pressure bearing purposes because of its fibrous structure.

The historical information given in this report is taken largely from a paper by G. H. Clamer in Proceedings of the American Society for Testing Materials, Vol. VII, 1907. The information on turntable discs is furnished by Mr. Carpenter and that on transfer bridges by Mr. Welty, both of the New York Central Railroad. Credit is given also to the studies of Mr. Clement E. Chase, Chief Inspector for Modjeski & Angier, Pittsburgh, Pa.

SPECIFICATIONS FOR BRONZE BEARING METALS FOR TURNTABLES AND MOVABLE RAILROAD BRIDGES.

1. Phosphor bronze shall be a homogeneous alloy of copper and tin of crystalline structure. It shall be made from new metals, except that scrap of known composition produced by the foundry at which the bronze is cast may be used. It shall not contain sulphur. The phos-

phorus shall be introduced in the form of phosphor-tin or phosphor-copper. Castings shall be sound, clean and free from blowholes, porous places, cracks and other defects.

2. The alloy shall be cast into ingots and allowed to cool, and the castings shall be poured from the remelted ingots. Care shall be exercised that the metal is not overheated and that the temperature at pouring and the conditions of cooling are such as will be most likely to secure dense castings.

3. There shall be four grades:

Grade A is to be used for contact with hardened steel discs under pressures exceeding 1500 lbs. per square inch, such as are used in turntables and centerbearing swing bridges.

Grade B is to be used for contact with soft steel at low speeds under pressures not exceeding 1500 lbs. per square inch, such as trunnions and journals of bascule and lift bridges.

Grade C is to be used for ordinary machinery bearings.

Grade D is to be used for gears, worm wheels, nuts and similar parts which are subjected to other than compressive stresses.

4. The chemical and physical qualities shall conform with the requirements in the following table:

	GRADE			
	A	B	C	D
Copper per cent	80 about	85 about	80 about	88 about
Tin per cent	20 about	15 about	10 about	10 about
Lead per cent			10 about	
Zinc per cent				2 about
Phosphorus per cent	1.0 max.	1.0 max.	1.0 max. 0.7 min.	0.25 max.
Other elements per cent	0.5 max.	0.5 max.	0.5 max.	0.5 max.
Elastic limit in compression, pounds per square inch	25,000 min. 40,000 max.	19,000 min. 23,000 max.	15,000 min. 20,000 max.	14,000 min.
Permanent set under 100,000 lbs.	.06 min. .10 max.	0.12 min. 0.25 max.		
Yield point in tension, pounds per square inch				To be Recorded
Ultimate strength in tension, pounds per square inch				33,000
Elongation in 2 inches per cent				14

5. The chemical analysis of each heat shall be furnished.

6. Test specimens shall be made from coupons which are a part of the casting, and which have been fed and cooled under the same conditions as the casting.

7. Compression test specimens shall be cylinders 1 inch high and of 1 square inch area. The elastic limit in compression shall be the load which gives a permanent set of 0.001 inch.

8. Tension test specimens shall be turned from a coupon not less than 1 inch in diameter to the form shown in Fig. 2 of the American Railway Engineering Association General Specifications for Steel Railway Bridges. The diameter of the turned specimen shall be ½-inch.

9. At least one compression test shall be made from each melt for Grades A, B and C; and one compression and one tension test for Grade D. For castings weighing over 100 lbs., finished, the prescribed tests shall be made for each casting.

10. The hardness of the finished castings shall be tested by the Brinell ball method and a record of the test furnished. The ball shall be of hardened steel 10 mm. in diameter. The load shall be 500 kg. and shall be applied for 30 seconds to a finished plane surface. At least two hardness tests shall be made upon each heat. A test shall be made on each trunnion bearing and each disc.

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PARTICULAR USES OF BRONZE IN MOVABLE BRIDGES.

By Clement E. Chase.

For each of the several distinct uses of bronze in bridge work, there is doubtless one composition that best combines entirely satisfactory quality with minimum cost, but conditions vary so, and scientific research into the matter is so meager, that it is hardly possible to do more than indicate the desirable qualities and name some compositions which have proved satisfactory in service. Further, most of these uses of bronze are not really severe tests of bearing metals, in that the loads usually are determined by other considerations than the strength of the metal, and that the bearings are not used constantly enough in motion to make endurance to wear or heating difficult problems.

Of the desirable qualities, it is first important that the friction be as little as possible. Theoretically, the harder the bearing metal the better as to friction, and consequently heating will be reduced. However, this presupposes perfect adjustment between bearings and the rotating parts, as otherwise there will be excessive wear and heating at the points of contact. From this has come the conception of the ideal bearing metal as one containing a hard constituent to support the load and a soft constituent to act as a plastic support for the harder grains. In this case the yielding of the soft constituent will remedy the irregularities of bearing.

For some uses the resistance to wear may decide between the various bronzes. Tests in the laboratory and in actual practice have shown that the softer bronzes wear less and that the bronzes with lead content are superior in this regard to those without, and that this advantage increases with the proportion of lead.

A certain amount of strength in compression, to resist pressure without flowing, is required. Computed unit stresses, however, usually are low, as they commonly are fixed in the case of trunnions or journal bearings by the amount that will allow the maintenance of an oil film between rotating part and bearing.

When used in gears or worms, the strength to resist tension is an important quality.

The hardness of the bearing must be regulated to that of the rotating parts, lest the latter suffer from abrasion.

The bronze should be as free from brittleness as compatible with its other qualities, as it may be exposed to shock both before and after being placed in use. It is a common experience for a bronze bushing made to meet the requirement of 24,000 or 27,000 lbs. minimum elastic limit to crack in machining or handling. There is also the risk of this happening after the bearing is in use. C. H. Mercer, Chief Engineer of the Pennsylvania Steel Company, writes: "We have had no reports of breakage due to material being too soft, but have had one report of the bearing breaking on account of being too hard. A sample was taken from the broken piece and it developed 21 per cent. tin."

Uniformity of structure and freedom from oxides are necessary features of good bronzes.

Fineness of microstructure is important in that this is found to accompany high physical properties and will have an important effect on the wear of both the bearing and the rotating part. Considering the agency of wear as the dislodging of the hard particles from the soft matrix, it is seen to be an advantage that these particles be as small as possible. Some day, it is hoped, microscopic examination for structure may be required for important bearings.

These are the four following distinct classes of duty for bronze in connection with movable bridges:

1. For center-bearing discs of drawspans, working between surfaces of hardened steel at low speed and under heavy pressures of from 3000 to 3500 lbs. per sq. in. When used in this way there is a chance of poor lubrication due to the oil film being squeezed out during the periods of rest. To reduce the friction of turning and meet the unit pressures, a hard bronze is necessary. Wear will not be an item of importance, as the number of revolutions during the lifetime of a bridge would never cause appreciable wear. Centerbearing discs are commonly used against hardened, or at least high carbon, steel surfaces, so that the hardness of the bronze usually need not be limited by fear of abrasion. The lenticular shape of the discs and the manner in which the load is applied make the risk from brittleness a minimum. The use of phosphorus in the bronze will aid in securing both hardness and freedom from oxides.

An extremely hard bronze usually is specified, the requirement for elastic limit in compression being a minimum of 24,000 or 27,000 lbs. per sq. in., with a set under 100,000 lbs. per sq. in. of not over 1-10-inch. Tool steel bearing surfaces, often oil-hardened, are commonly used with this bronze. The foundry must make a bronze with tin content about 20 per cent. and phosphorus 0.8 to 1.2 per cent. to meet this specification which places no limit on hardness. The result is an extremely brittle material that, the bridge shops have learned, must be handled with every precaution. Test results on bronze made to this specification frequently show elastic limits of from 30,000 to 40,000 lbs. per sq. in. in compression. The bearing surfaces are very apt to warp slightly in hardening after being machined and it then becomes a very difficult matter to secure uniform bearing on the disc. The writer believes that a somewhat softer bronze, with tin content about 16 to 18 per cent. (elastic limit about 20,000 or 24,000 lbs. per sq. in.) working between high carbon (not hardened) steel bearing surfaces would be found equally satisfactory in service. For working in the shop it would be greatly superior to the harder metal, and a uniform bearing would be comparatively easy to obtain.

2. For trunnion bearings carrying medium or structural steel trunnions at low speed under moderate *computed* pressures, usually from 1500 to 2000 lbs. per sq. in. These unit pressures, computed on the projected area of the trunnion, are limited to these amounts by considerations of lubrication. A hard bronze is desirable for two reasons: First, during periods of rest the oil film may well be squeezed out and then a hard bronze is advantageous, as friction will be less and the chance of gripping of the trunnion less. Friction is important, as the power consumed in opening and shutting the bridge will depend largely on it. Second, it is entirely probable that the actual unit pressures in the surface of contact

between trunnion and bearing are for a long time, possibly always, considerably in excess of those computed. Wear is not important in this case. Trunnions are commonly of structural grade steel and B. R. Leffler refers to two cases in which shafts, where a very hard bronze was used, became abraded. The possibility of uneveness of the support of the bushing, its comparative thinness and the chance of shock make the question of brittleness rather important. The breakages in handling in the shop, and during and after erection, usually have occurred in bronzes of this type when made of hard (20 per cent. tin) bronze.

While phosphor bronzes of the hard type (copper 80-82 per cent., tin 20-18 per cent.) have been used frequently in trunnion bearings, as also has been the standard lead bronze (copper 80, tin 10, lead 10 per cent.), the medium bronze recommended by Mercer and incorporated in Leffler's specifications, seems for many reasons best. The physical qualities can be met with a bronze of about 14 per cent. tin content.

3. For shaft bearings working under light loads at high speeds. In this case wear is a matter of first importance, as it usually is a matter of great difficulty and expense to replace the bushings of an important bearing in the machinery of a movable bridge. This makes a fairly soft lead bronze desirable. Lubrication usually can be counted on to be continuous, and the pressures hardly are great enough to make it likely that the shaft would be gripped even if the bearing ran dry for a short time. The tin content should be comparatively low, because it then is easier to have the lead uniformly distributed throughout the casting. For uniformity and freedom from oxides which may cause heating, phosphor bronze should be used.

The "standard" lead phosphor bronze (copper 80, tin 10, lead 10 per cent.) is used commonly and probably is as well adapted as any other to the purpose. Specifications should not call for physical properties incompatible with these proportions.

4. For gears and worms, requiring resistance to both tension and wear. The composition must be hard so as not to flow, but not so hard that the pinion or gear that is engaged will become abraded, nor brittle, as shock is very likely to occur. High tensile strength, ductility and denseness are prime requisites.

A lead bronze is unsuitable, being too soft and uncertain in tension. Probably there is nothing better for this use, where its strength is sufficient, than the venerable gun metal formula, copper 88, tin 10, zinc 2 per cent. This is familiar to most foundries, and splendid sound castings can be obtained. Phosphorus does not seem necessary with the zinc present, and some authorities assert that the bronze is injured by the presence of both.

Appendix D.

RELATIVE ECONOMY OF VARIOUS TYPES OF MOVABLE BRIDGES.

REPORT OF SUB-COMMITTEE D.

The Committee has tabulated the weights of 20 bridges. All of these except one are movable in a vertical plane. The other is a horizontal rotating structure. The bridges movable in a vertical plane range in span from 40 to 235 feet. Seven of the bridges are of the direct vertical lift type.

Interesting progress is being made and it is expected that the work of the coming year will furnish valuable data for the subsequent report.

A STUDY OF WORKING STRESSES FOR BRIDGE STRUCTURES.

By a Sub-Committee of the Committee on Iron and Steel Structures.

INTRODUCTION.

In 1907 the subject of impact was taken up by the Committee on Iron and Steel Structures as a special subject for investigation, and a Sub-Committee was appointed to carry on experimental work. Field work was undertaken to a small extent in the summer of 1907, and quite extensively in the summer of 1908. The results of this experimental work were presented, together with a general discussion of the subject, in Bulletin 125, of this Association, dated July, 1910. These results indicated that the impact formula now in use does not represent very exactly the actual impact as determined by observation. However, before any recommendation should be made leading to a modification of the present formula, it was thought desirable to investigate also the question of secondary stresses. The same Sub-Committee was therefore asked to make a study of this subject. Pursuant to this action, the Sub-Committee conducted a considerable amount of experimental work in the field, and presented the subject from the theoretical side. The results of this work were published in Bulletin 163, 1914.

Having thus treated at some length the two fundamental problems involved, it seems that the time has come to make some effort to apply the results obtained to the problem of working stresses, particularly with respect to how these may be modified by the accumulated information pertaining to impact and secondary stresses.

The question of a safe and economical working stress is a very complex one, and any modification of the present practice should be made only after the most careful consideration. Because of this fact and the great importance of the subject, the Sub-Committee has not felt prepared to make any definite recommendations at this time. but presents herewith the results of a careful study of the subject. Various suggested modifications of the present units and formulas are presented with the view to obtaining further suggestions and criticism. Before taking up the question of working stresses, a resumé will be given of the results of the Committee's work on impact and secondary stresses, together with certain conclusions relative thereto. The material of this paper will, therefore, be divided into three parts, as follows:

I. Impact;
II. Secondary Stresses;
III. Working Stresses.

I. IMPACT.

TESTS BY THE AMERICAN RAILWAY ENGINEERING ASSOCIATION COMMITTEE.

The most extensive series of experiments on Impact, which have ever been made, are those conducted by this Committee, and reported on at length in Bulletin 125, July, 1910. These experiments include tests on about fifty girder and truss bridges, of span lengths from 25 feet to 550 feet. These tests were made by means of special test trains, which were run over the structures a large number of times at various speeds, from a low speed of ten to fifteen miles per hour to as high a speed as practicable. In this way the most unfavorable speed for the structure in question was determined and conditions secured resulting in a maximum value for the impact effect. In many cases the results were undoubtedly considerably greater than would occur under traffic. On this account it is believed that the results given herein and used as a basis for a proposed impact formula represent maximum and not average conditions.

The most important conclusions expressed in Bulletin 125 are here repeated:

(1) With track in good condition the chief cause of impact was found to be the unbalanced drivers of the locomotive. Such inequalities of track as existed on the structures tested were of little influence on impact on girder flanges and main truss members of spans exceeding 60 to 75 feet in length.

(2) When the rate of rotation of the locomotive drivers corresponds to the rate of vibration of the loaded structure, cumulative vibration is caused, which is the principal factor in producing impact in long spans. The speed of the train which produces this cumulative vibration is called the "critical speed." A speed in excess of the critical speed, as well as a speed below the critical speed, will cause vibrations of less amplitude than those caused at or near the critical speed.

(3) The longer the span length the slower is the critical speed, and therefore the maximum impact on long spans will occur at slower speeds than on short spans.

(4) For short spans, such that the critical speed is not reached by the moving train, the impact percentage tends to be constant so far as the effect of the counterbalance is concerned, but the effect of rough track and wheels becomes of greater importance for such spans.

(5) The impact as determined by extensometer measurements on flanges and chord members of trusses is somewhat greater than the percentages determined from measurements of deflection, but both values follow the same general law.

(6) On account of the influence of the "critical speed," the maximum impact on web members (excepting hip verticals) occurs under the same conditions which cause maximum impact on chord members, and the percentages of impact for the two classes of members are practically the same.

(7) The impact on stringers is about the same as on plate girder spans of the same length and the impact on floor beams and hip verticals is about the same as on plate girders of a span length equal to two panels.

(8) The effect of differences of design was most noticeable with respect to differences in the bridge floors. An elastic floor, such as furnished by long ties supported on widely spaced stringers, or a ballasted

floor, gave smoother curves than were obtained with more rigid floors. The results clearly indicated a cushioning effect with respect to impact due to open joints, rough wheels and similar causes. This cushioning effect was noticed on stringers, floor beams, hip verticals and short-span girders.

(9) The effect of design upon impact percentage for main truss members was not sufficiently marked to enable conclusions to be drawn. The impact percentage here considered refers to variations in the axial stresses in the members and does not relate to vibrations of members themselves.

(10) The impact due to the rapid application of a load, assuming smooth track and balanced loads, is found to be, from both theoretical and experimental grounds, of no practical importance.

(11) The impact caused by balanced compound and electric locomotives was very small and the vibrations caused under the loads were not cumulative.

(12) The effect of rough and flat wheels was distinctly noticeable on floor beams, but not on truss members. Large impact was, however, caused in several cases by heavily loaded freight cars moving at high speeds.

The important results are herewith given in Figs. 1 and 2. Fig. 1 is taken from Plate 5 of Bulletin 125 and shows the maximum impact percentages as determined by deflection measurements for the various spans tested. Fig. 2 is from Plate 9 and shows maximum results obtained from extensometer measurements on chords, girder flanges and end posts. The results obtained by the American Railway Engineering Association Committee are represented on this diagram by open circles.

It is to be noted that both these diagrams show not average but maximum values for each of the structures tested.

An important result noted under (2) above is the fact that for spans exceeding about 75 feet in length there is a critical speed of locomotive, which, on account of cumulative effect, produces the maximum impact. These critical speeds are approximately indicated in Fig. 1. They are, of course, dependent upon diameter of locomotive driver as well as upon weight and span length of bridge.

OTHER EXPERIMENTS ON IMPACT.

Brief descriptions of other experiments are given in Bulletin 125. Many of these are foreign experiments, which can hardly be applied to American conditions on account of the very great differences in locomotive design. In one of the most important of the foreign papers referred to, it is stated, for example, that there is no danger of cumulative vibrations in railroad bridges. This is entirely contrary to the experience of this Committee, and is doubtless based on tests with balanced locomotives.

The most useful experiments of those mentioned, for purposes of the Committee, are those conducted by Mr. J. E. Greiner, and reported in Vol. 6, 1905, of the Proceedings of the American Railway Engineering Association, and those by Mr. F. E. Turneaure, reported in Transactions American Society of Civil Engineers, Vol. 41, 1899, page 410. In the former case the records were destroyed in the Baltimore fire and detailed results have never been published. The results given in

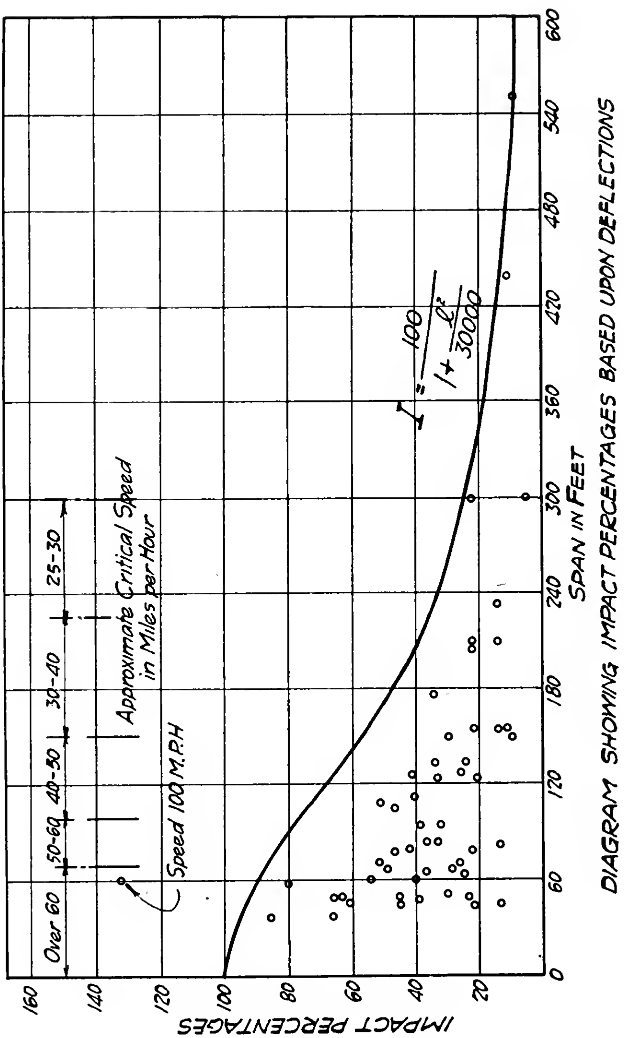
DIAGRAM SHOWING IMPACT PERCENTAGES BASED UPON DEFLECTIONS
SPAN IN FEET
IMPACT PERCENTAGES
0
60
120
180
240
300
360
420
480
540
600
160
140
120
100
80
60
40
20
$I = \frac{100}{1 + \frac{l^2}{30000}}$
Approximate Critical Speed in Miles per Hour
Over 60
50-60
40-50
30-40
25-30
Speed 100 M.P.H

FIG. 1.

the Proceedings are the minimum and maximum results observed at fast speeds on six girder and truss bridges from 31 ft. 6 in. span to 207-ft. span. In the latter case tests were reported on 12 girder and 11 truss spans varying from 25- to 200-ft. span length.

The maximum results obtained in these two series of tests are brought together in Fig. 2, as indicated thereon.

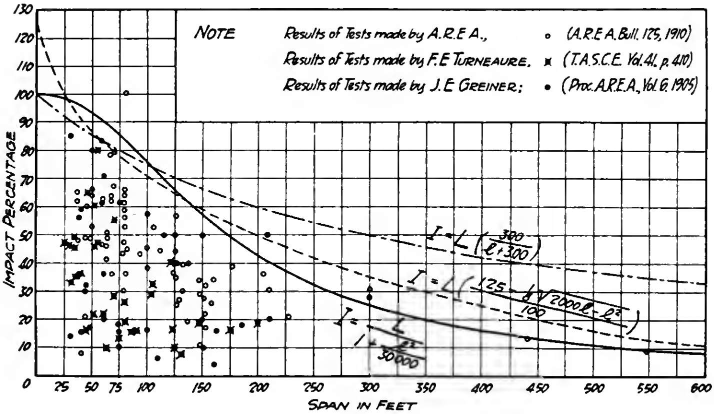

FIG. 2.

THEORETICAL ANALYSES.

Considerable attention has been given by various writers to theoretical analyses of this subject. Such analyses have covered, generally, only two elements of the problem:

(1) The theoretical impact effect of a rapidly moving load crossing a span which deflects under the load and thereby forces the load to travel in a curved path, concave upwards. Such a load will exert a certain amount of centrifugal force upon the structure. This effect may be called the effect of speed alone, all effect of counterweight, etc., being eliminated. It has been shown that this part of the impact effect is very small and may be entirely neglected in spans exceeding 50 feet in length. If properly cambered, this effect disappears entirely.

(2) The centrifugal force exerted by the counterweights of the locomotive at high speed. This can be calculated and will give results of value applicable to stringers and short-span structures. This effect is proportional to the square of the speed. Some attempt has been made to apply results of such calculations to long spans. This is very difficult or impossible to accomplish. It has been clearly shown by tests that for spans exceeding about 100 feet in length the cumulative effect of the counterweight force is the important thing. About the only result obtainable by applying theory to this condition is to show the evident possibility of high impact results. These high results are limited, however, in

a very great degree by the fact that for the longer spans, the speed which favors cumulative effect is not very high.

Under these circumstances the Committee is of the opinion that very little aid can be had from theory and that results of experiments must be relied upon. This is particularly true with respect to theories used by various foreign writers, on account of the great differences in working conditions.

PROPOSED IMPACT FORMULA.

The Committee proposes the formula $I = \frac{100}{1 + \frac{l^2}{30000}}$, where I = impact percentage and l = span length, or loaded length for maximum stress.

So far as the observations of the Committee go, the maximum impact percentage on all web members (except hangers) is about the same, irrespective of position in the truss. The reason for this is pointed out in paragraph (6) quoted above. However, owing to the influence of the dead-load on the over-load capacity of a bridge, as discussed in Part III, and other practical considerations, it is probably desirable to use for all web members a value of l equal to the loaded length for maximum stress. This results in some increase in the size of the web members, particularly near the center of the span, which, on the whole, is a desirable condition. For hangers and floor members, both theory and observation indicate that l should be taken as the loaded length.

For electric locomotives the rotating parts are well balanced, and the experiments of the Sub-Committee indicate that the impact under such loads is very small. In fact, what little impact exists would be caused by such features as poor joints and other irregularities in the track or in the locomotive wheels. The impact under electric locomotives is so much smaller than that under the ordinary steam locomotive that the Committee believes that where structures are to be used exclusively under electric traction, the impact to be assumed should be very considerably less than that given by the proposed formula.

The proposed formula is shown in Figs. 1 and 2. It will be seen that the curve exceeds somewhat all experimental values in Fig. 1, and all but four values in Fig. 2. The only value in Fig. 2 considerably above the curve is for a 75-foot span. Considering the fact all but a few of the experimental results in these diagrams are maximum values and the fact that the curve exceeds practically all of these maximum values, it is believed that the proposed formula gives values abundantly high to represent maximum impact effect.

On Fig. 2 are platted two other curves, namely, the formula now in use, $I = \frac{300}{l + 300}$, and the formula proposed by Mr. H. B. Seaman.*

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*Trans. Am. Soc. C. E., Vol. 75, p. 313.

It seems evident that the present formula of the specifications gives considerably too high values for the longer spans. It should be said, however, that this formula was originally intended to cover, not only impact, but some allowance for secondary stresses. Inasmuch as it does not appear to be too high for short spans, the actual allowance for secondary stresses obtained by its use is variable. It would seem to be more rational to separate these two elements and endeavor to provide in the impact formula a proper allowance for impact only, treating secondary stresses as a separate matter.

The form of proposed impact curve may be objected to on account of its reversed curvature. There is, however, a good theoretical foundation for this form. For short spans the impact is largely a function of speed, and tends to be constant for spans up to 75 to 100 feet. For long spans, where cumulative effect enters, the impact begins to drop off according to a law approximately inversely proportional to the span length.

II. SECONDARY STRESSES.

Before making use of results of impact investigations in the direction of a modification of present working formulas, it appeared to be necessary to make a study of the subject of secondary stresses. It has generally been assumed that in the design of members the elastic limit stress should not be exceeded, and a good part of the margin between the allowable working stress and the elastic limit of the material has been intended to cover these secondary or uncalculated stresses. As a more exact knowledge of the amount of impact or dynamic effect is obtained, it becomes more desirable to consider closely the subject of secondary stresses. It was with this condition in mind that the Sub-Committee was requested to investigate this subject and report thereon.

In accordance with these instructions the Committee made a considerable study of the subject, both experimentally and theoretically, and reported at some length in Bulletin 163, January, 1914. The more important results of this study on secondary stresses are here summarized.

PRINCIPAL CLASSES OF SECONDARY STRESSES.

The important secondary stresses which are likely to arise in bridge design may be classified under the following heads:

(1) Bending stresses in the plane of the main truss due to rigidity of joints.

(2) Bending stresses in vertical posts or members of a transverse frame due to the deflection of floor beams.

(3) Stresses in a horizontal plane due to longitudinal deformation of chords, especially the stresses in floor beams and connections.

(4) Variation of axial stress in different elements of a member.

(5) Stresses due to vibration of individual members.

(1) STRESSES IN PLANE OF THE TRUSS DUE TO RIGIDITY OF JOINTS.

Where the members of a truss are rigidly connected by means of riveted joints, or continuity of construction, the longitudinal deformations of the members due to their primary stresses cause a certain amount of bending in the members, giving rise to bending stresses which have a maximum value at or near the joints. These bending or secondary stresses are sometimes of large amount and require careful consideration. It is generally possible and sufficient to so design a structure as to keep these stresses within reasonable limits and then to neglect them in the calculations, but in many special cases and in large and important structures they should be calculated.

The discussion in the Bulletin referred to included certain general principles and conclusions which are of assistance in determining upon a design without going into detailed calculations. The most important of these general principles are as follows:

(1) The secondary stresses are in general proportional to the primary stresses and, therefore, are conveniently expressed in percentages of primary stresses.

(2) Other things being equal, or similar, the percentages of secondary stress are directly proportional to the widths of the members in the plane of the bending, and inversely proportional to their lengths. Thus, if two trusses are compared whose general dimensions and moments of inertia of members are proportional, but the ratio of width to length of the various members of one truss is in all cases twice this ratio in the other truss, then the percentages of secondary stress in the first truss will be twice the percentages in the second truss.

(3) The more uniform the proportions of a truss the less, in general, will be the secondary stresses. Sudden changes in length, width, or in moment of inertia, are likely to result in relatively large secondary stresses.

(4) Trusses consisting of approximately equilateral triangles, and without hangers or vertical struts, present the most uniform conditions and will have, in general, the lowest secondary stresses. A truss composed of right-angle triangles will show somewhat higher secondary stresses, and such stresses will be large if the ratio of height to panel length is large.

(5) Wherever hangers or vertical struts are used to support single-joint loads, as in a Warren truss with verticals, or in a Pratt truss (at the hip vertical, or at the center vertical in the case of a deck bridge), the secondary stresses in the adjacent chord members are likely to be considerably larger than elsewhere. The best arrangement so far as secondary stresses are concerned is where each member forms an integral part of the entire truss, so that its stress will gradually change as the load progresses.

(6) From the fact that secondary stresses are, in general, proportional to the ratio of the width of member to length, it follows that these stresses in the loaded chord of a truss with sub-panels are likely to be

relatively large as such a chord will be relatively deep, and the distortion of hanger or sub-strut relatively great.

(7) The additional secondary stresses due to eccentric connections are likely to be large at the joint in question, but this effect is not great in surrounding joints.

SECONDARY STRESSES IN TYPICAL TRUSSES.

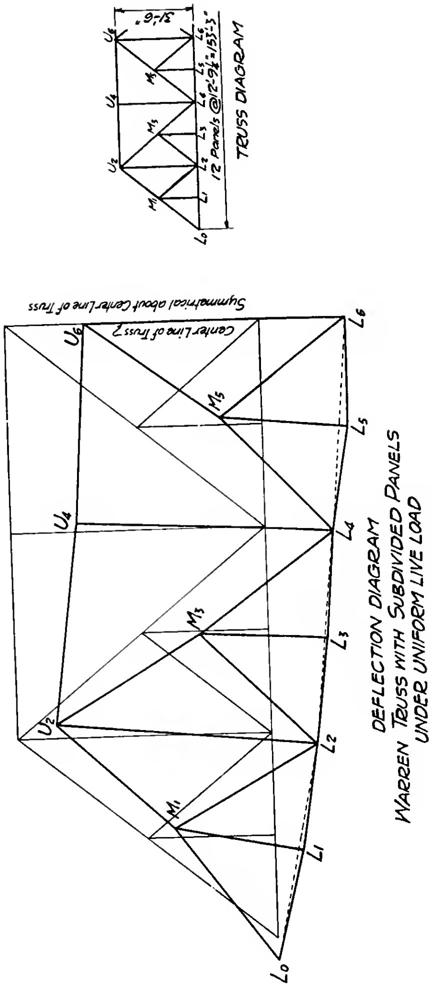
From results of calculations of typical trusses of different forms certain general conclusions may be drawn as to the amount of secondary stresses in trusses of usual forms and proportions.

In ordinary single intersection Pratt and Warren trusses the percentage of secondary stress is approximately equal to $300 \times \frac{\text{width}}{\text{length}}$ for tension members and $200 \times \frac{\text{width}}{\text{length}}$ for main compression members. In actual percentage these stresses will ordinarily run from 15 per cent. for top chords in ordinary through truss spans to as high as 40 per cent. for bottom chords in truss spans in which the members are relatively wide. The maximum stresses are likely to occur in the end panels, especially in the lower chord and end post, this effect being due to the elongation of the hip vertical. Generally speaking, the percentage of the secondary stress in ordinary design may be placed at from 20 to 35 per cent. in the various parts of the truss.

In trusses with sub-divided panels the percentage in the lower chord (assuming a through bridge) is certain to be higher than in a simple Pratt design, reaching, ordinarily, 50 to 60 per cent., and equal to about $500 \times \frac{\text{width}}{\text{length}}$. These high values are due, in part, to the very short panel length of the loaded chord, making the ratio of width to length large, and in part to the effect of the suspenders. The top chord in such trusses will show only the usual amount of secondary stress unless supported by sub-struts, which will tend to increase such stresses. In the case of trusses with very short panels, the calculated secondary stress may reach as high as 100 per cent. at certain joints and from 60 to 80 per cent. in most panels of the lower chord.

Figs. 3 and 4 illustrate two types of trusses in which the secondary stresses are very different. Fig. 3 shows to an exaggerated scale the actual movements of the joints of a sub-divided truss under live-load. The irregular nature of the deflections explain clearly the cause of high secondary stresses in this type of truss. Fig. 4 gives the same information concerning a so-called "K" type of truss, in which the secondary stresses are exceptionally low. Fig. 3 brings out quite clearly the effect of hangers and other secondary members.

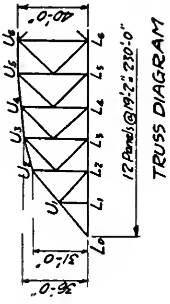
Double intersection trusses are almost certain to show very high secondary stresses in the chord members under concentrated loads, due to

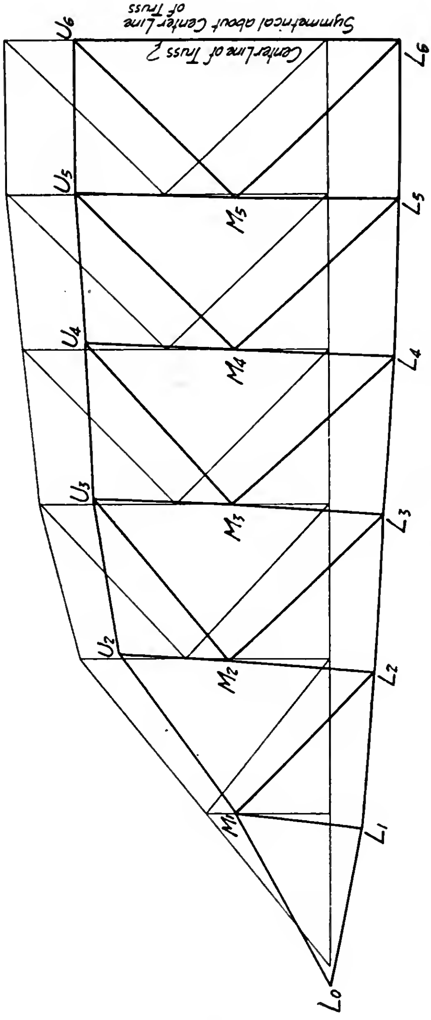


TRUSS DIAGRAM

DEFLECTION DIAGRAM
WARREN TRUSS WITH SUBDIVIDED PANELS
UNDER UNIFORM LIVE LOAD

FIG. 3.





DEFLECTION DIAGRAM
RIVETED K TRUSS
UNDER UNIFORM LIVE LOAD

Fig. 4.

the independent action of the two web systems. This is particularly true for spans of moderate length.

TRESTLE TOWERS AND LATERAL BRACING BETWEEN CHORDS OF TRUSSES.

Where the lateral bracing of a trestle tower or the laterals between chords of a truss are of the single Warren system, or the double system without verticals, the vertical distortion of the tower legs or the longitudinal distortion of the chords due to the direct stress load will give rise to a lateral bending of the members in the plane of the lateral system, thus producing considerable secondary stresses. This effect can be easily avoided by the use of transverse ties or struts. The same principles apply to very large columns whose segments are connected only by diagonal lacing.

(2) BENDING STRESSES IN VERTICAL POSTS DUE TO DEFLECTION OF FLOOR BEAMS.

Where floor beams are rigidly connected to vertical posts, as in the usual modern design, the deflection of the floor beams produces bending of the posts in a transverse plane, with corresponding stresses. This problem can readily be approximately analyzed as shown in Bulletin 163.

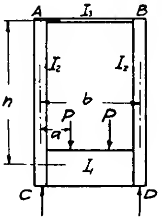


FIG. 5.

Referring to Fig. 5, the results of this analysis are as follows, M being the bending moment in the post near the floor beam:

Case 1. Top Strut Assumed Hinged at A and B.

$$M = P\frac{3a\ (b-a)\ I_2}{2\ hI_1 + 3bI_2}$$

Case 2. Top Strut Assumed Fixed at A and B.

$$M = P\frac{2a\ (b-a)\ I_2}{hI_1 + 2bI_2}$$

It can be shown that under the above assumptions, and for the usual spacing of track stringers in single-track bridges, the ratio of fiber stress in the post to the fiber stress at the center of the beam is approximately as follows:

$$\frac{f_p}{f_b} = (0.7\ \text{to}\ 1.0) \times \frac{c_p}{c_b}$$

In which f_p = fiber stress in post, f_b = fiber stress at beam center, c_b = depth of beam and c_p = width of post in a transverse plane. Thus the ratio of post stress to maximum beam stress is nearly equal to the ratio of widths of members. Where knee braces are used at the top and high gusset plate connections at the bottom the bending effect is increased, as the equivalent value of h is decreased thereby.

Results of observations bear out these theoretical conclusions. Bending stresses in posts have been observed as high as 40 per cent. of the floor beam stress, and invariably the observations have shown quite large values. In the case of compression verticals in Pratt trusses, the maximum bending stresses do not occur simultaneously with the maximum primary stresses; however, an increase of 20 to 25 per cent. in the maximum primary stress may be expected from this cause. In the case of tension verticals, such as hip verticals, the maximum bending stress occurs simultaneously with the maximum primary stress, thus increasing very greatly the maximum fiber stress in the member.

(3) STRESSES IN FLOOR BEAMS DUE TO LONGITUDINAL DEFORMATION OF CHORDS.

Here, again, an approximate analysis can be made under certain assumptions. If there are no expansion joints in the stringers the center beam will tend to stand fast and the other beams will bend towards the center, the maximum deflection taking place in the end beams. If it is assumed that the stringers do not elongate and that the connections are unyielding, the following analysis results (Fig. 6): CD is the first beam from the center. Then

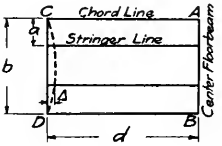


FIG. 6.

$$f = \frac{3cd}{a\ (3b-4a)} \times s$$

in which f = fiber stress in beam due to horizontal bending, c = flange width, s = unit stress in chords.

Assuming, for example, d = 300 in., c = 12 in., b = 192 in., and a = b/4, we find that f = .58s. For the second beam f = 1.16s, etc.

Actual strain measurements on floor beams show the presence of large bending stresses therein; in fact, stresses approaching the large values resulting from the above theoretical analysis. Such results are given in Bulletin 163. It is sufficient here only to point out the very high values of these stresses.

In some designs an attempt is made to resist the bending by horizontal trusses at the ends of the span. Such a plan would appear to be unwise. The elongation of the chords cannot be prevented and the beams can only be held in line by forcing the stringers or their connections to distort an equal amount. Any attempt to do this results in heavy stresses on rivets and connections with little benefit. Excessive stresses can only be prevented by the use of expansion joints in stringer connections in long span bridges and by using a wide gage for the outstanding leg of the angle connecting the stringer to the floor beam for the shorter spans. Conditions are especially unfavorable in double-track structures where the distance between outside stringers and end of beam is relatively small. Where it is desirable to introduce horizontal trusses in the floor system to resist the traction or braking stresses, the most suitable place for such a truss is at one or two beams near the center of the span, or at the center of the space between expansion joints, if such are used.

Besides the stresses in beams and connections the extension of the chords gives rise to considerable stress in the lateral members and their connections. With fairly rigid joints the unit stress in the laterals may easily reach one-third to one-half the unit stress in the chords themselves. In the end panels, where the chord section is small and the laterals relatively large, a considerable proportion of the chord stress will be carried by the laterals. This consideration shows the importance of good lateral connections, especially near the ends of the span. Observations on end posts and end sections of lower chords have shown very high secondary stresses in these members, due to eccentric connections of lower laterals.

The connection of lower laterals to stringers is of doubtful value. Owing to the relative movement between chords and floor system here discussed, such a connection, if rigid, will cause considerable lateral bending in the stringers, especially near the ends of the span. If a connection is made, it should be flexible in a direction parallel to the bridge axis.

(4) VARIATION OF AXIAL STRESS IN DIFFERENT ELEMENTS OF THE SAME MEMBER.

In addition to the secondary stresses in a vertical plane due to rigid joints, there will exist more or less bending in a direction at right angles to the vertical plane. In the case of eye-bar members this lateral bending will be shown in the inequality of stress in the various bars; in the case of riveted members it will be shown as a lateral bending similar to the bending in a vertical plane. It is impossible to apply theoretical analysis to any great extent in this case, but results of observations have shown such variation to be considerable, especially at lower ends of end posts, due probably to the effect of the laterals. In other riveted members variations generally of 5 to 10 per cent. have been noted. In eye-bars a variation of 10 to 20 per cent. from the average, both for lower chord and diagonals, is not uncommon.

(5) STRESSES DUE TO VIBRATION OF INDIVIDUAL MEMBERS.

Slender members, such as long eye-bars, are subjected to very considerable vibration under moving loads. This vibration not only tends to cause wear, but also causes a considerable increase in fiber stress, which, if excessive, tends to produce some permanent elongation. Actual observations in the field have shown stresses due to this cause amounting to 2,000 to 3,000 lbs. per square inch in comparatively large eye-bars acting as long diagonals. Eye-bars used for chord members in spans exceeding about 150 feet, especially where designed for heavy loads, are not likely to be subject to any considerable increase of stress due to this cause. It is the long diagonal eye-bar which is likely to show large vibrations.

(6) CONCLUSIONS REGARDING SECONDARY STRESSES.

1. The amount of secondary stress to be expected in main truss members of the ordinary Pratt and Warren trusses ranges from about 15 to 35 per cent.

2. If members are exceptionally deep in the plane of the truss the percentage may run to 50 or 60 per cent.

3. Excessively deep members should be avoided, especially in tension chords and in chords of trusses with subdivided panels.

4. Hip verticals and other suspenders should be of liberal cross-section, and where these suspenders are of considerable length and attached to the lower chord, it is desirable to make them somewhat shorter than the calculated length, as in the shortening of members to produce camber.

5. Where a top chord in a subdivided truss is supported by means of secondary members, these should be made slightly longer than the calculated length to avoid excessive deflection under live loads.

6. Lateral connections should be made as concentric as possible, especially for lower laterals in through bridges and at panel points at and near the ends of the truss.

7. Posts supporting floor beams should be made of moderate width in a transverse direction and floor beams made relatively deep. In good designs, bending stresses in posts are likely to be as high as 25 per cent. of the primary stresses.

8. To avoid excessive bending stresses in floor beams due to chord action, expansion joints should preferably be used in the stringer system in single-track spans, exceeding about 200 feet in span length, and, in double track spans, exceeding about 150 feet in span length. For short through truss spans, the use of wide hitch angle legs attached to the floor beams will answer. In deck spans the provision of expansion joints is of especial importance.

9. If horizontal trusses are used in a floor system to resist traction stress, these should be placed near the center of a span or midway between expansion joints and not at the ends of the span.

10. Laterals should not be rigidly connected to floor stringers, merely supported.

11. Secondary stresses of considerable amount are developed when the single Warren system, or the double Warren system without verticals, is used for a lateral system or for bracing the legs of a trestle tower. These can readily be avoided by using transverse members of relatively small sections.

III. WORKING STRESSES FOR TENSION MEMBERS.

(1) GENERAL CONSIDERATIONS.

In determining the proper working stress for tension members of structural steel, the fundamental requisite is that no stress to which the material may be subjected by any possible combination of loads shall exceed its elastic limit strength. On the other hand, it is desirable for the sake of economy to work as close to this limit as practicable. In mild steel the margin between elastic limit and the ultimate strength is large, and so long as no part of the structure is stressed beyond the former limit the factor of safety against absolute failure is ample. In fact, an elevation of stress at rare intervals beyond the elastic limit would not necessarily injure the material or endanger the structure, but the permanent distortions which would be caused thereby would result in a new and uncertain distribution of stress and would, in general, be inadmissible.

While the elastic limit may, therefore, be taken as the limit towards which the actual stress may approach with safety, yet for several reasons it is necessary that the working stress be made considerably less than such elastic limit. A considerable margin of strength must be left to provide for the following:

(a) Variations and imperfections in the material and workmanship;

(b) Corrosion or other deterioration of the material;

(c) Secondary and other stresses not taken account of in the calculations;

(d) Some increase in live load, and sometimes in the dead load, beyond that specified without endangering the structure;

(e) The dynamic effect of moving loads (commonly called impact), whereby the actual stresses produced in the structure are considerably greater than the calculated static stresses;

(f) The possible effect of repetition of stress on the elastic strength of the material, especially with reference to details where secondary stresses may be high.

(g) In the case of unlikely but possible combination of circumstances, the working stress is made to depend somewhat, also, upon the probability of the assumed stress occurring.

Items (a) and (b) are not usually specifically allowed for, but some provision is made in a general way in selecting the working stress. Corrosion will vary greatly under different conditions and will frequently be a large factor in the life of a structure. Ordinarily at least 10 per cent. should be allowed for these two items.

Item (c), secondary stresses, have been discussed in Part II. These stresses are proportional to the primary or axial stresses for both dead and live loads. They are seldom calculated, but are provided for in the working stress in a general way. They may also be kept within reasonable limits by observing good principles of design.

Items (d), (e) and (f) relate to live load effects and item (g) to various combinations of variable loads which are more or less probable.

The selection of the proper unit stresses and the treatment of the various elements mentioned above can best be discussed under the following heads:

The Elastic Limit;

The Dead-Load Working Stress;

The Live-Load Stress, including (a) future increase in load, (b) impact, and (c) repeated stresses;

The Live-Load Unit Stress;

Comparison of Various Formulas for Impact and Dead- and Live-Load Working Stresses;

The Overload Capacity of Bridges designed with various working stresses.

(2) THE ELASTIC LIMIT.

For the standard structural steel the average commercial elastic limit (yield point) in tension is about 32,000 lbs. per sq. in. A minimum of 30,000 lbs. per sq. in. in specimen tests is allowed and 29,000 lbs. per sq. in. for full-sized eye-bars. A value of 30,000 may be taken as about the elastic limit value to consider in fixing the working stress.

The true elastic limit, that is to say, the limit of proportionality of stress and deformation, is somewhat below the yield point; but the permanent deformations for these low stresses are very small, and as this lower limit is likely to be exceeded only in the case of excessive secondary stresses, and then only in extreme fibers, this theoretical elastic limit is of little significance in connection with the question under discussion.

(3) THE DEAD-LOAD WORKING STRESS.

The dead-load stress is a static stress of fixed amount. If all secondary stresses were calculated so that the true maximum fibre stress could be known, it would be safe to allow a working fiber stress in tension members, for dead load alone, practically equal to the minimum elastic limit, as above indicated. In fact, a slight overstepping of the elastic limit, if due to bending from secondary stress, could do no more than to give a slight set to the member as in cold straightening. However, as any considerable permanent set, or inelastic deflection, is objectionable as disturbing the distribution of the stress on rivets and connections, the elastic limit should be considered as the limit of fiber stress.

The dead-load working stress for structural steel for tension members is usually placed at from 16,000 to 20,000 lbs. per sq. in., secondary stresses being neglected. The higher value can be employed only when the live-load stresses are fully provided for in the live-load working stress. Taking a value of 20,000 lbs. per sq. in. and an elastic limit at 30,000 lbs., the margin would be utilized about as follows:

Primary static stress	20,000	lbs. per sq. in.
Secondary stress at 35 per cent	7,000	" " " "
Total fiber stress	27,000	" " " "
Additional margin for corrosion, etc.	3,000	" " " "
Elastic limit	30,000	" " " "

It would appear from this analysis, that with ordinary conditions as to secondary stress, a working stress of 20,000 lbs. per sq. in. is about the maximum permissible value for the dead-load alone.

It should be understood that the above discussion relates to *elastic* strength and not to *ultimate* strength. Before failure in a tension member can occur the stress at some point would have to reach the ultimate strength of the material, a minimum value of about 55,000 lbs. per sq. in. Should a member be stressed considerably beyond the elastic limit, the relative amount of secondary stress becomes much less than it is below that limit, so that at failure, the axial, or primary stress, would reach nearly the ultimate strength of the material. With a working stress of 20,000 lbs. per sq. in. for the calculated primary stress, the factor of safety against ultimate failure would then be as much as 2½, which is ample for static loads.

In the case of compression members the relations between the elastic and ultimate strengths are very different from those above described.

(4) THE LIVE-LOAD STRESS.

The live or variable load differs in its characteristics from the dead-load in three ways. It is subject to future increase, it causes stresses whose true values are considerably larger than the calculated static values, and it is repeatedly applied and removed. Differentiation between dead- and live-load stress in determining sectional areas is made by three general methods: (1) By increasing the calculated live-load stress by a certain estimated amount to cover "impact" and then applying the same, or nearly the same, unit stress as for dead-load; (2) by using a comparatively low unit stress for live-load and applying it directly to the calculated static stress, the effect of impact, repetition of stress, etc., being covered by the unit stress, and (3) by the use of a "fatigue" formula applied to the combined dead- and static live-load stresses, and usually neglecting the effect of impact as such. The various elements involved will be discussed first, after which these methods of treatment will be considered.

Secondary stresses have the same relative magnitude as in the case of dead load and should be provided for in the same general manner: that is, by allowance in the unit stress.

(a) FUTURE INCREASE IN LOAD.

The most rational method of providing for future increase in load is to estimate what such load will be and use it in the stress calculations. However, owing to the impossibility of correctly estimating future conditions, either in the amount of such load or in its distribution, it is desirable to have some margin in the unit stress itself. For very costly structures a larger margin for growth should be allowed than in ordinary structures. In the former case it is also customary to assume a much heavier load than for ordinary structrues, thus insuring a longer life. On account of the effect of dead-load, the assumption of a relatively heavy live-load and high dead-load working stress gives a better balanced design, so far as future increase in load is concerned, than a light live-load and low dead-load stress. Again, by reason of the greater weight of long spans, the available margin in the dead-load unit stress gives a greater percentage of excess live-load capacity than in short spans. If properly distributed, this greater excess capacity is, to a certain extent, desirable, as long spans should, in general, have a longer life than short spans.

(b) IMPACT.

The true live-load stresses are considerably larger than the calculated static stresses on account of the dynamic effect of the moving load. The logical method of procedure is to estimate or calculate such impact stresses as closely as possible, and add the results to the static live-load stresses.

The various impact formulas in use have been discussed in a previous part of this report. The formula suggested by the Sub-Committee is as follows:

$$I = \frac{L}{1 + \frac{l^2}{30000}}$$

where L = live-load stress and l = loaded length for maximum stress.

(c) THE EFFECT OF REPEATED STRESSES.

It has been amply shown by experiments that when structural steel is subjected to a large number of repetitions of stress, exceeding somewhat its elastic limit, failure will ultimately result even though the maximum stress so repeated is considerably below the ordinary ultimate strength of the material. Recent tests indicate, further, that under a very large number of repetitions (running into the billions) the breaking load may be considerably below the ordinary elastic limit. However, it appears well proven that for repetitions extending only to a few millions (corresponding to the service of the steel in a bridge structure), the ultimate strength for loads varying from zero to the maximum is somewhat above the ordinary elastic limit.*

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*For a review of this subject see paper by H. F. Moore and by F. B Seely, Trans. Am. Soc. Test. Mat., Vol. 15, 1915, p. 437.

Working formulas have been used to a considerable extent, based on the theory of fatigue as brought out by the above-mentioned experiments. Such working formulas may correctly represent *ultimate* strength of the material under the different assumed conditions, but inasmuch as repetition of load does not affect *elastic* strength, these formulas do not give proper relative factors of safety with respect to the elastic strength. In practice they can be made to give fairly good results by omitting from the live-load stress the element of impact, thus making the formula take account of the impact; but if impact is first added so as to get the true live-load stress the usual fatigue formula gives results quite outside of the ordinary rules of practice. For example, in the case of a very short span, where the actual impact may be 100 per cent., and the ratio of minimum to maximum very small, the ordinary fatigue formula logically applied according to the fatigue theory, gives a dead-load working stress about four times as great as the working stress for static live load.

In view of present knowledge regarding both impact and fatigue, your Committee is of the opinion that the better practice is to make use of an impact formula directly and to neglect fatigue as such.

(5) THE LIVE-LOAD UNIT STRESS.

The most common method of treating live-load stress in use at the present time is to first add to the static stress the effect of impact as nearly as can be estimated, and then to treat the results substantially the same as the dead-load stress, secondary stress being allowed for in the same way as in the case of dead-load. It is a question whether or not this method gives proper relative weight to live-load stress as compared to dead-load stress, even assuming that the total live-load stress is correctly determined. It would appear that there is a sufficient difference between the action of live-load stresses and dead-load stresses to warrant some difference between the unit stresses.

The Committee is not prepared to make a definite recommendation on this important matter at this time, but suggests the following units as worthy of study and discussion:

$$
\text{a}\begin{cases}\text{20,000 lbs. per sq. in. for dead-load.}\\ \text{16,000 lbs. per sq. in. for live-load and impact.}\end{cases}
$$

$$
\text{b}\begin{cases}\text{18,000 lbs. per sq. in. for dead-load.}\\ \text{15,000 lbs. per sq. in. for live-load and impact.}\end{cases}
$$

$$
\text{c}\begin{cases}\text{16,000 lbs. per sq. in. for both dead-load and live-load}\\ \quad\text{with impact.}\end{cases}
$$

It is believed that with a specified live-load, which provides liberally for future increase of load, the units 20,000 and 16,000 are entirely safe and proper. These units do not, of course, allow as great an increase of live load, especially in long span bridges, as the present specifications, but it is a question whether the desired margin should not be secured by the use of a heavier specified live-load.

From the discussion here given it would appear that different values for the two classes of stresses would be the more rational provision, but a single unit stress is more convenient to use in practice, and if limited in use to spans of moderate size gives reasonably consistent results.

With the use of different working stresses for dead and live-load the resulting design will be better balanced and more economical in the long run than designs based on present practice. Under present rules the excess strength secured in using 16,000 lbs. for dead-load is not well distributed to take care of the possible increased live-load.

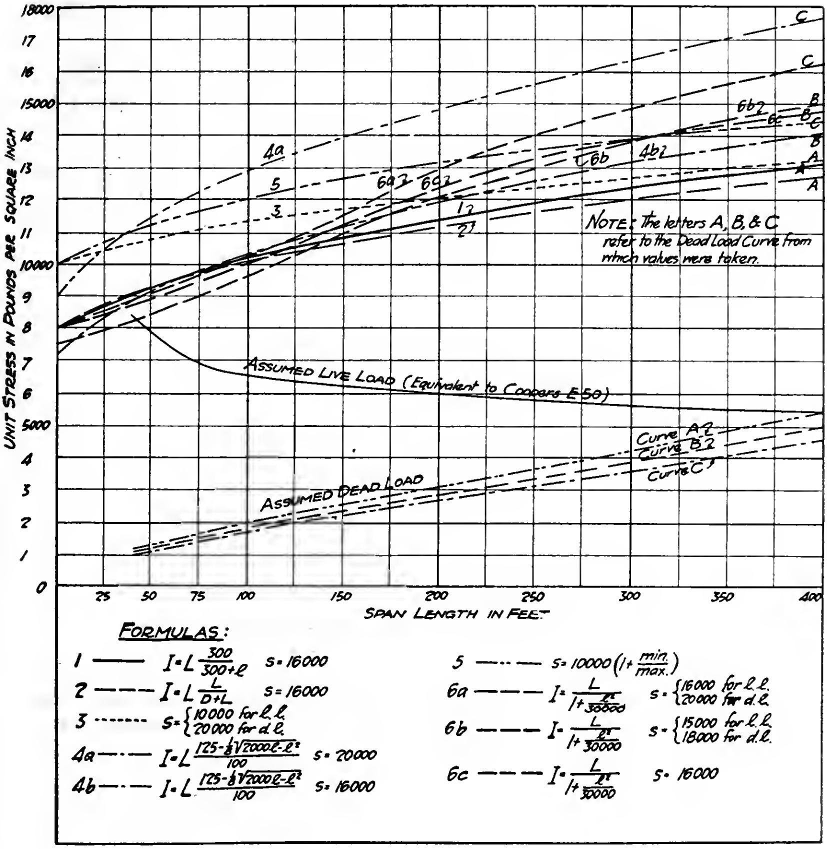


FIG. 7.

(6) COMPARISON OF RESULTS FROM DIFFERENT FORMULAS.

To bring out as well as possible the effect on a design of applying various formulas and unit stresses the diagram of Fig. 7 has been prepared

The ordinates represent the net unit stress, which, if applied to static live-load and dead-load stress, would give the same sectional area in each case as the use of the various formulas and unit stresses noted. These values are determined from an estimate of the actual weights of single-track railroad bridges of various spans, using a uniform load equivalent to Cooper's class E-50. Chord stresses only are considered.

The sectional areas of chord members are thus inversely proportional to the respective unit stresses shown by ordinates to these curves. Curves for the following formulas and unit stresses are plotted:

1. American Railway Engineering Association; $I = L \times \frac{300}{300 + l}$; $s = 16{,}000$.

2. Chicago & North-Western Railway and others; $I = \frac{L}{D + L}$; $s = 16{,}000$.

3. Cooper's units; $s = \begin{cases} 10{,}000 \text{ for L. L.} \\ 20{,}000 \text{ for D. L.} \end{cases}$

4. Seaman's Specifications;* $I = L \frac{125 - \frac{1}{8}\sqrt{2000\,l - l^2}}{100}$,

   (a) $s = 20{,}000$,
   (b) $s = 16{,}000$.

5. Fatigue formula; no impact. $s = 10{,}000\ (1 + \frac{\text{min.}}{\text{max.}})$.

6. Proposed by Committee; $I = \frac{L}{1 + \frac{l^2}{30{,}000}}$;

   (a) $s = \begin{cases} 16{,}000 \text{ L. L.} \\ 20{,}000 \text{ D. L.} \end{cases}$
   (b) $s = \begin{cases} 15{,}000 \text{ L. L.} \\ 18{,}000 \text{ D. L.} \end{cases}$
   (c) $s =$ 16,000 for both D. and L. L.

From this diagram we find, for example, that the equivalent unit stresses for chord members, derived from the various formulas for a 200-ft. span bridge, are approximately as follows:

Formula		Unit Stress
1		11,400 lbs. per sq. in.
2		11,200 " " " "
3		12,100 " " " "
4	(a)	14,900 " " " "
	(b)	12,000 " " " "
5		13,100 " " " "
6	(a)	13,000 " " " "
	(b)	12,100 " " " "
	(c)	12,400 " " " "

---

*Trans. Am. Soc. C. E., Vol. 75, p. 313.

To show more directly the effect of the application of these formulas upon the weights of structures, the diagram of Fig. 8 has been prepared. This shows approximately the steel weights of structures designed by the different formulas, expressed in percentage of the weights of spans designed under the present specifications. These curves are based on the assumption that the weights of trusses are closely inversely proportional to the allowable unit stresses and that the weights of the floors are practically constant. The results are, of course, roughly approximate, but it is believed that the curves give a fair idea of the effect on steel weights of the use of the several formulas mentioned. Referring to Fig. 7, it will be seen that the use of the proposed units of 18,000 and 15,000 lbs. leads to somewhat heavier structures than the present specifications for spans up to about 150 ft. in length and somewhat lighter structures for spans of greater length. At 300 feet the difference in weight is about 9 per cent., as shown in Fig. 8.

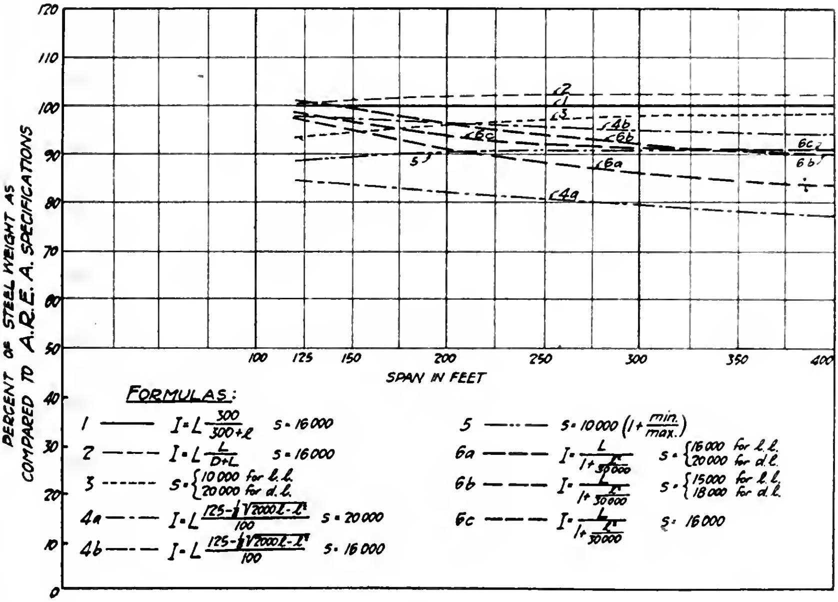
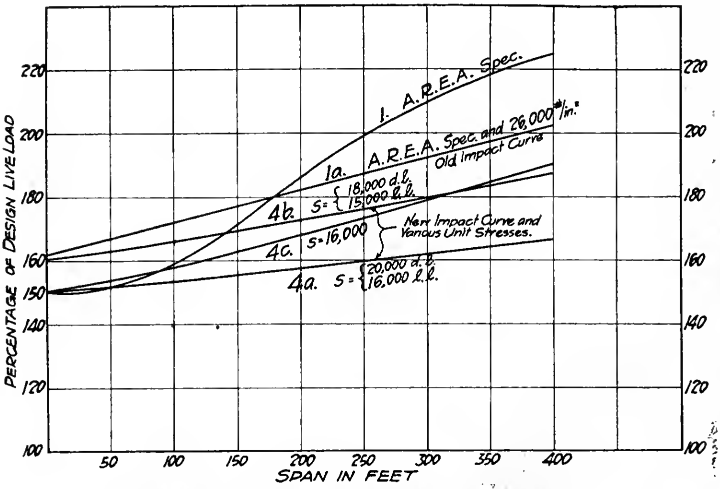


FIG. 8.

(7) COMPARATIVE EFFECT OF PRESENT SPECIFICATIONS AND PROPOSED FORMULAS ON THE CAPACITY OF A BRIDGE TO CARRY INCREASED LIVE-LOAD.

The life of a steel railroad bridge has for many years been limited by its capacity to carry a steadily increasing live-load. While future increase in load is not likely to be nearly so rapid as in the past, yet it can hardly be assumed that there will not still be a considerable increase in the future. Therefore, it is probable that the life of railroad bridges will in many future cases be determined by their capacity to carry an increased load. Such being the case, some attention should be given to the question of the effect of an increase of live-load beyond that specified, upon the stresses in the various parts of the structure.

Under over-load conditions it is good practice to allow, under careful supervision, a considerable increase in total stress over the allowable stresses for new structures, and many bridges are operated under these conditions for long periods of time before they are replaced. Under favorable conditions the recommended practice of this Association is to



. MAXIMUM LIVE LOAD CAPACITY OF CHORD MEMBERS OF BRIDGES WHEN DESIGNED ACCORDING TO VARIOUS FORMULAS. BASED ON NEW IMPACT CURVE AND 24,000 LBS. MAX. STRESS.

FIG. 9.

consider a maximum stress of 26,000 lbs. per sq. in., on the basis of the regular impact formula, not in itself cause for immediate action to replace the structure or to modify traffic. If the proposed impact formula be used, it is believed that a maximum stress of 24,000 lbs. per sq. in. would correspond very well with the present practice of 26,000 lbs. This figure would give slightly less capacity to short spans and slightly greater capacity to long and heavy spans than present practice.

On the basis of a maximum stress of 24,000 lbs. per sq. in., the over-load capacity of various span lengths has been approximately calculated and represented in Fig. 9. In this diagram the over-load capacity is expressed in terms of the percentage which the maximum allowable live-load, under an assumed stress of 24,000 lbs. per sq. in. in chord members and flanges of girders, will bear to the specified live-load, adopting the proposed impact formula as representing the true impact. Web members have not been considered in this diagram, but if loaded length is used for web member impact, these members will be somewhat heavier relatively than chord members.

Curve 1 represents the over-load capacity for structures designed under present specifications. Curves 4, (a), (b) and (c), represent the capacity when designed on the basis of the proposed impact formula, and using various unit stresses as indicated on the curves. Curve 1 (a) shows results obtained according to present methods of calculation, using 26,000 lb. per sq. in. as the maximum allowable stress.

This diagram shows clearly how the over-load capacity of structures varies with the span length, and, further, that under present specifications this capacity ranges between a minimum of about 150 per cent. to a maximum of over 220 per cent.

The increased capacity of the longer span is, of course, due to the fact that the dead-load unit stress is in all cases considerably below the maximum allowable stress of 24,000 lbs. per sq. in. If the dead-load stress were made 24.000 lbs., the over-load capacity of all spans would be the same, and would be equal to the ratio of 24,000 lbs., divided by the live-load unit stress.

In applying this information to the problem in hand, it would appear to be wise and proper that longer spans should have a somewhat greater over-load capacity than short spans on account of greater expense involved in replacement, and generally the more difficult conditions to be met with in other ways. It is also probably true that the over-load capacity of plate girders is actually somewhat greater than here assumed on account of the greater simplicity of these structures, smaller secondary stresses and a smaller element of uncertainty in various details.

The over-load capacity of a bridge should also be studied in other ways. In order to utilize a structure to the highest degree of economy under over-load conditions, all parts of the structure should reach their over-load capacity at about the same time, that is, should have about the same over-load capacity. Under present specifications this is far from true. Truss members in which the dead-load stress is relatively large will have a greater capacity than those members, such as hangers and floor members, where the dead-load stress is small.

By reference to Fig. 9 we find, for example, that under present specifications the capacity of spans of 50 feet and less, corresponding to floor members, is about 150 per cent., while for chord members in trusses of 200-foot spans it is about 185 per cent., and for 300-foot spans it is about 210 per cent. For working stresses of 18,000 and 15,000, using the proposed impact formula, the capacity of floor members and hangers is about 162 per cent., and of truss members of 200-foot spans 172 per cent., and 300-foot spans 180 per cent. The use of the units 20,000 and 16,000 gives capacities varying from 150 per cent. for floor members to about 162 per cent. for chords of 300-foot spans. This gives the most uniform results of all.

It may therefore be concluded that the use of a relatively high dead-load working stress will lead to structures of a more uniform strength than present practice, and that the margin of safety for increasing live-load will be better distributed by giving attention to the live-load and the live-load working stress. If the specified live-load is taken high, so that future increase beyond that specified is practically eliminated, then the working live-load stress may also be taken high; if future increase is quite certain to go beyond the specified load, then the live load stress should be taken lower. There is no reason, however, why the dead-load stress should not be the same in both cases. Present practice of engineers includes both of these methods. In the design of very large and costly structures it is not uncommon to assume a very heavy live-load, such as E-80 or E-90, which will never be exceeded, and then to use high unit stresses such as would be suitable for dead-load alone. On the other hand, the practice of most engineers in the design of ordinary structures is fairly represented in this respect by present specifications, which contemplate a moderately heavy specified load, but at the same time one which can be very considerably increased (and will probably be actually so increased) without endangering the structure.

The Committee is of the opinion that, on the whole, a better balanced design would result by the adoption of approximately such units as 20,000 and 16,000, together with some increase in specified live-load if the resulting structures would otherwise be too light to meet future conditions. If, however, such a change in unit stress, involving as it does an increase in average value, is undesirable, about the same relative effect would be secured by the use of somewhat lower values, such as 18,000 and 15,000, as suggested.

The Committee has endeavored here to present the elements of this problem, deferring definite recommendations until opportunity is given for full discussion.

WORKING STRESSES FOR COMPRESSION MEMBERS.

The working stresses herein discussed are intended to apply only to tension members. In the opinion of the Committee the base unit stress for compression members acting as long columns may well be made less than for tension members. In long columns the elastic limit is practically the ultimate strength, while in tension members a considerable margin of strength remains beyond this limit. However, until the results of the tests now in progress are available, it would seem unwise to attempt to go into this subject at length, and the Committee, therefore, presents no discussion of this question.

Respectfully submitted,

F. E. Turneaure,
C. L. Crandall,
Albert Reichmann,
A. F. Robinson,
A. C. Irwin,
Sub-Committee on Impact.

Appendix F.

POWER INPUT OF TRACTOR OPERATED TURNTABLES.

By B. R. Leffler,

Bridge Engineer, New York Central Railroad, West of Buffalo.

Some time ago the writer had some tests made of the power input of turntables. All tables were equipped with electric tractors. A self-recording Esterline wattmeter was used.

The results are shown on a tabulation herewith. The graphical records for items 1, 2, 3 and 6 are shown. The records are typical except that for direct current the curve is quite smooth.

For the curves the ordinates represent kilowatts, and the abscissa time in seconds.

The tables were first accelerated through a period of about 15 seconds to a uniform rotation and then turned several times through 360 degrees. The various loads are shown in column 6.

Columns 1 to 6 inclusive and 13 are field data. The remainder of the columns are obtained by calculation.

The table in item 1 had a new center and tractor. This equipment was in excellent condition. Without the tractor attached, one man, by lightly pushing the table through an arc of 20 feet along the pit wall, caused the empty table to make a rotation of 360 degrees under its own momentum.

The center of the table in item 2 was lubricated with graphite grease. The table had been in use six months.

The disk in item 6 ran in oil. The table had been in use about four years.

The tractor in item 7 had been in use about eleven years, and the center about five years. The tractor was barely sufficient to do the work. The center was not in good shape. This item may be taken to represent a poor and inefficient equipment.

It is well to state a few mechanical ideas. Work equals force times the distance through which the force is applied; it is usually expressed in foot-pounds. Power equals the work divided by the time through which the work is done. It is thus seen that power involves three fundamental ideas; namely, force, distance and time.

Closely, a kilowatt is work done at the rate of 44,000 foot-pounds per minute.

In column 9, the numbers multiplied by 44,000 will give the work done for a full rotation of the respective loads. The numbers multiplied by cost of power per kilowatt minute will give the cost of the various rotations.

We will discuss item 1. As already noted, the table has an easy-running center. One man turning the empty table would not exert more than 0.18 kilowatt. Since it took 1.8 kilowatt, the tractor loss was 1.62 kilowatt. The number in column 10, namely 1.62, is roughly the kilowatt minutes (losses of combined tractor and empty table not counted) required to turn through 360 degrees the total locomotive weight of 707,000 lbs. The number is gotten by subtracting from 6.931 three times 1.77. The other numbers in column 10 were obtained in a similar way.

In calculating column 10 it was assumed that the losses in the tractor would be the same for the loaded table as for the empty table. The losses due to engine loads would then appear mostly in the center. This is only approximately true, as the increased current in the tractor affects the electric losses. An increase in the pull of the tractor also increases the frictional losses in the tractor. The figures in column 10 are only rough approximations.

A graduated spring balance placed between the tractor and the table would have shown the tractor pull. Knowing this pull the tractor losses in the center could have been respectively determined. On account of complications, this was not done.

It should be seen that columns 7, 9 and 10 represent frictional and electric resistance losses only since the tables were rotating uniformly.

Column 11 may be taken to represent the relative efficiencies of the various combined tractors and tables. The relative losses of tractor and center are not seen. The number, 156,000 for item 1, is gotten by dividing 1,088,000 by 6.931. Column 12 represents, roughly, the relative efficiencies of the centers. The number 437,000 for item 1 is gotten by dividing 707,000 by 1.62.

The numbers for the other items are similarly obtained, as explained for item 1.

An examination of column 12 shows that the roller centers for items 1 and 4 are nearly equally efficient. Likewise for the disk centers, items 2 and 6.

The disk centers are about 23 per cent. as efficient as good roller centers. Comparing the numbers in column 11, it is seen that on account of the large tractor losses, the efficiency of the combined disk and tractor is about 43 per cent. of that of a roller center and tractor.

For the remaining items, the efficiencies of the centers, and of the tractors are low.

Item 7 shows that a combination of a poor roller center and a poor tractor may have a lower efficiency than a combination having a disk center.

It is evident that the application of power to turntables is a field for improvement.

The present method of attaching a tractor to the end of a turntable is wrong in principle. All of the inherent resistances of the tractor are overcome through the long path of the circular pit rail. This means the expenditure of a large number of foot-pounds of work.

The writer has seen an attempt made to turn a table by hand with the tractor attached; it was impossible to do it.

The writer suggests the following: Place the motor and a train of gears upon the table. The pinion gear should mesh with a circular rack which is securely fastened to the center. The arrangement would then be similar to that for a swingbridge. An objection is the possible accumulation of ice and dirt on the rack. Any resistance at the circular rail, such as an unbalanced locomotive, would be multiplied at the circular rack. The objections can be largely overcome by proper construction, maintenance and operation of the table.

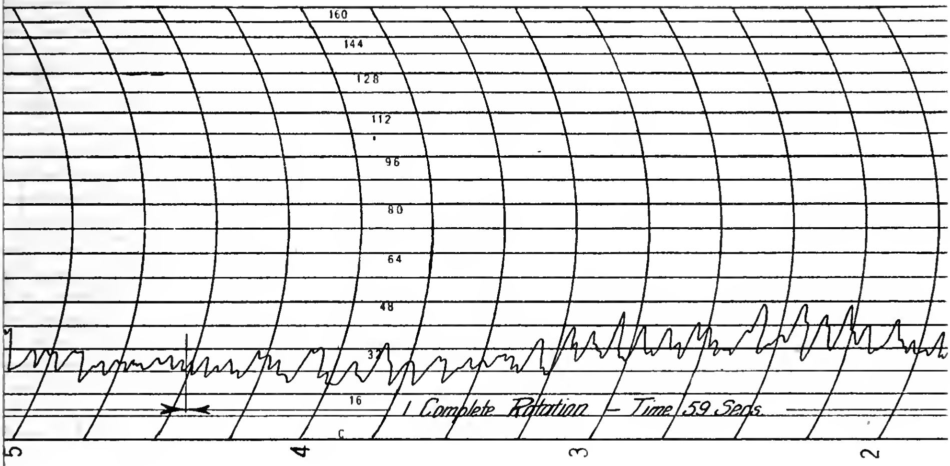
With improved power installation and careful operation of the table, it should be practicable to turn a 200-ton engine at a cost of one-eighth of a cent if the cost of power is four cents per kilowatt hour. This is about one-third to one-half of the present cost.

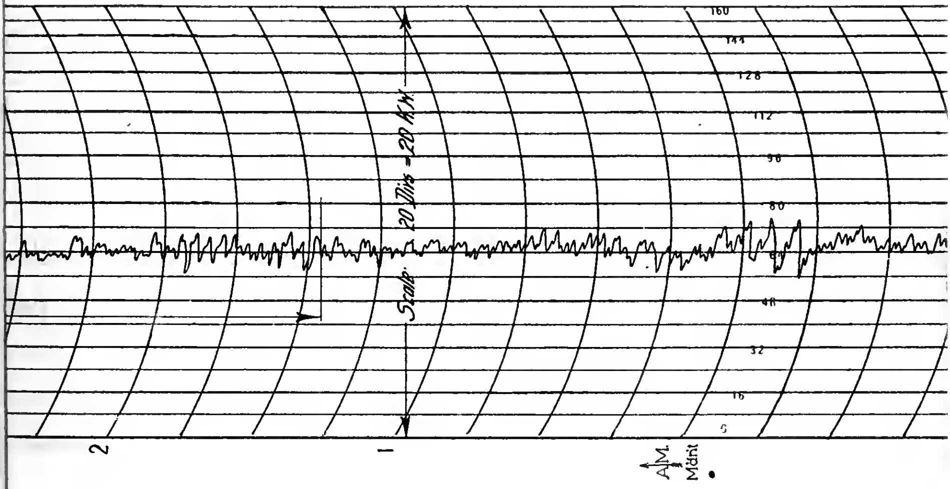
The writer is indebted to Mr. C. S. Albright, Electrical Engineer, and assistants, who installed the wattmeter and took the records.

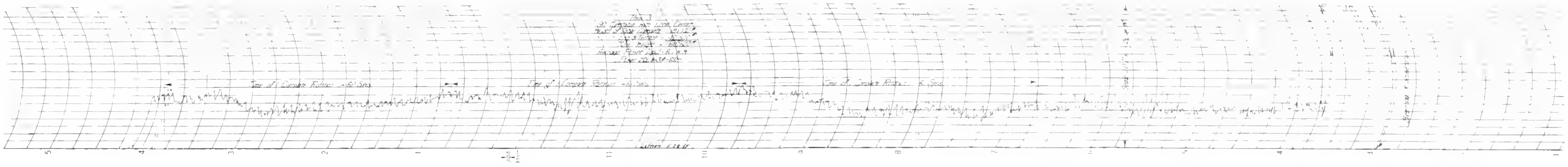
TURNTABLE TESTS BY BRIDGE DEPARTMENT - NEW YORK CENTRAL RAILROAD.

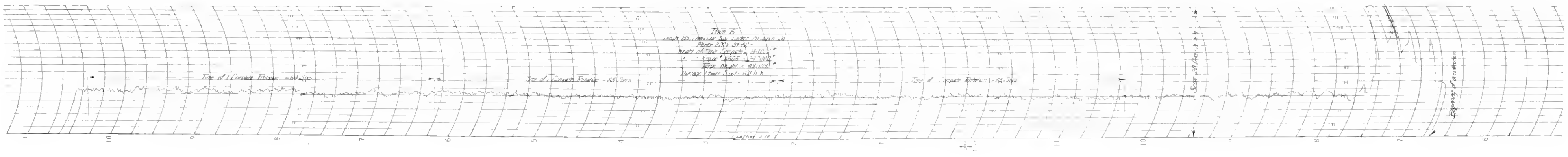
Date of Test 1	Length of Table in Feet 2	Type of Center 3	Weight of Table in Pounds 4	Weight of Engine on Table in Pounds 5	Total Weight 6	*Power Input in K. W. Table not accelerated 7 K	Time of Complete Rotation in Seconds 8 S	Gross K W Minutes 9 $\frac{K \times S}{60}$	Total Net K. W. Minutes for Locomotives only; losses for Tractor and Table eliminated 10	Numbers showing relative efficiency based on total power input 11 (6)÷(9)	Numbers showing relative efficiency based on Net Power for Locomotives only 12 (5)÷(10)	Kind of Power 13
(1) 7-15-14	85'	Cone Roller	127000	......	127000	1.8	59	1.77				220V-3φ-60~
"	"	"	"	324500	451500	2.3	59	2.261				"
"	"	"	"	382500	509500	2.95	59	2.90				"
				707000	1088000			6.931	1.62	156000	437000	
(2) 7-21-14	90'	24"Flat Disc	166000	......	166000	4.25	61	4.32				440V-3φ-25~
"	"	"	"	304500	470500	6.75	62	6.98				"
"	"	"	"	423700	589700	8.0	62	8.27				
				728200	1226200			19.57	6.61	62700	109500	
(3) 8-31-14	90'	Cone Roller	181100	......	181100	4.1	62	4.24				220V-3φ-60~
"	"	"	"	336000	517100	5.75	62	5.94				"
"	"	"	"	421500	602600	6.1	61	6.20				"
				757500	1300800			16.38	3.66	81800	206000	
(4) 8-10-14	90'	Cone Roller	181100	......	181100	3.0	44	2.20				110 - D.C.
"	"	"	"	220000	401100	3.4	49	2.78				"
"	"	"	"	293900	475000	3.25	49	2.65				"
"	"	"	"	336000	517100	3.6	51	3.06				"
				849900	1574200			10.69	1.89	147300	448000	
(5) 8-13-14	70'	Cone Roller	115000	......	115000	2.25	48	1.80				220 - D.C.
"	"	"	"	220000	335000	2.6	54	2.34				"
"	"	"	"	380000	495000	3.1	62	3.20				"
				600000	945000			7.34	1.90	128000	316000	
(6) 9-9-14	85'	20" Lenticular Disc.	144000	......	144000	2.95	60	2.95				220 - 3φ-60~
"	"	"	"	155000	299000	4.9	59	4.82				"
"	"	"	"	347000	491000	6.3	65	6.83				"
"	"	"	"	373000	517000	6.5	61	6.60				"
				875000	1451000			21.20	9.40	68500	93000	
(7) 9-14-14	85'	Cone Roller	124183	......	124183	4.9	85	6.94				220V-3φ-60~
"	"	"	"	210300	334483	5.75	85	8.15				"
"	"	"	"	423700	547883	6.3	85	8.93				"
				634000	1006549			24.02	3.20	41700	199000	

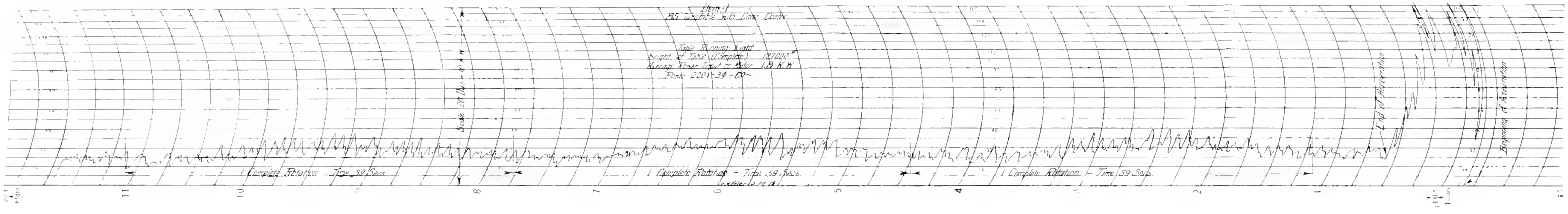
*For any table and its load, the maximum power for starting and accelerating the table through the first fifteen seconds is about three to four times the power shown in this column. This column shows the average power input for the table after it has been started and accelerated, and hence is rotating at a uniform velocity.


160
144
128
112
96
80
64
48
32
16
c
1 Complete Rotation – Time 59 Secs.
5
4
3
2

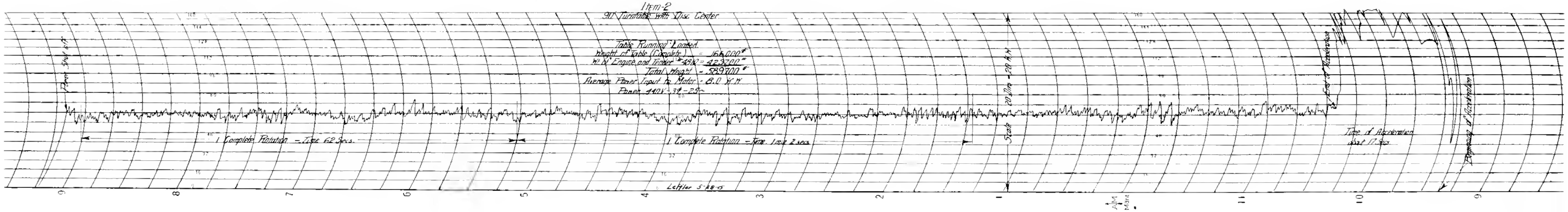

160
144
128
112
96
80
64
48
32
16
5
Scale 20 Divs = 20 K.W.
2
1
A.M.
Midt


Trip 3
Average Power Load - 6_ H.P.
Time of 1 Complete Running - 60 Secs
Time of 1 Complete Running - 65 Secs
Time of 1 Complete Running - 6_ Secs
5
4
3
2
1
11
10
9
8
7
6
5
4
3
1


Trip 6
Height of Tape Complete
Total Height
Average Power Load - 63 H.P.
Time of 1 Complete Running - 60 Secs
Time of 1 Complete Running - 65 Secs
Time of 1 Complete Running - 6_ Secs
1
10
9
8
7
6
5
4
3
2
1
10
9
8
7
6



Item-1
85' Turntable with Cone Center
Table Running Light
Weight of Table (Complete) 127000#
Average Power Input to Motor 1.8 K.W.
Power 220V-3Φ-60~
Scale 20 Div. = 10 K.W.
1 Complete Rotation - Time 59 Secs.
1 Complete Rotation - Time 59 Secs.
1 Complete Rotation - Time 59 Secs.
Leffler 5-28-15
End of Acceleration
Beginning of Acceleration
11
10
9
8
7
6
5
4
3
2
1
Noon
11



Item-2
90' Turntable with Disc Center
Table Running Loaded
Weight of Table (Complete) = 166,000#
Wt of Engine and Tender "4310" = 423700#
Total Weight - 589700#
Average Power Input to Motor - 8.0 K.W.
Power 440V-3Φ-25~
Power Shut off
1 Complete Rotation - Time 62 Secs.
1 Complete Rotation - Time 1 min 2 secs
Scale 20 Div. = 20 K.W.
End of Acceleration
Time of Acceleration about 17 Secs.
Beginning of Acceleration
Leffler 5-28-15
9
8
7
6
5
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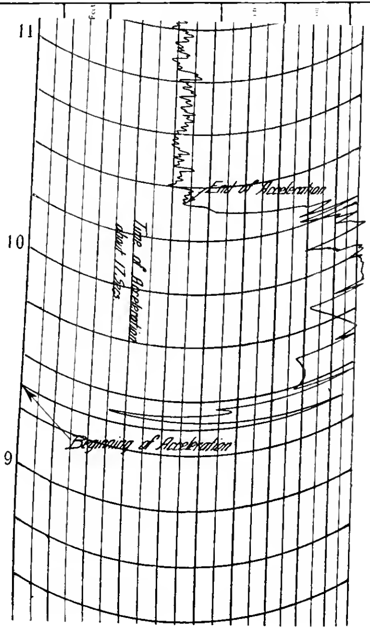
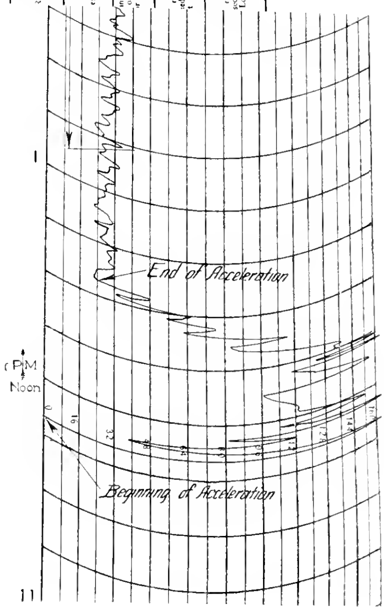
3
2
1
Mdnt
11
10
9

TURNTABLE TESTS BY BRIDGE DEPARTMENT - NEW YORK CENTRAL RAILROAD.





Appendix G.

"ADAPTATION OF DESIGNS OF MOVABLE BRIDGES TO SIGNAL AND INTERLOCKING APPLIANCES REQUIRED."

The information on the above subject prepared by the writer for presentation to the Committee on Iron and Steel Structures was not ready in time for adoption by the Committee, but the gist of the information was presented verbally to the convention in March, 1915.

At a recent meeting of the Committee it was deemed desirable to present the matter to the members in the Bulletin, in order that there might be written discussion in advance of the next convention; the writer was therefore requested to prepare the information and submit it to the Association for such publication.

The report as prepared and the verbal discussion at the convention are printed on pages 1098 to 1105, inclusive, of the Proceedings of the American Railway Engineering Association for 1915. They are reprinted in the following pages for convenient reference. As a result of study given the subject, the writer has recommended that the conclusions as outlined on pp. 274 and 275 of this Bulletin be adopted.

The entire matter is now presented to the membership in the hope that the members will participate in a thorough written discussion, in order that it may be disposed of by the Committee and the Association.

Respectfully submitted,

C. E. Smith,
Chairman, Sub-Committee.

RAIL-END CONNECTIONS FOR DRAWBRIDGES.

(Reprint from Proceedings, Vol. 16, pp. 1098 to 1105.)

Many early drawbridges had continuous rails spiked down on the approaches and on the drawspan, the rails being connected over the openings at the ends by ordinary angle bars or fish plates which were removed and replaced by hand. Later, on account of the burden of delay due to handling the angle bars or fish plates, the draw rails were extended a short distance onto the approaches and supported on shoes designed and placed to hold the ends of approach and draw rails in line and to hold the ends as close together as practical, the space being usually intended as not more than 2 inches.

The latter made it necessary, in order to turn the draw, to raise the overhanging ends of the draw rails a sufficient distance to clear the shoes and other obstructions. As the movable rails could not be spiked down, or otherwise permanently fastened, they were supported by shoes or troughs of various designs to hold them in proper position and were held to gage by connecting bars, there being many such bridges in service at present. The openings at the bridge ends caused objectionable pounding, leading to rapid deterioration of the rails and their supports as well as the structural work at the ends of the bridge. Efforts to eliminate this pounding and to secure a firmer connection led to great diversity of practice in the use of mitered rail ends, easer bars, and pointed rails resembling switchpoints. The special construction and arrangement of the rail-end connections created points of special hazard and received the early attention of Signal Engineers.

There has not been in the past and is not at present any accepted standard method of arranging rail ends of movable bridges. Both mitered rails and square-end rails with easer bars have given entire satisfaction and entire safety on heavy traffic lines when properly maintained, while on the other hand, both designs have caused trouble when not properly maintained.

In 1906, the General Manager of the Pennsylvania Lines West, desiring to ascertain the then present "state of the art," appointed a Committee consisting of J. C. Bland, Engineer of Bridges, and W. McC. Grafton, Signal Engineer, to investigate and report. Part of their report follows:

"We interviewed the officers of the following named railroads, the following Consulting Engineers and Bridge Companies, and visited certain bridges to see the devices in working order:

"East of Pittsburgh:

"The American Bridge Company, Pittsburgh; the Union Switch & Signal Company, Swissvale, Pa.; Pennsylvania Railroad; Pennsylvania Steel Company, Steelton, Pa.; New York Central & Hudson River Railroad; the New York, New Haven & Hartford Railroad, New Haven, Conn.; Boston & Maine Railroad, Boston, Mass.; Theodore Cooper, Consulting Engineer, New York City; Boller & Hodge, Consulting Engineers, New York City; the American Bridge Company, New York.

"*West of Pittsburgh:*

"The Lake Shore & Michigan Southern Railway, Cleveland, Ohio; the Strauss Trunnion Bridge at Cleveland; the Toledo-Massillon Bridge Company, Toledo, Ohio; all the drawbridges over Maumee River at Toledo, four in number, which included our own bridge; the Michigan Central Railroad, Detroit, Mich.; our Strobel Retractile drawbridge at Delphos; E. C. Shankland, Consulting Engineer, Chicago; C. L. Strobel, Civil Engineer, Chicago; R. Modjeski, Consulting Engineer, Chicago; the Scherzer Rolling Lift Bridge Company, Chicago; the Rock Island Railroad; the Chicago & Eastern Illinois Railroad; the Chicago & Western Indiana Railroad; the Chicago, Milwaukee & St. Paul Railway; the Chicago & Northwestern Railway; the Atchison, Topeka & Santa Fe Railway; the drawspan at Peoria on the Toledo, Peoria & Western Railway; the drawbridge at Rock Island, Ill., on the Chicago, Rock Island & Pacific Railway; all our own drawbridges, viz., those around Chicago; one at Louisville; one at Zanesville, Ohio, and one at New Comerstown, Ohio.

"The 'state of the art' is as follows:

"*Type I—Rails Lifting; Revolving Drawspans:*

"The rails at end of the bridge are free to move vertically for a length of from 10 to 30 feet; they rest in chairs on the ties, or between angle irons forming a trough. The rails are held to gage by bridle rods. The joint in rails between shore rails and bridge rails is over the backwall, and at that point the rails rest in chairs or seats, the joints of rails being either square, mitered or halved. These movable rails are attached to the mechanism operating the end lifts or wedges, so that rails are lifted out of end seat in order that bridge may be revolved. There are two methods of managing these movable rails when lifted:

"Class A—The lifted rail is allowed to fall into its seat, and there rests merely by gravity.

"Class B—The lifted rail is pulled down by the mechanism to its place, and hence cannot be moved unless the end lifts are moved.

"Fully 90 per cent. of the revolving drawbridges are provided with attachments of this Type I, the older bridges being Class A as to managing the movable rails, the new bridges of Class B. Some few bridges also have the rails locked up with the signaling device.

"*Type II—Fixed Rails. Used in both Revolving Drawspans and for Bascule or Trunnion or any kind of Lift Bridge:*

"In this type the rails at ends of bridge are fastened firmly to the ties as in a fixed span. The rails where joining the shore rails are butt or square joints, and this joint occurs *over* the backwall in lift bridges, and immediately in *front* of backwall in swing bridges. There is a cast-steel coupler or slider attached to the bridge rail and when bridge is in place sliding forward to shore rails, the coupler or slider embracing the rails or sides and underneath. This slider or coupler has trunnions on each side, to which is attached the operating mechanism. When slider is in place the rails are fixed both vertically and laterally. In some five or six cases the operating mechanism of these couplers is locked up with signaling devices, so that clear signal cannot be given unless the coupler is 'home.' In the recent bridges, on the slider, outside the rail head, is a tread piece of hardened or tool steel, reversible and removable, acting as a 'Barschall' Rail Joint, in carrying the wheel treads over the open joint in main rails.

"This Type II rail lock is the standard on the Lake Shore & Michigan Southern Railway and on the Michigan Central Railroad. It was also used by John N. Ostrom in his swing bridge for the Wheeling & Lake Erie Railroad at Toledo, which was built in 1898, where it is used in connection with mechanical signals.

"This Type II is also used in the Strauss Trunnion bridge for the Wheeling & Lake Erie Railroad at Cleveland, Ohio. It is also used in our Bridge No. 443 over the Calumet River at South Chicago (Pittsburgh, Fort Wayne & Chicago Railway), where it is operated by power from center of bridge, and is interlocked with the signals.

"*Type III—Fixed Rails. Revolving and Vertically Moving Bridges:*

"In this type the end rails are fixed or spiked down to the ties as is the case in Type II, the joint in rails being square and occurring over the free space between end of drawspan and face of backwall. The ends of rails rest in cast or wrought chairs with lugs or guides outside of rail. There is a tongue of cast or hardened steel operating on outside of rail, between the rail and aforesaid lugs or guides. The operating mechanism is hence entirely outside of gage line of rails and is operated generally in connection with the end lifts of wedges.

"This Type III is used on our bridge on the Calumet Western Railroad, where it is operated by hand and with no interlocking or signals.

"A very good improvement is that the chairs or seats are of cast-steel, and the tongue of hardened tool-steel. The main rail is planed down to a width of about 2 inches at head, and the tongue is slightly beveled on top to take the wheel treads. This modified type is in use at the Rock Island drawspan at Rock Island, operated jointly by the United States Government and the Chicago, Rock Island & Pacific Railway. It is also to be used by R. Modjeski in his new drawspans at Portland, Oregon, for the Northern Pacific Railway.

"In a somewhat modified form it is in use at our Delphos drawspan (Pittsburgh, Fort Wayne & Chicago Railway). Also is used by the Santa Fe Railway in its quite recent drawspan over the Illinois River, where it is not interlocked.

"A modification of this Type III, which also presents features common to Type II, is in use at the drawspan on the Pennsylvania Railroad over Delaware River at Trenton. This device has a wedge action, and is operated from the shore span outward to the drawspan, which is unusual. It has been in use some six or seven years, acts well, but has been so poorly maintained that the rail tread is worn down so as to be useless as a rail joint.

"Drawbridges equipped with lift rail device of Type I, Class A, when not interlocked, we consider dangerous, because it is possible that rails may not be home (when end lifts are in place) and the operator have no knowledge of such fact. Drawbridges equipped with lift rail device of Type I, Class B (i. e. the rails pulled down to place) even when not interlocked, we do not consider dangerous *per se*, since, if for any reason the rails are prevented getting in place, the operator has knowledge of the fact by the working of his machinery. However, it might be possible to break the rail pulls and no knowledge of such conveyed to operator; also, the integrity of the device is so dependent upon perfect maintenance and operation that we consider the use of any device of Type I (either Class A or Class B) inadvisable, unless interlocked, and even then there is possibility of the movable rails being broken under traffic, and this really did occur on a Lake Shore & Michigan Southern bridge at Sandusky. Also, we do not consider the use of angle-iron guides for the movable rail, forming a trough as they do, at all desirable. They form, between rail head and angle, places where anything dropping or dragging from the train may lodge, wedge and so cause trouble.

"Drawbridges equipped with devices of Type II or Type III, we consider safe, even when not interlocked, provided telltales showing the several movements of pulling the end bridge latch; end lifts or wedges, and rail locks are shown in the operator's house. When interlocked, however, such devices are safe beyond peradventure.

RECOMMENDATIONS.

"In view of the uncertainties in devices of Type I, whether Class A or Class B, and considering as we do that the first essential of perfect safety is that rails be spiked down, i. e., that there is no stretch of loose or unspiked rail, we recommend that all our bridges be equipped at an early date with devices of Type III, preferring Type III rather than Type II, because all the operating members come on outside of rail, and hence nothing between gage line of rails to be harmed by trailing brakebeams or such like.

"We further recommend the use of the rail lock shown by the sketch attached, which is in all essentials the one used by R. Modjeski at his Rock Island drawspan, and to be used for his new Portland drawspan. This is a minor modification of the locks we have in use at our bridge over the Calumet River, South Chicago, and used in the Santa Fe bridge over the Illinois River.

"We also recommend that the rail locks be interlocked in case of all bridges which are frequently turned."

Since the above report the square-end rails with sliding tongues have been largely used, while extensive use has also been made of mitered rail ends. On account of the comparatively even and continuous surface offered by the mitered ends they ride more smoothly and quietly than the square ends, and the reduced pounding causes less wear and less danger of breakage than with the square ends. The mitered rails need not be loose, as they can be so supported as to be much more secure than switchpoints.

As the wearing surface of the easer bar or sliding tongue used with square ends must of necessity be outside the rail head, the bearing of the wheel tread is widened for a short distance through which the easer bar carries the wheel over the joint.

For the exact tire wear for which the top of the bar is adjusted there will be no lifting of the wheels; wheels with less wear must drop into the opening between the rail ends before coming down on the easer bar; wheels with greater wear strike the easer bar sooner and are lifted over the open space. In any case the weight is transferred from rail to bar to rail in a small fraction of a second; the resultant pounding rapidly wears down both rail ends and easer bar and causes hard noisy riding.

Among the roads using square-end connections with rails spiked down for the full length on the movable span and approaches and provided with sliding tongues or shoes are the following:

Atchison, Topeka & Santa Fe;
Boston & Maine;
Baltimore & Ohio;
Chicago Great Western;
Chicago, Milwaukee & St. Paul;
Chicago, Rock Island & Pacific;
Grand Trunk;
Illinois Central;

Lake Shore & Michigan Southern;
Lehigh Valley;
Michigan Central;
New York, Chicago & St. Louis;
New York, New Haven & Hartford;
Pennsylvania Lines West;
St. Louis & San Francisco.

The reports of these roads indicate that approximately four times as many roads use the sliding bar or easer outside the rail as those roads that use a sliding shoe of the Lake Shore type, completely enclosing the rail.

The Chicago, Milwaukee & St. Paul reported using sliding easer bars at the ends of a drawspan near a yard, but account of switch engines operating frequently over the bridge the moving parts were difficult to operate on account of accumulation of sand and debris, for which reason their use was abandoned and other arrangements made; similar troubles have been reported by other roads. The reports also indicate that this arrangement does not result in smooth riding.

Among the roads using mitered and lapped rail ends with rail lifts are the following:

Atlantic Coast Line;
Baltimore & Ohio;
Chicago & Northwestern;
Chicago, Milwaukee & St. Paul;
Central Railroad of New Jersey;
Philadelphia & Reading;
Illinois Central;
Seaboard Air Line.

The ends of these rails are bent and heads and flanges planed off so that the full webs and rail ends lap by 12 inches, giving practically a continuous bearing surface, the ordinary width of the rail head. The lift rails vary in length from 15 to 30 feet and are held to true gage by bridle rods at intervals and held in line by chairs consisting of individual or continuous troughs. The same style of miter rail is also used on a number of lift bridges on which the rails are spiked down for full length of movable and fixed spans.

Many roads still use lift rails with the ends cut square with nothing to hold them in line other than the chairs in which they rest, meeting the ends of the approach rails in chairs on the ends of the approach spans or backwall.

A slight departure from this, having the rail ends sawed off at an angle of about 30 degrees, is also in use.

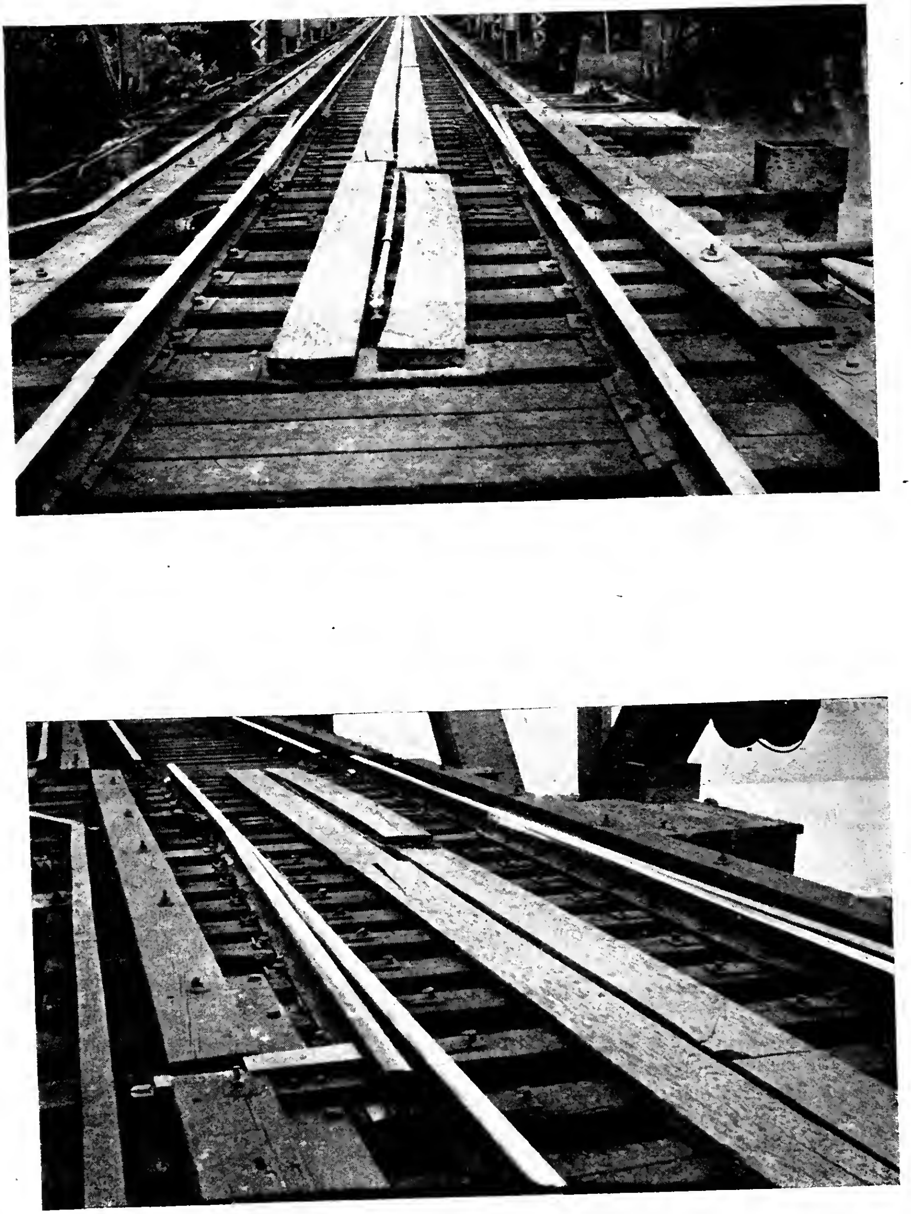
The miter rail used by the Pennsylvania Railroad (Lines East) has the ends sawed at an angle of about 45 degrees, but the space between lift rail and fixed rail on approach is bridged by a short stretch of fixed easer consisting of rail section planed to fit and bolted to the outside of the end of the fixed rail, overlapping the end of the fixed rail 18 inches and overlapping the end of the lift rail 12 inches.

On a number of lift bridges the outside of the rail head on the lift span is planed off for a length of 18 inches and an easer bar 30 inches long riveted to each lift rail with 12-inch overhang, which slides by and fits up against the end of the fixed rails on the approach spans.

The Long Island Railroad has in use long beveled rails similar to switchpoints, fitting against wing or stock rails on two drawbridges over 7½ years, carrying 400 to 500 trains daily; one double-track bridge with points trailing traffic in normal direction and one single-track bridge with points trailing traffic entering the drawspan. Guard rails are attached to the sides of the lift rails at each end of the bridge. The devices have never given any trouble. The lift rails are interlocked with the signal mechanism and report indicates that it is impossible to have the rail blocked or in any way out of place and get a clear indication of the signal.

Rail-Lock for Swingbridges, Nashville, Chattanooga & St. Louis Railway.

Perhaps the most complete rail end connection is a patented device in use on the Nashville, Chattanooga & St. Louis. It consists of switchpoints on the draw facing toward the end about 8 feet from the approach. The switchpoints are backed up by stock or wing rails which extend over the gap of 8 feet to the end of the draw and reach over onto the approach span, the square ends of the rails being held between angle bars in contact with the square ends of the approach rails. The stock or wing rails are withdrawn from the angle bars and driven into them by the rail-operating mechanism. The movable rails rest on bearing plates and are held to true position by screw spikes, eliminating the possibility of their movement laterally. This device was adopted after long experience with



Rail-Lock for Swingbridges, Nashville, Chattanooga & St. Louis Railway.

square ends, beveled rail lifts, easer rails, etc., and, if properly installed and maintained, is undoubtedly the safest of the rail-end connections.

There are various other types of rail-end connections in use, some of which consist of fixed easer bars similar to those already described but welded or forged onto the rail ends.

Where rail heads are planed off to fit easers it is customary to leave a width of head of 2 inches in the running rail, although in some cases the heads are planed off even with the face of the web, while in other cases the head is not planed at all. Unless the easer bars are made of special steel they will wear rapidly. Crucible steel, nickel steel and manganese steel have given good results.

Regardless of the type of rail-end connection, creeping must be absolutely avoided, either by use of sufficient anti-rail creepers or by inserting switchpoints in the track at proper places, the latter in every case being protected by guard rails against the opposite rail.

On account of the special joint at the rail ends special precautions must be taken in the design of the ends of approach spans and drawspans, particularly in the details, in order that the structural work may not be broken down under the unusual impact.

Special locks are used on lift spans for lining purposes, which locks cannot be driven home until the lift spans have reached the final position. On drawspans there are comparatively few departures from the well-known vertical end latch, which engages a casting on the bridge seat. While the end latches are very necessary for stopping swing bridges at nearly the correct position, they should not be relied upon to automatically line the bridges as is the present almost universal practice, but the end-lifting device should be so designed as to permit of more accurate lining.

Two special types of lock bars for drawspans were reported, but they appear entirely inadequate to remove any appreciable distortion of a long drawspan due to inequalities in temperature.

Comparatively few bridges are reported as having end-lifting devices so designed as to bring the bridge end to exact alinement. The information at hand indicates about equal use of toggles and sliding wedges for vertical adjustment. The bearing blocks and bed plates in connection with either arrangement can readily be provided with the necessary sloping surfaces to force the bridge ends to correct line. Either type lends itself readily for interlocking with the rail ends, the signaling and the operating machinery, as may be desired.

The practice as to interlocking the various parts of the bridge-operating mechanism each with the others and with the signals is far from standard, as widely different arrangements are reported by a number of different roads. In some cases the end-lifting mechanism and rail-operating mechanism are interlocked; in other cases directly connected. In some cases only the rail-operating machinery is interlocked; in others also the end-lifting mechanism. One road reports the sliding-rail sleeves connected up with the automatic signals, copper tongue on the side of one of the rail locks entering a forked contact on the approach span

Rail-Lock for Swingbridges, Nashville, Chattanooga & St. Louis Railway.

when the rail lock is driven home and automatically clearing the signal. In the reverse movement the signal goes to "Danger."

Illustrations accompanying the report show several designs of mitered rail-end connections and sliding sleeves, easer bars and wing rails, as well as several details illustrating the adaptation of the designs to interlocking.

DISCUSSION.

Mr. Himes:—Perhaps Mr. McDonald will describe the appliance Mr. Smith referred to.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—Mr. Smith has already described it as well as I could do. It has been in use on two drawbridges on our lines for about four years. On one of them we have about 60 trains a day. It was developed as a result of complaints on the part of the Signal Department, that they could not properly maintain the interlocking where square joints with easer rails were used. It was thought that the split rail raised up was not a safe device. Constant complaints from the Signal Department, coming through the management, drove us to some other device. It provides for the movement of a stock rail alongside of a split switchpoint. The split switchpoint is confined to the stock rail, by means of a permanent cuff. It cannot separate more than one-sixteenth of an inch, but allows easy longitudinal movement of the stock rail. There is no danger in using the splitpoints in the main line under these conditions. As soon as the stock rail is driven home into the socket prepared for it on the fixed span, a heel block is driven behind it by means of the interlocking which holds it in position. That heel block is of course necessary to keep the stock rail from coming out in case an engine should stop on the bridge and slip. Our attention was brought to its necessity on that very account. It is removed by the same lever which sets the danger signal.

I can only say that since we put it in about four years ago, our expenses for repairs have been very small. One was installed on a drawbridge 397 ft. in length and the other on a drawbridge 365 ft. in length, the latter being opened about three times a week and the former about three times a day.

Mr. Himes:—I would like to get into this discussion a paragraph from the book by F. E. Turneaure, J. B. Johnson and C. W. Bryan on "Modern Framed Structures," relating to end-lifting arrangements. I submit it for the purpose of placing before you a statement of the need for properly supporting the ends of a bridge:

"END LIFTING ARRANGEMENTS.—In the early designs for swing bridges very little attention was paid to the proper elevation of the ends of the arms when the bridge is closed; and even at this late day a great many important swing bridges are built by contractors with an utter disregard of the condition of the end supports. In fact, the majority of swing bridges have no provisions for lifting the ends whatever; while others have all kinds of makeshifts, which generally shirk their duty entirely. It is safe to say that in this country it is the exception to find a swing bridge where proper provision is made for raising the ends when the bridge is closed. It has been shown in Chapter XII, that if the ends are not raised we cannot obtain the conditions necessary for a beam continuous over three rigid supports. In other words, if the ends are not raised, we must, in our analysis for finding the stresses, make an assumption which will satisfy this condition of the ends under the extreme variations of temperature. Now, it is difficult to say just what this condition should be. Furthermore, if the ends are left free to hammer, under extreme variations of temperature, the ends may be thrown out of line so far as to cause derailment of a train coming on the bridge. In fact, a swing bridge, wherein no proper provision is made for raising the end, is a dangerous structure at all times."

Mr. A. W. Carpenter:—I think we ought to make some progress on this subject, and to get something into the Proceedings as adopted. I would therefore offer this motion, on the interlocking of the signal and bridge functions:

"The bridge operating functions shall be interlocked with the signal system in such a manner that none of the functions for opening can be performed until the signals have been set at stop indication and so that the signals cannot be set at proceed indication until all of the functions for closing have been completed.

"The bridge operating functions shall be interlocked with each other so that they must be performed in a predetermined order, both for opening and for closing."

Mr. Thos. S. Stevens (Santa Fe):—I would like to see that motion changed so that the home signals shall be put at stop, or that the signals shall be put to give the stop or caution indication. That is not a very good statement, though. We want one signal at stop, and that is really what is in interlocking parlance known as the home signal, and then there will be another signal some distance from that which will give the caution indication for that stop indication. I think it would be advisable to put the motion as requiring that the home signals shall display the stop indication.

Mr. A. W. Carpenter:—My understanding would be that you would have this clause read in this way: "Bridge operating functions shall be interlocked with the signal system in such manner that none of the functions for opening can be performed until the home signals have been set at stop indication."

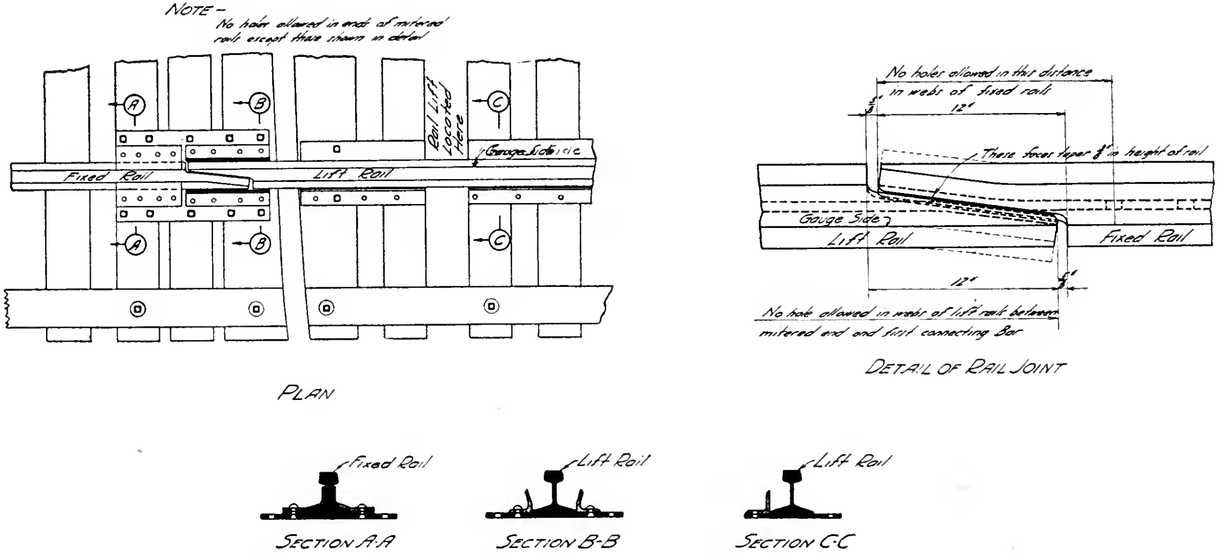
Mr. C. E. Lindsay (New York Central):—I think the case would be covered if we say "until the signals controlling the movement of trains over the draw have been set at stop indication."

Mr. A. W. Carpenter:—We will accept that.

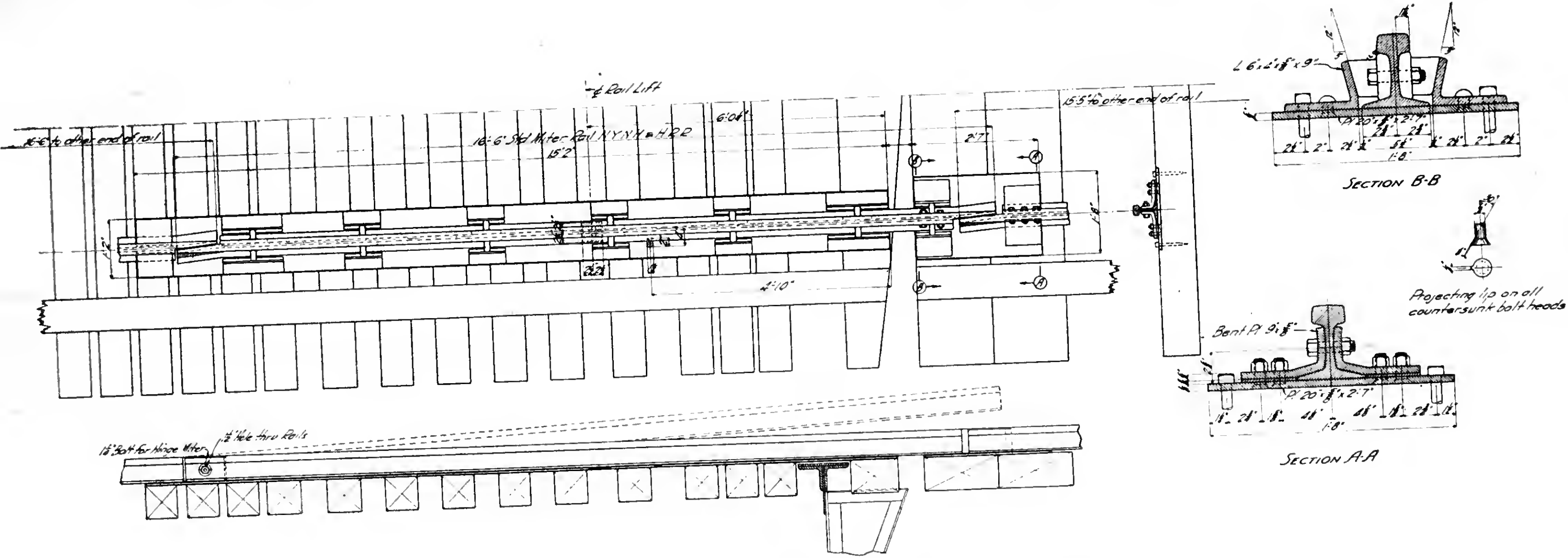
Mr. Thos. S. Stevens:—A caution indication controls movements over the draw just as much as the home signal indication does. I simply want to prevent confusion, because there will be signals which properly will be allowed to give a caution indication, which gives specific indications for the trains actually passing over the draw in the proceed indication. I think if the gentleman would use the words "home signal," it would cover the case entirely.

Mr. W. H. Elliott (New York Central):—Is Mr. Carpenter's motion made for the purpose of having the matter received as information or as a standard to be entered in the Manual? In my opinion it is important that anything that is to go in the Manual should be carefully considered so that there will be no misunderstanding as to its meaning, and if it is something to be formally adopted, I believe it should be held over for further consideration.

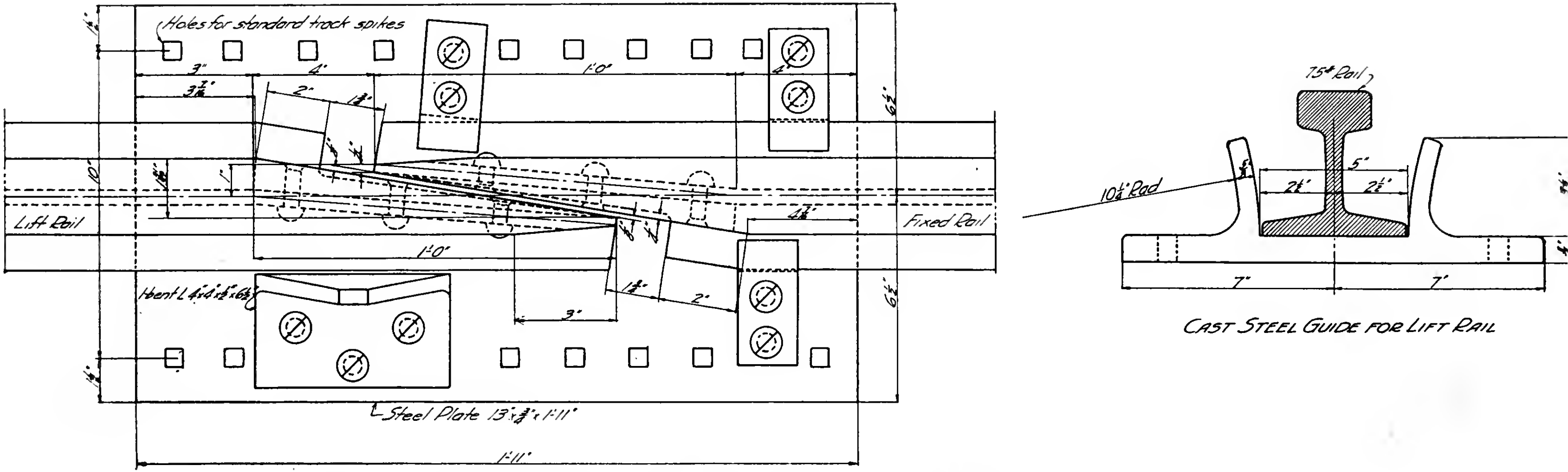
Mr. Loweth:—I would like to inquire whether the motion offered provides that all drawbridges shall be interlocked. If the intent of the motion is to interlock all drawbridges, it seems to me that it should not be approved, as there are many bridges for which there is no necessity of interlocking. The speaker knows of many drawbridges where there are not more than four to six trains daily, all unimportant, and where the bridges are opened but a few times each navigation season. In such cases, and there are many such, interlocking is certainly not necessary.



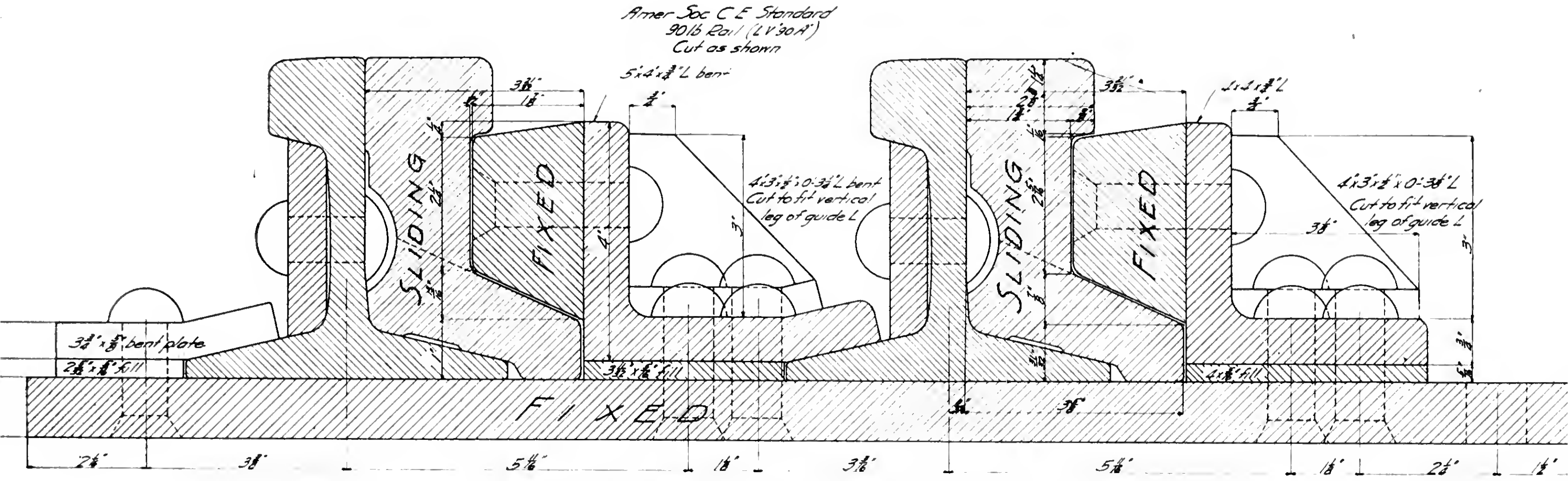
Mitered Rail for Single-Track Drawbridge. Atlantic Coast Line.



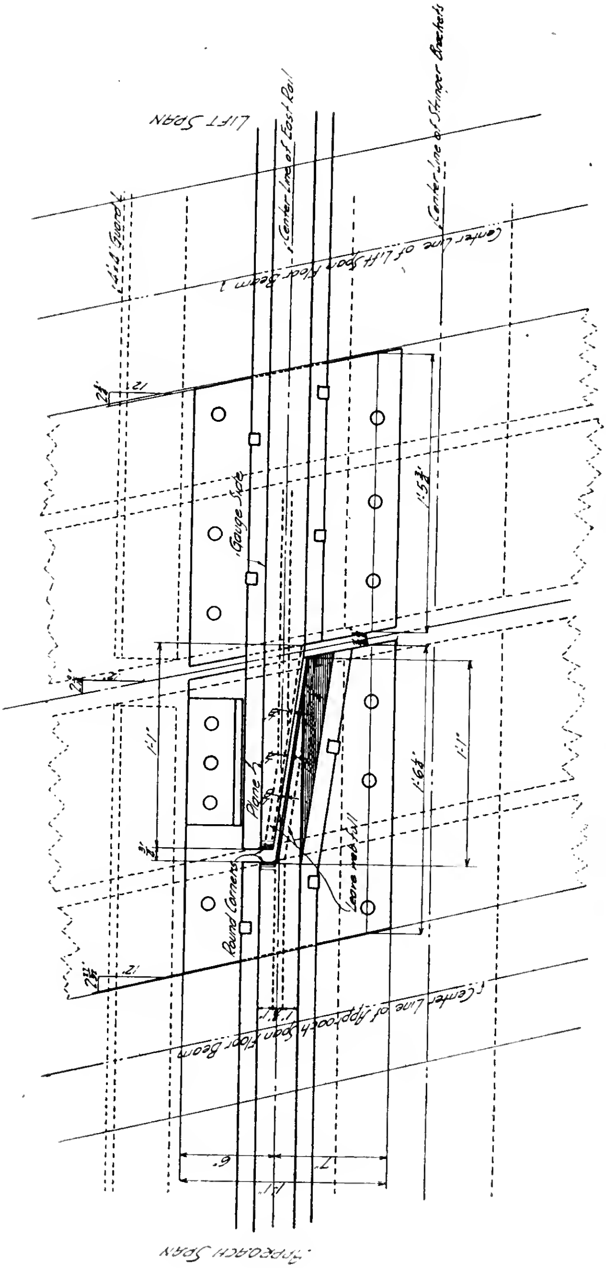
Lift Rail. New York, New Haven & Hartford Railroad.



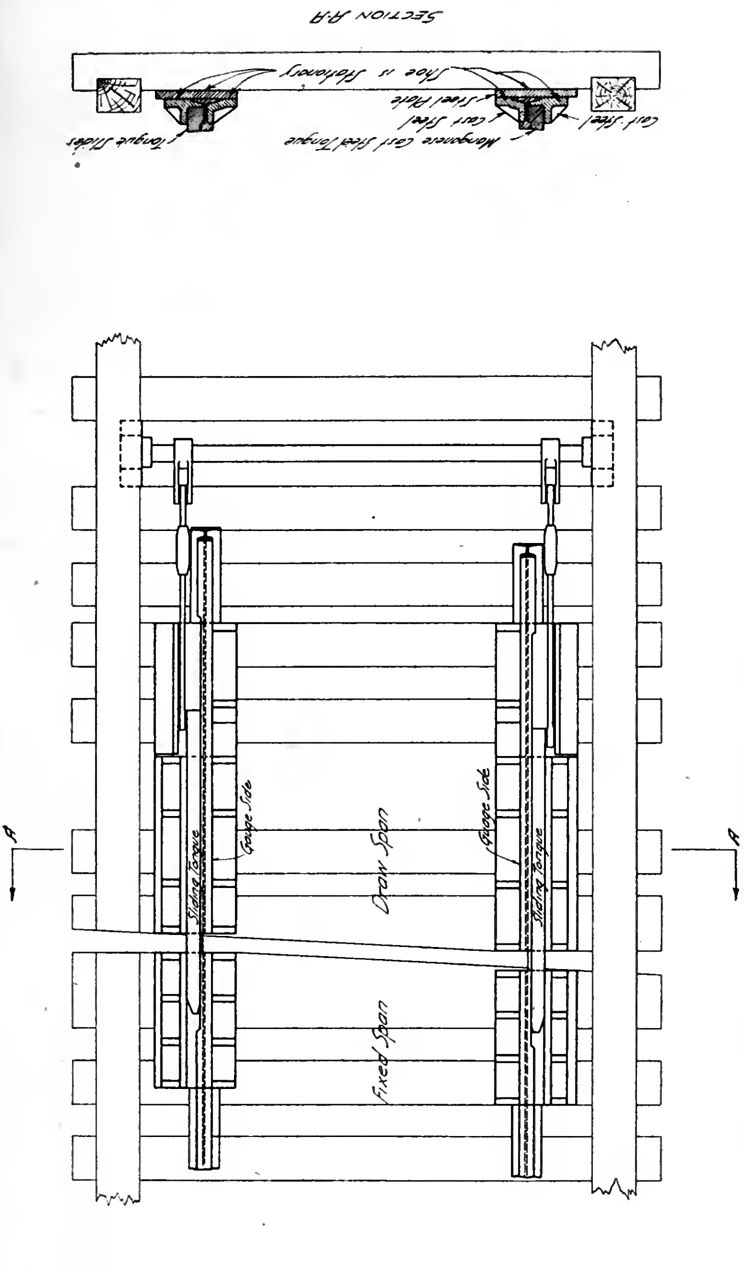
Lap Joint for Lifting Rails at Drawbridge Ends. Chicago, Milwaukee & St. Paul Railway.



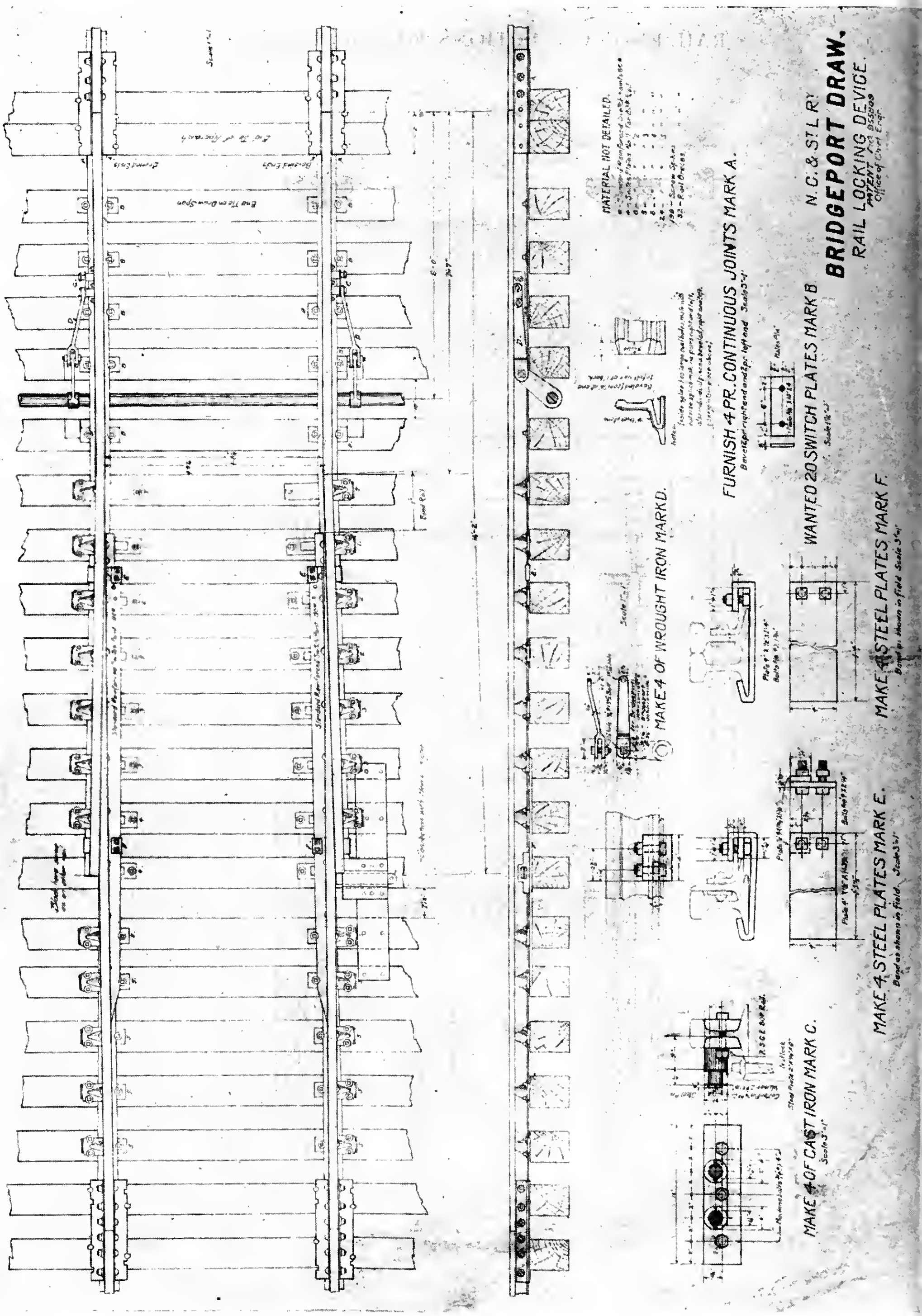
Rail-End Connections. Lehigh Valley Railroad.

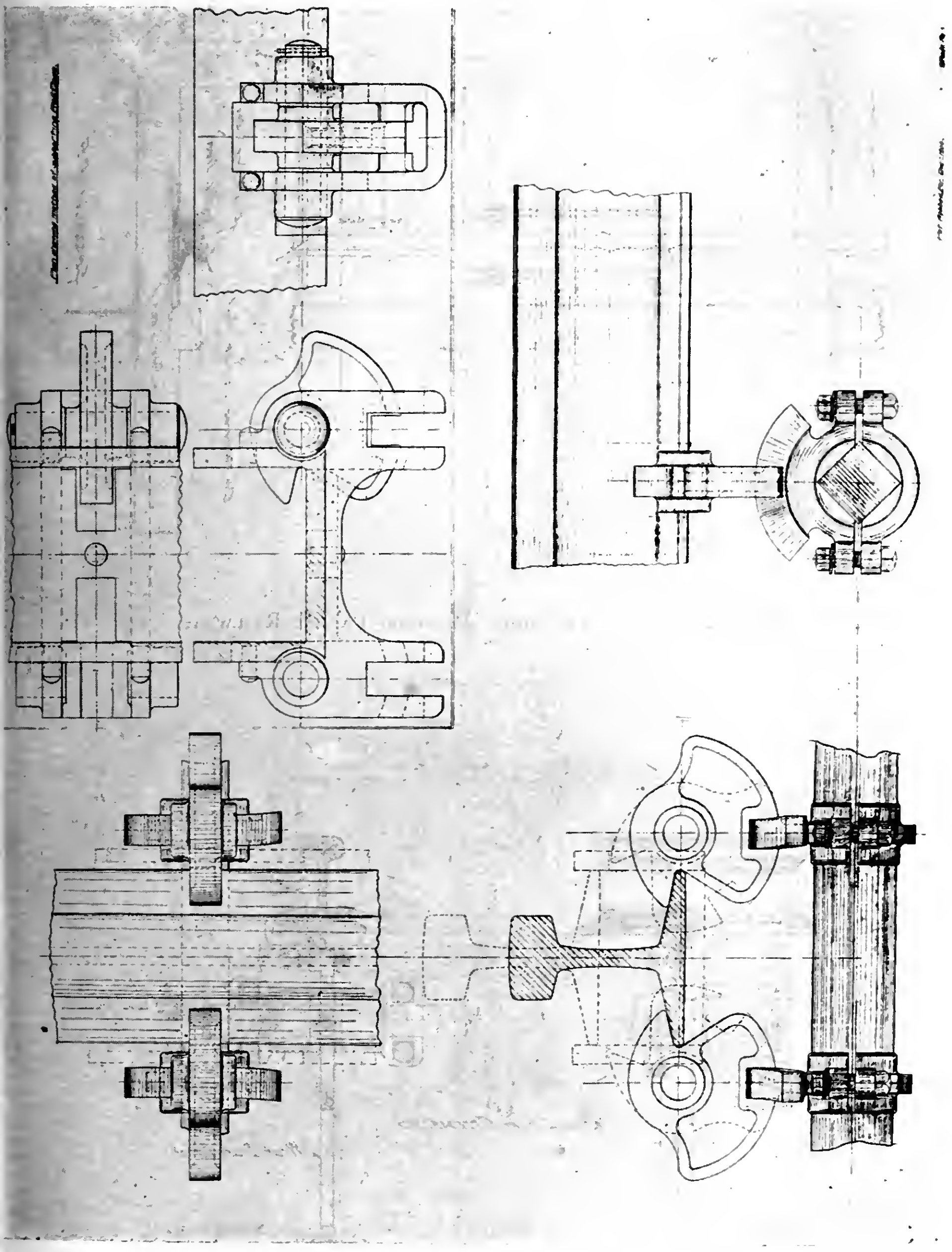


RAIL PLATES AND END RAILS. CHICAGO & NORTHWESTERN RAILWAY.

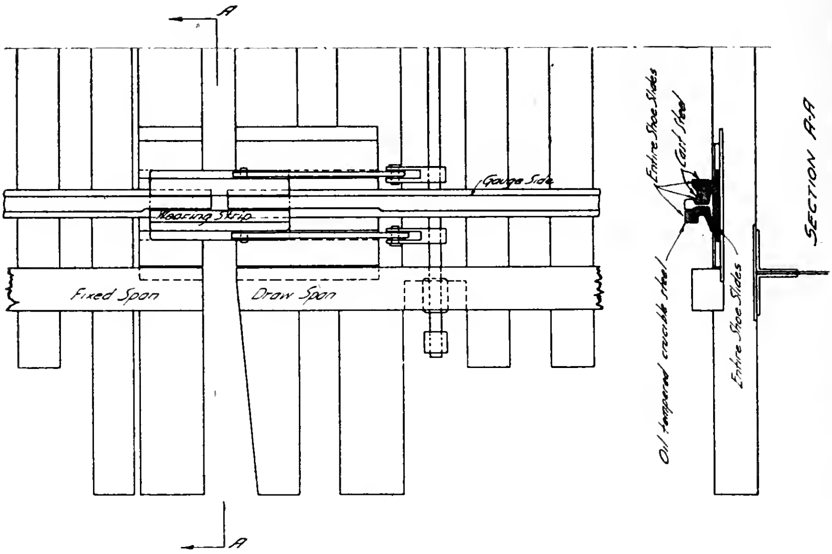


Rail Lock—Sliding Tongue. Missouri Pacific Railway.

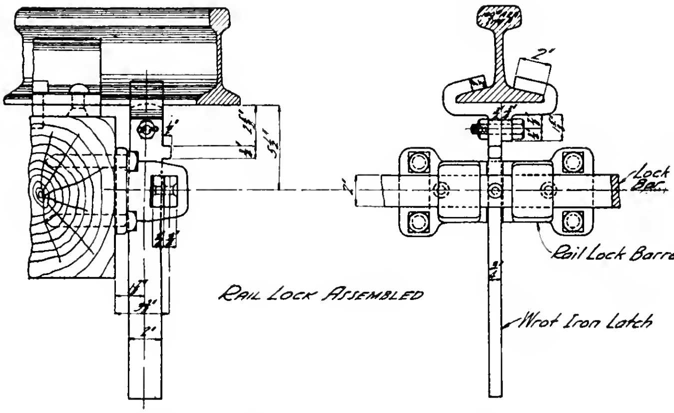

N. C. & St. L. Ry.
BRIDGEPORT DRAW.
RAIL LOCKING DEVICE.
Office of Chief Engr.
MATERIAL NOT DETAILED.
FURNISH 4 PR. CONTINUOUS JOINTS MARK A.
WANTED 20 SWITCH PLATES MARK B
MAKE 4 OF WROUGHT IRON MARK D.
MAKE 4 STEEL PLATES MARK F.
MAKE 4 STEEL PLATES MARK E.
MAKE 4 OF CAST IRON MARK C.
End Tie on Draw Span
End Tie of Approach
Bevelled Ends
End Rail
Standard Reinforced Joint



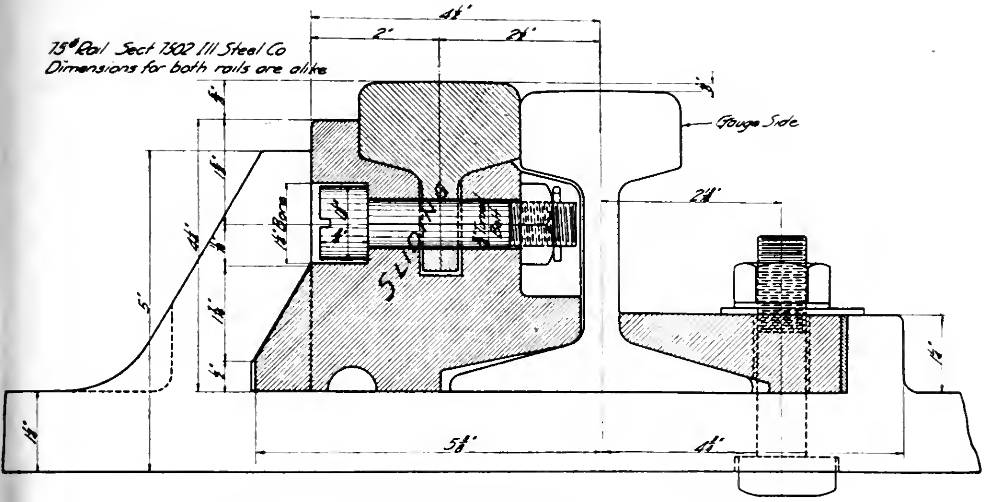
Plan Showing Arrangement of Drawbridge Lock.
Chicago Great Western Railroad.



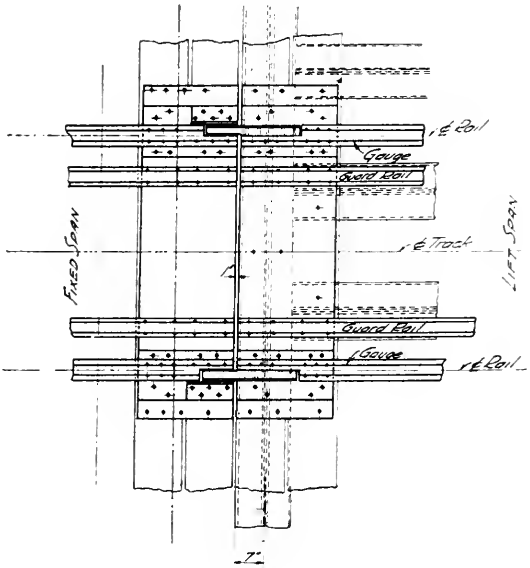
Rail Lock—Sliding Shoe. Missouri Pacific Railway.



Standard Drawbridge Locking. Central Railroad of New Jersey.

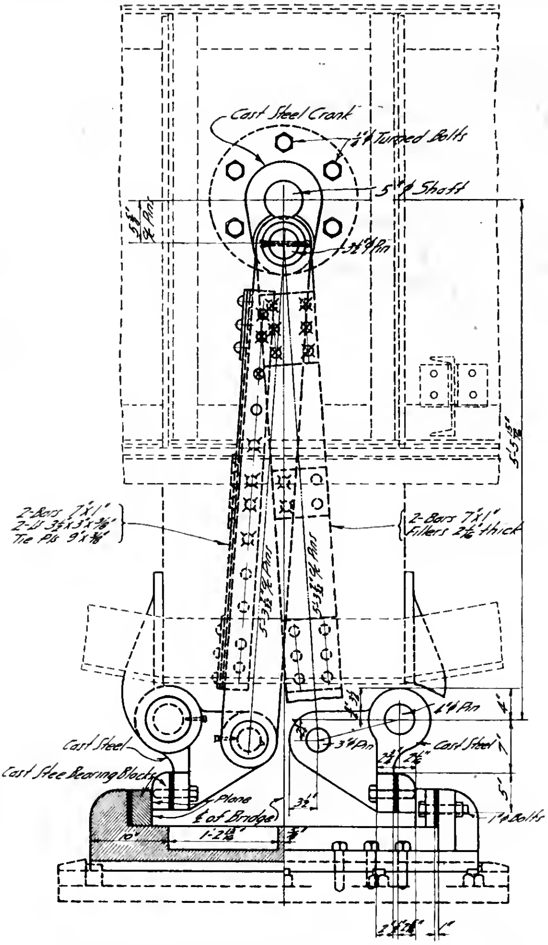


Rail Lock. Chicago, Milwaukee & St. Paul Railway.

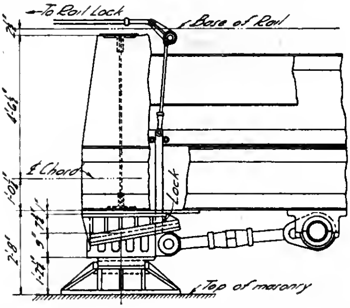


Easer Rail.

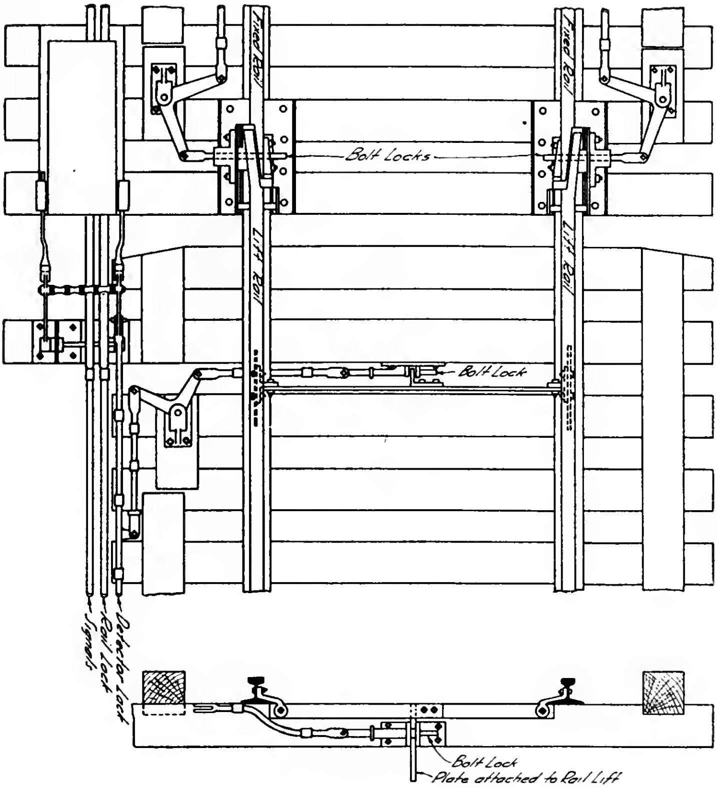
Rail Locks for Lift Span. Chicago Great Western Railroad.



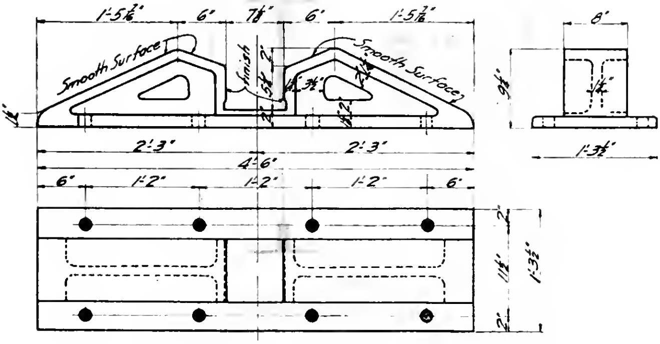
Lining Device. Interstate Bridge, Duluth, Minn.



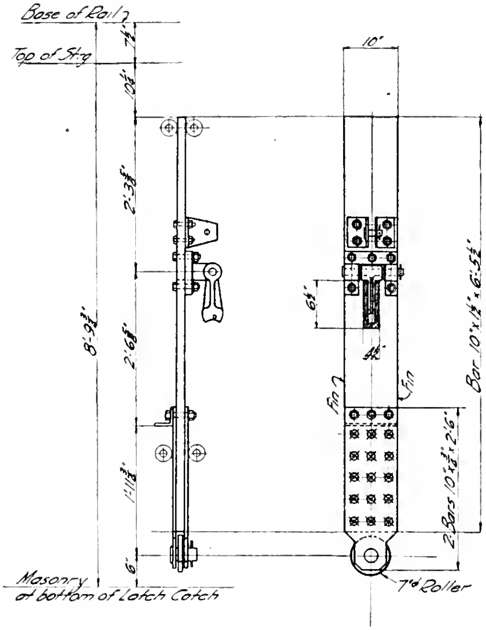
Bolt Lock for End Wedge. Michigan Central Railroad.



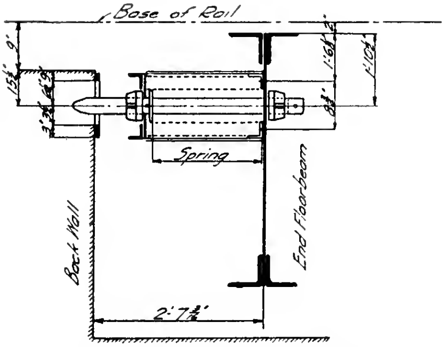
SIGNAL APPARATUS FOR DRAWBRIDGES. SEABOARD AIR LINE.



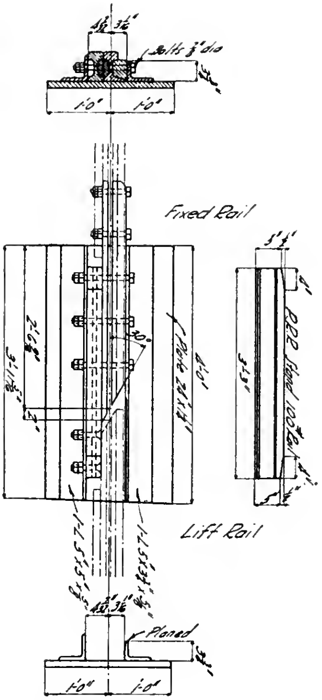
LATCH CATCH. BALTIMORE & OHIO RAILROAD.



Latch Bar. Baltimore & Ohio Railroad.



Latch. Newark Bay Draw.



Rail Shoe. Pennsylvania Railroad.

CONCLUSIONS.

REQUIREMENTS FOR THE PROTECTION OF TRAFFIC AT MOVABLE BRIDGES.

The protective appliances at drawbridges consist in devices for insuring that the bridge is in proper position, and the track in condition for the passage of trains over draw, or for reduction to a minimum of the damage in case of trains not stopping when track is not in condition for passage of same over draw; also the usual devices for protection against damage in case of derailment.

The protective devices may be classified under the headings:

(A) Interlocking power and bridge devices.
(B) Bridge surfacing, aligning and fastening devices.
(C) Rail-end connections.
(D) Signaling and interlocking.
(E) Guard rails.

(A) *Interlocking Power and Bridge Devices.*—Interlocking the drawbridge devices so that their movements must follow in a predetermined order to protect the drawbridge machinery.

(B) *Bridge Surfacing, Aligning and Fastening Devices.*—Drawbridges should be equipped with proper mechanism to surface and align them accurately and fasten them securely in position. This condition can be secured by the use of efficient end lifts in case of swing bridges, and by proper end locks in case of lift bridges.

(C) *Rail-End Connections.*—Rail ends may be mitered or cut square. Mitered rails where lapped should retain the full thickness of the web to the points. The points should be trailing to normal traffic where possible; on single-track bridges the points should be trailing to traffic entering the movable span.

Where rail ends are cut square or mitered and not lapped, they should be connected by sliding sleeve or joint bars or by easer rails to carry the wheels over the opening between the end of bridge and approach rails.

(D) *Signaling and Interlocking.*—If trains are to proceed over drawbridges which are in service, without first stopping, interlocking should be installed which will provide that the drawspan, tracks and switches within the limits of the plant are locked in the proper position. This will require:

(1) Locking drawbridge devices.

(2) Locking providing for the proper order of operation of signaling devices, such as signals, switches and derails.

This interlocking will require the following order of operation:

Before Opening a Drawbridge.	*Before Operating Trains Over Drawbridge.*
1. Display stop signals.	1. Lock bridge and rail devices.
2. Unlock rail and bridge devices.	2. Display clear signals.

Since there are various types and designs of drawbridges and various drawbridge devices for each of the types, and also various designs and types of signaling devices, as well as various locations, from which they all may be interlocked and operated, a typical example only of the detail order of operations is given; viz., a swingbridge with all its devices operated from one location on the drawspan, having home and distant signals, derails, etc.:

To Open Drawbridge.

1. Display stop signals.
2. Unlock derails.
3. Open derails.
4. Uncouple interlocking connections.
5. Unlock rail-end connections.
6. Unlock bridge surfacing, aligning and fastening devices.
7. Operate power-controlling device to position permitting application of power to bridge machinery.
8. Withdraw rail-end connections.
9. Withdraw bridge surfacing, aligning and fastening devices.
10. Open bridge.

To Pass Trains Over Drawbridge.

1. Close bridge.
2. Insert bridge surfacing, aligning and fastening devices.
3. Insert rail-end connections.
4. Operate power-controlling device to position preventing application of power to bridge machinery.
5. Lock bridge surfacing, aligning and fastening devices.
6. Lock rail-end connections.
7. Couple interlocking connections.
8. Close derails.
9. Lock derails.
10. Display clear signal.

Derails.—The above example of order of operation includes derailing switches, but their use is not recommended in all cases. Each situation must be given special study with respect to (a) the use of derails, smash boards or similar devices; (b) their location with respect to drawspan, and (c) the use and length of guard rails.

(E) *Guard Rails.*—Guard rails should be provided as for fixed bridges, except for the necessary breaks at the ends of the movable span. Obstructions to derailed wheels which are guided by the guard rails should be reduced to a minimum.

Appendix H.

BEARING METALS.

By Geo. H. Tinker,

Bridge Engineer, New York, Chicago & St. Louis Railroad.

A bearing metal should have a low co-efficient of friction, high resistance to wear and sufficient strength to resist distortion by crushing. In the case of gears and screws a certain tensile strength and resilience are also required.

The final criterion for the suitability of a metal for a specific purpose is its behavior under actual use. To determine the probable behavior of a metal submitted for such purpose the nearer the test applied duplicates the actual conditions of service the greater our confidence in the probable outcome. It is also necessary that the test should be easily, quickly and cheaply applied, and last, but most important, it should give concordant results.

Friction tests are difficult to make. So also are wear tests. Resilience tests are unsatisfactory. There remain compression and tension tests, which fulfill all the requirements of a test except that it appears doubtful if they furnish sufficient evidence of the probable behavior of bearing metals in service.

Our knowledge of the nature of the phenomenon of friction is theoretical. Latest theories lead to the corollary that the harder a substance the greater its anti-friction qualities. There is some evidence of a definite relation between hardness and tensile strength. The existence of a definite relation between hardness and compressive strength is not established. As to the relation between hardness and resilience, there is a point in the hardness scale where hardness is accompanied by brittleness and resilience decreases. It thus appears that hardness may or may not indicate the presence of the qualities desired in a bearing metal.

There is some evidence that the ability to resist wear is indicated by density rather than hardness. The suggestion of adding a small amount of lead to phosphor bronze has been made with the idea of increasing density. It is undoubtedly true that the addition of lead tends to raise the friction co-efficient, but it does not follow that the metal having the most desirable qualities will have the lowest co-efficient of friction. It is not shown that the several qualities desired follow the same law; they may be antagonistic, in which case the most suitable compromise must be chosen.

It is recognized that neither compression nor hardness tests on bronzes always give concordant results, owing to the effect of various conditions of manufacture. That is one very good reason for controlling the chemical composition within narrow limits.

Although the making of hardness tests has increased in the last few years, the data are not yet sufficient to enable a definite set of figures to be adopted for bearing metals. There is not yet evidence to show that a bronze of a given hardness is the most suitable for a specified use. It should be kept in mind that the hardness test is an indirect test. A metal is suitable for a bearing not because it is hard, but because being hard it is likely to have a low frictional resistance, or is likely to wear well, or is likely to be able to sustain a certain pressure without distortion. In the case of steels the hardness values corresponding to certain specific qualities are better known.

The compression test is a direct test of one of the qualities desired and should not be discarded until we are better and more definitely informed as to the proper hardness numbers. To this end the collection of data should be at once undertaken by all users of bearing metals.

The extracts in Appendix A are from the Proceedings of the Sixth Congress of the International Association for Testing Materials, and show the need of further data on the proper hardness of bearing metals. In the paper by A. Portevin and E. Nusbaumer, the table headed Ball-Hardness has been rearranged in the order of the resistance to wear and the hardness numbers computed.

Reference is also made to the work of the Society of Automobile Engineers on the hardness of various alloy steels.

In the specifications presented in Appendix B the customary tests are retained and provision made for the accumulation of data as to hardness of bronzes, which may be later compared with the record of service.

If it develops that the hardness number is a reliable criterion of suitability of a bronze for a specific use, the hardness test may later be made a requirement for acceptance.

EXPERIMENTAL TESTS OF WHITE METALS FOR ENGINES.

By Nino Pecoraro.

On the acceptance tests of white metals, the compression tests appear suitable for arriving at an estimate as to how far the respective metal will be able to satisfy the conditions of compression without undergoing any practically inadmissible deformation.

Abrasion tests appear always most desirable since the resistance to abrasion is an important characteristic of anti-friction alloys. These tests are, however, neither easily conducted, nor can they rapidly be carried out. It would, nevertheless, be advantageous to substitute for them some simple experiments, which would likewise enable us to make a comparison between different alloys as regards their resistance to abrasion. The hardness test by the Brinell method constitutes such an expedient. Further experiments to elucidate this matter more fully would be desirable.

The determination of the hardness number of anti-friction alloys of equal chemical compositions may perhaps supply us with the possibility of establishing a comparison in broad features between the different alloys as to their suitability for diminishing friction. If this should be confirmed, the exact determination of the average hardness numbers of anti-friction alloys would acquire an extraordinary importance, because it would, in many cases, enable us to arrive at a quick estimate in the place of the tedious, expensive and difficult friction test, for which, moreover, suitable arrangements are not always available.

HARDNESS TESTING AND RESISTANCE TO MECHANICAL WEAR.

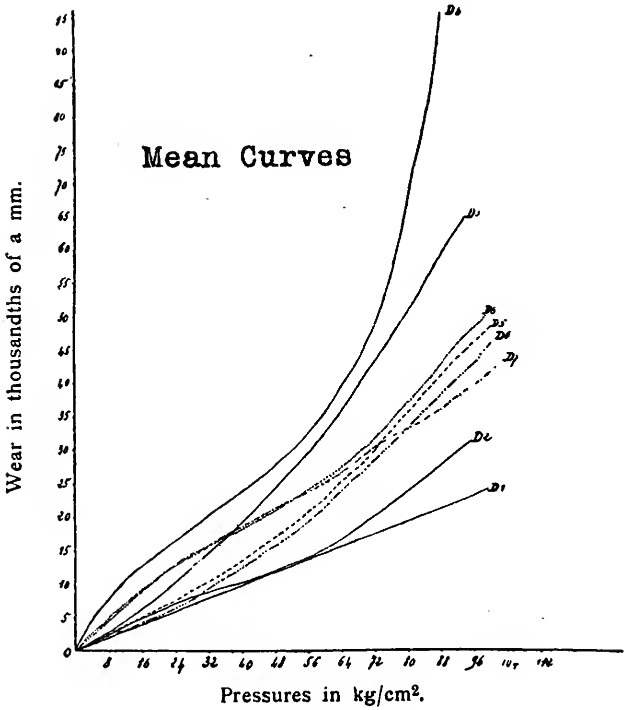
By E. E. Saniter.

The general conclusions are that, while a high Brinell number may be expected to give better wear, there are so many exceptions that its use for the purpose of indicating wearing properties is unreliable as far as the methods of wear testing reviewed are concerned. The relation of either Brinell tests or wear tests to wear in actual practice requires investigation.

NOTE ON WEAR OF BRONZES.

By A. Portevin and E. Nusbaumer.

NOTES FROM PROCEEDINGS OF INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS. SIXTH CONGRESS.



Courbes moyennes = Curves of means.

BALL-HARDNESS.

Mark.	Diameter of Impression.	Extreme Deviations.	Hardness Number.
D1	4.325	± .175	65
D2	3.9	± .1	80
D7	3.45	± .05	103
D8	2.9	± .05	148
D5	4.1	± .1	77
D6	3.9	± .1	80
D3	3.65	± .15	92
D4	2.920	± .075	146

Pressure = 1000 kg.
Diameter of ball = 10 mm.

CHEMICAL COMPOSITION.

Mark.	Cu	Sn	P	Pb	Fe	Zn
D1	91.12	5.73	0	0.12	0.15	2.68
D2	88.31	8.78	0	trace	0.31	2.40
D3	84.45	13.89	0	0.23	0.04	1.22
D4	80.22	19.16	0	trace	0.13	0.43
D5	94.80	5.08	0.011	0	0	0
D6	89.54	10.02	0.012	0	0.05	0.21
D7	85.45	14.42	0.015	0	0.05	trace
D8	80.11	19.79	0.020	0	0.08	trace

SPECIFICATIONS FOR PHOSPHOR BRONZE BEARING METALS FOR TURNTABLES AND MOVABLE BRIDGES.

1. Phosphor bronze for bearings shall be a homogeneous alloy of copper and tin. It shall be made from new metals, except that scrap of known composition and produced by the foundry at which the bronze is cast may be used.

2. The phosphorus shall be introduced in the form of phosphor copper or phosphor tin. There shall be no sulphur in the metal. Unspecified elements shall not exceed 0.5 per cent.

3. The alloy shall be cast into ingots and allowed to cool, and the castings poured from the remelted ingots. Care shall be exercised that the metal is not overheated, and that the temperature at pouring and the conditions of cooling are such as will be most likely to secure dense castings.

4. Castings shall be sound and free from blowholes, sandholes, porous places, cracks or other defects.

5. Grade "A" shall be used for contact with hardened steel discs under pressures exceeding 1500 lbs. per square inch, such as used in turntables and center-bearing swing-bridges.

Grade "B" shall be used for contact with soft steel at low speeds under pressures not exceeding 1500 lbs. per square inch, such as trunnions and journals of bascule and lift bridges.

Grade "C" shall be used for ordinary machinery bearings.

Grade "D" shall be used for nuts, gears, worm wheels and similar parts which are subjected to other than compressive stresses.

6. The composition of Grade "A" bronze shall be approximately copper, 80 per cent.; tin, 20 per cent.; phosphorus not more than 1.0 per cent.

Grade "B" bronze shall be approximately copper, 85 per cent.; tin, 15 per cent.; phosphorus, not more than 1.0 per cent.

Grade "C" bronze shall be approximately copper, 80 per cent.; tin, 10 per cent.; lead, 10 per cent.; phosphorus, not less than 0.7 per cent. nor more than 1.0 per cent.

Grade "D" bronze shall be approximately copper, 88 per cent.; tin, 10 per cent.; zinc, 2.0 per cent.; phosphorus, not more than 0.25 per cent.

7. For Grade "A" bronze the elastic limit in compression shall be 25,000 to 40,000 lbs. per square inch. The permanent set under a load of 100,000 lbs. per square inch shall be 0.06 to 0.10 inch.

For Grade "B" bronze the elastic limit in compression shall be 19,000 to 23,000 lbs. per square inch. The permanent set under 100,000 lbs. per square inch shall be 0.12 to 0.25 inch.

For Grade "C" bronze the elastic limit in compression shall be 15,000 to 20,000 lbs. per square inch.

For Grade "D" bronze the elastic limit in compression shall be not less than 14,000 lbs. per square inch. The ultimate strength in tension shall be not less than 33,000 lbs. per square inch, and the elongation in two inches not less than 14 per cent. The yield point in tension shall be recorded.

8. At least one compression test shall be made from each melt for Grades "A," "B" and "C" and one compression test and one tension test for Grade "D."

9. If a test fails to show the specified properties a retest shall be permitted. If the second test fails the melt shall be rejected.

10. The test specimen shall be turned from coupons or sinkheads attached to and a part of the casting and poured and cooled under the same conditions.

11. The specimens for compression tests shall be cylinders one inch high and of one square inch area.

12. The specimens for tension tests shall be turned to a diameter of one-half inch. The coupon shall be not less than one inch in diameter and shall be fed through a gate running the entire length of the coupon.

13. The elastic limit in compression shall be taken as the load, which produces a permanent set of 0.001 inch.

14. The chemical analysis of each melt shall be determined.

15. The hardness of the finished castings shall be measured by the Brinell ball method and a record of same furnished. The ball shall be of hardened steel, 10 mm. in diameter. A load of 500 kg. shall be applied for thirty seconds to a finished plane surface.

16. At least two hardness determinations shall be made on each melt. Each disc and each trunnion bearing shall be tested.

BRONZES—COMPOSITION AND PHYSICAL PROPERTIES.

BRONZES-COMPOSITION AND PHYSICAL PROPERTIES

Item No.	Kind or Source	Copper	Tin	Lead	Zinc	Phosphorus	Phosphor-Tin	Aluminum	Manganese	Antimony	Iron	Other Elements	Elastic Limit Compression Pounds per Sq In	Permanent Set Under 100,000 lbs. Inches	Purpose and Remarks
1	Babbitt Metal	3.7	8.9							7.3					Machinery bearings-low pressures-in general use.
2	Bearing Metal Used Until 1887	87.5	12.5												
3	"S Brand"	79	10	10		1									Patented by Dicks
4	S Bearing Metal	78-80	9-11	8-11		0.7-1.0									Pennsylvania R. R. specifications
5	Ajax Metal	77	11.5	11.5											Introduced by F.J. Clamer, 1876
6	Ex. B Metal	77	8	15		.25									Developed by C. B. Dudley
7	Plastic Bronze	65	5	30									15,000 Ultimate		Ajax Metal Co. Developed by G. H. Clamer.
8	O. E. Hovey	76.8	8	15		0.2									Penna. R. R. experiments, 1892.
9	Waddell & Harrington	79.7	10	9.5		0.8							15,000		Information by O. E. Hovey.
10	Missouri Pacific Ry	79.7	10	9.5		0.8									Information by C. E. Smith—For discs.
11	B. R. Leffler	79.7	10	9.5		0.8								.10	Suggested specification 1912.
12	N. Y. C. & St. L. R. R.	80	10	10		0.8									
13	N. Y. N. H. & H. R. R.	80	9.2	10		0.8							27,000	.0625	
14	W. H. Moore	80	10.5	9		0.5							27,000	.10 Trunnions .0625 Discs	"Provided this chemical composition gives the physical requirements."
15	E. S. Sperry	80	10	10		0.10	2								For bearings.
16	U. S. Engr. Department	79.7	10 (9-11)	9.5 (8-11)		0.8 (0.7-1.0)									Specifications for Ohio River dams.
17	U. S. Navy Department	78-81	(9-13)	8-11	Remainder	(0.7-1.0)					.06 Max				Specifications Grade 2
18	J. E. Greiner	79.7	(9-11)	8-11		(0.7-1.0)							15,000 20,000		Specifications Hanover St Bridge. For bushings of journals and shaft bearings.
19	85 ft. Turntable at Syracuse	79	10	10		1							23,500	.30	14" disc removed after 4 months because too soft
20	Transfer Bridge No. 1	79.5	10.9	9.1	0.5	0							19,500	.30	For worm gear rings and nuts for hoisting screws.
21	City of Chicago	80	10	10		Quantum Suf							15,000 Min	.25 Max	Specifications for trunnion bascule bridges.
22	Lead Bronze	80	10	8-11		1.0 Max.						0.5 Max.	15,000 20,000		Proposed by Clement E. Chase for low pressures and high speeds
23	Scherzer Rolling Lift Bridge Co	80	10	10		0.8	10						18,000		
24	C. C. Schneider	80	20			0.2	5						24,000		Elastic limit given is per former specifications
25	Ajax Metal Co	85	15											.0625	Suggested to meet the 1-16" specification
26	Strauss Bascule Bridge Co.	85	14.2			0.8							22,000	.10	Specifications for one bridge 1915.
27	85 ft. Turntable at West Albany	85	15.0			0.8							40,000	.074	
28	85 ft. Turntable C. C. C. & St. L. Ry	79.2	19.8	Trace	0.1	.32									
29	Transfer Bridges 3 and 4	84.8	12.8	0.3	0.6	.83							25,300	.174	Bushings for pins supporting girders.
30	Transfer Bridges 3 and 4	84.8	13.3	0.03	1.0	.43							23,500	.25	Worm gear rings and nuts for hoisting screws.
31	British Admiralty	90	9.7			0.3									
32	85 ft. Turntable C. C. C. & St. L. Ry.	77.1	21.3	Trace	1.3										
33	J. E. Greiner												27,000	.10 Trunnions .0625 Discs.	Thinks best not to specify chemical composition.
34	Strauss Bascule Bridge Co												27,000	.0625	Specifications for one bridge 1910.
35	Strauss Bascule Bridge Co.												24,000	.125	Specifications for one bridge 1913.
36	A. W. Carpenter	98.5	98.5									1.5	40,000	.0625	
37	Transfer Bridge No. 1												62,000	.05	For bushings for pins supporting girders. Brittle.
38	Manganese Bronze												28,000	.10	American Manganese Bronze Co.
39	Phosphor Bronze No. 1												15,000	.27	American Manganese Bronze Co.
40	Phosphor Bronze No. 2												22,000	.15	American Manganese Bronze Co.
41	Phosphor Bronze No. 3												35,000	.062	American Manganese Bronze Co.
42	Titanium Aluminum Bronze												53,000	.016	American Manganese Bronze Co.
43	80 ft. Turntable at Newburgh													.0625 .125	Installed 1906. Reported no trouble 1910.
44	80 ft. Turntable at Oswego													.0625 .125	Installed 1907. Reported "no trouble" 1910.
45	85 ft. Turntable at Rensselaer													.0625 .125	Installed 1908. Reported "giving good satisfaction" 1910.
46	85 ft. Turntable at Dewitt												14,000	.04-.06	Installed 1908. Reported "has given good service" 1910.
47	High Tin Bronze					1.0 Max.						0.5 Max.	22,000 27,000	.06-.18	Proposed by Clement E. Chase for high pressures and low speeds.
48	Medium Tin Bronze					1.0 Max						0.5 Max.	19,000 23,000	.12-.25	Proposed by Clement E. Chase for high pressures and low speeds.
49	Gun Metal	88	10		2										Designated as gun metal by C. E. Chase. Recommended for gears and Worms.
50	U. S. Navy Department	85-90	6-11	0.2 Max	Remainder	0.3 Max					0.06 Max.				Specifications Grade 1
51	Isthmian Canal Com	87-87.25	10.9-11.0	0.15-0.20	1.65-1.85										Specifications for Worm Wheel rims.
52	American Bridge Co.	89.5	10							0.5			15,000		For worm wheel rims. Copper to be 81.5 Pig. Cu + 8.0 Manganese Cu
53	J. E. Greiner					1.0 Max.							19,000 23,000	.12-.16	Specifications Hanover St Bridge for trunnion bearings
54	R. W. Hunt & Co.	80	18		2										Good mixture for wheel castings
55	St. Louis S. W. Ry.	84.14	10-13	2.60	1.07	.24					2.24				Castings for White River draw span. Iron indicates scrap.
56	E. S. Sperry	90	10			.05	1								For the highest possible strength.
57	Gun Metal	88	10		1.75-2.25	1.0 Max.						0.5 Max			Proposed by Clement E. Chase for gears and worms ultimate tensile strength 35,000 lbs minimum.
58	Tensilite Bronze	67.0			24.0	.01		4.4	3.8				60,000	.0133	85 ft. Turntable at W. Albany Installed 1913. This is brass not bronze.
59	Turntable at Rensselaer														Installed 1907. Disc broken into small pieces.
60	Turntable at Utica														Bronze disc too soft—upset in oil box.
61	Turntable at Utica														Bronze disc replaced by hardened steel disc which had to be taken out in two days on account of hard turning
62	Turntable at Minoa														Took out bronze disc Oct. 1908 account edges being chipped off.
63	Penna. R. R. Experiments	76.8	8	15		0.2									Journal Franklin Institute Feb. and March, 1892.
64	Manganese Bronze	56-57	1		38-40						1.5		35,000 40,000		Average qualities given by C. R. Spare.

REPORT OF COMMITTEE VII—ON WOODEN BRIDGES AND TRESTLES.

E. A. FRINK, *Chairman;*	W. H. HOYT, *Vice-Chairman;*
H. AUSTILL, JR.,	H. S. JACOBY,
J. E. BARRETT,	A. O. RIDGWAY,
H. C. BROWN, JR.,	I. L. SIMMONS,
E. A. HADLEY,	D. W. SMITH,
F. G. HOSKINS,	W. F. STEFFENS,
	Committee.

To the Members of the American Railway Engineering Association:

The following subjects were assigned for the consideration of your Committee during the past year:

(1) *Continue study of design of docks and wharves.*

(2) *Report on relative merits of ballast deck wooden trestles as compared with reinforced concrete trestles.*

(3) *Continue study of the use of lag screws in trestle construction.*

The Committee was divided into three Sub-Committees, which have worked during the year on the subjects assigned. A general meeting was held in the Association's rooms at Chicago on December 11th, which was attended by Messrs. Austill, Brown, Frink, Hoyt, Jacoby and Ridgway. A second meeting was held in the Association's rooms on January 29th, at which were present Messrs. Austill, Brown, Hoyt, Ridgway, Simmons and Smith.

From the work at these meetings, and correspondence during the year, your Committee submits the following report:

During the year a communication was received from a firm manufacturing cypress lumber, suggesting the advisability of formulating a specification for cypress bridge and trestle timber. After conference with the Board of Direction and with the Committee on Grading of Lumber, it was decided to await the completion of specifications now being prepared by a committee of the Southern Cypress Manufacturers' Association, after which the advisability of preparing a standard specification for this Association will be considered.

In May a communication on pile specifications by Mr. E. P. Goodrich, suggesting a modification of the Association's specification for wooden piles, was referred to the Committee. Mr. Goodrich suggests the following:

"The pile shall be so straight that a line held in contact with any two points selected, so as to give the maximum deviation, shall not be distant from the surface of the pile at any point more than the diameter of the pile opposite that point."

The present specification of the Association, page 145, paragraph 3, of the Manual, requires that:

"A line drawn from the center of the butt to the center of the tip shall lie within the body of the pile."

Mr. Goodrich's clause would permit bends of twice the amount permitted by our present specifications. It is the opinion of the Committee that our present requirements should not be lessened.

RECOMMENDATION FOR NEXT YEAR'S WORK.

Your Committee recommends that the following subjects be assigned for next year's work:

1. Continue study of design of docks and wharves.
2. Continue report on relative merits of ballast deck wooden trestles as compared with reinforced concrete trestles.
3. Continue study of the use of lag screws in trestle construction.
4. Investigate and report on merits of galvanized iron fastenings for timber trestles as compared with plain iron and steel fastenings, especially in relation to their use on creosoted structures.

Respectfully submitted,

COMMITTEE ON WOODEN BRIDGES AND TRESTLES.

DESIGN OF DOCKS AND WHARVES.

Your Sub-Committee No. 1 on "Design of Docks and Wharves" submits the following progress report for information:

A circular letter was sent to certain members of the Association, who were in a position to furnish data and plans concerning the latest and best practice in the construction of freight-handling docks. Much information and many plans were received showing a great diversity of design adapted to the many varying conditions that are met on our seacoast cities and Great Lakes ports.

In the study of these plans and specifications many questions have come up as to the extent of the field of inquiry to be covered by this Committee. This is the day of permanent improvements in most of the territory covered by the railroads represented in this Association, and it is pertinent to ask if it is worth while to confine our investigation to strictly wooden structures. If this were to be done, it would greatly restrict the work, as there are very few docks and wharves being built at the present time which are not partly or entirely built of steel and concrete. Your Committee, however, has assumed the broader inquiry and will present for your information a few selected plans of what appear to be examples of the latest and best practice.

DETERMINING FACTORS OF DESIGNS.

In considering the general plan for a dock or a wharf, the character of the service to be rendered is of prime importance. If the structure is to accommodate passenger service, its arrangement, as to safety and convenience, should be given careful attention. Ease of transferring passengers from trains or from land approaches to floating equipment, ample room for allowing rapid and safe movements, are factors that will very largely control the general design of the structure, as will also the character of the passenger service as to whether for ocean-going long-voyage trips or for short-voyage ferry service.

If the structure is to accommodate freight service, there are even more questions arising that will have very important bearing on the design. To handle miscellaneous package freight, its adaptability to the use of loading and unloading machinery, to the movements of freight from floating to rolling equipment, or vice versa, must be considered. To handle bulk freight such as coal and iron ore, either from boats to docks or from stock piles, docks or cars to floating equipment, requires an entirely different class of structure from that designed to handle package freight exclusively.

The character of the floating equipment as to whether ocean-going, lake and canal or river barges, as well as the relation between ownership of the docks and transportation equipment, is of importance. If the dock property is owned by transportation interests it may be economical to use more permanent construction than if the property was not assured of long-continued service.

Natural Conditions.

The height of a structure is often determined by its location on a shore line, subject to rise and fall of the water due to tides or other causes. The foundation details are variously affected by the character of the soil in which the structure is to rest. Soft alluvial deposit or sand will often require very long piling, while if rock bottom may be reached without great expense, cribs or piers may be economically constructed.

The action of salt water upon different structural materials, the climatic conditions and their effects upon steel, concrete and wood, decay and deterioration due to marine growths, violence of wave action and the general prevalence of storm conditions will all have their bearing on materials to be used in construction.

Artificial Conditions.

On most of our harbors conditions imposed by the general layout of government harbor lines affect the general shape of the work. Where the government harbor lines are laid out far from the natural shore line, construction will develop long and slender docks, while if the government harbor lines are closer in shore, construction will develop broad and probably filled docks.

If the developments of the adjacent channel courses have not yet assumed permanent position, or are not in prospect in the very near future, it might be unwise to adopt permanent construction.

Business and Economic Conditions.

The business and economic conditions governing construction of this kind have a most important bearing. For instance, a lumber dock built in a country where the timber business will last only ten or fifteen years, will suggest a cheap first cost, while a structure to handle package or bulk freight serving ocean liners and permanent railroad lines would naturally suggest structures of permanent design.

The volume of business to be handled at the dock, its rush times at certain seasons of the year, its possibility of increased growth or change of character of shipments may develop a special design if these points are of leading importance.

At the present time the tendency toward government ownership and control may influence the amount of the expenditure to be made for the improvement. In case of a transfer of ownership a permanent structure would bring a larger proportion of returns than one of temporary character. On the other hand, other conditions of public sentiment may tend to heavy taxation of the corporation and its property, thus the advantages to be gained by expending money in permanent construction would be offset by the additional taxes on such property.

The fire hazard and insurance rate on property of this kind is very important. If located in the immediate vicinity of hazardous structures, fireproof construction might be advisable, and rates of insurance in different localities should be carefully considered. Every dock problem is one to be handled as an individual proposition.

Oftentimes the facility of approach of the railroad tracks, complications of manufacturing and improved properties, general layout of the ground over which the approaching railroads are to be operated, may materially alter the general design, consequently it is impossible to lay down any hard and fast lines to be recommended as standard dock construction.

SUBSTRUCTURE OR FOUNDATIONS.

By far the greater number of all docks yet built or being built in this country are designed with wooden piling to carry their loads. In many cases these are being surmounted above water line by concrete piers, either with or without timber grillage.

Some structures are surrounded by timber sheet piling well-anchored back with steel rods and the dock then filled to the required height. A few have already used steel sheet piling for this purpose, thereby building a very permanent foundation.

The natural conditions have very important bearing on the foundation design. In soft earth piling must be long and driven until a secure bearing is found, but if the bottom is of rock formation, timber cribs designed to fit more or less the uneven rock bottom may be sunk in place and filled up to the proper level.

It is becoming more and more the practice at the present time to use treated timber and treated piling in all work subject to destruction by the teredo or other form of marine borers. In the replies to inquiries of this Committee, this recommendation has been often made.

During the past a great many docks have been constructed of timber cribs sunk along the dock line without placing under them piling or other permanent form of support. These structures have been very unsatisfactory. They have caused trouble by settling under load, and by being easily overturned toward deep water whenever it became necessary to deepen channels. This practice has been almost entirely abandoned and it is now recognized that filled cribs should never be placed except upon solid, unyielding foundations. Where the improvement will warrant the expenditure, the use of some form of steel sheet piling is very satisfactory, and its use will doubtless be increased very greatly in the future.

Where piling is driven in very deep water and future plans contemplate permanent filling of the dock, it is often good practice to fill in around the piling to a certain depth with rubble stone, thus stiffening the foundation and causing less damage to buildings and structures due to the shock of berthing boats.

The present depth of channel, as well as depth that may be required in the future, should be given careful consideration. If the structure is one to be used a long time, its future improvement by changing timber foundations to foundation of more permanent design of concrete and steel must be considered.

One of the most common causes of failure and perhaps the most common defect in dock foundation construction is the improper spacing of the supporting piling. The tendency is to space piling more or less uniformly throughout the structure with utter disregard of the unequal distribution of load. Often the parts of the dock carrying no load at all are supported by the same distribution of piling as the part of the structure carrying the maximum loads.

The following is a list of the more important items to be given consideration in designing dock foundations:

Timber Piling;
Concrete Piling;
Steel Sheet Piling;
Wood Sheet Piling;
Concrete Sheet Piling;
Rock for Masonry and Fill;
Rock Filled Cribs;
Concrete Filled Cribs;
Sand Filling;
Retaining Walls;
Depth of Channel adjacent;
Future Depth of Channel adjacent.

SUPERSTRUCTURE.

The superstructures of many docks and wharves constructed during the past few years are of a composite character. Timber, concrete and steel are used in various combinations, and there seems to be great diversity of opinion as to the best practice. Of course there are many conditions to be considered in planning a dock for a particular locality to handle certain classes of traffic, and each dock is a problem by itself.

Designs submitted to this Committee show considerable variation in the construction of dock floors. Timber structures are generally decked by cutting off the piling to proper level, capping same with standard-sized timbers and placing a plank floor securely spiked to the caps. This form of deck is very satisfactory for wooden structures, and, up to the present, on account of the low price of timber, has probably returned more on the investment than would have been produced by any permanent form of construction.

In the past few years some designers have placed concrete decks on timber structures, others have used concrete with asphalt wearing surface. It would seem that either of these methods of construction were hardly satisfactory. Concrete or asphalt decks should be placed on filled or permanent structures so they would not deteriorate rapidly from the action of an unstable foundation.

The superstructure of many wharves is of very simple construction, being principally a more or less extensive roof supported upon posts from the dock foundation. Of late years many very fine examples of steel and concrete buildings have been erected and the tendency in all our large shipping centers, at the present time, is to erect structures of this character.

The danger of fires and the tremendous loss incident to the destruction of wharves and their contents, as well as the loss that may entail on shipping in the immediate vicinity, has been a very decided factor in producing a permanent form of construction. The constant rise in prices of timber in all forms and the lower prices of steel and concrete is making it more feasible to put up fireproof structures of permanent design.

Plans for proper distribution of electric current for light and power, water pipes for drinking purposes and sanitary uses and fire mains, together with fire alarm and hose storage points, are all questions to be carefully considered in designing superstructures.

DISCUSSION OF VARIOUS TYPES.

(1) Pile and Timber Structures—Untreated.

Up to very recent times by far the greater number of wharves built have been of plain untreated pile and timber design. The cheapness of timber, the ease with which it can be handled and placed, its ready adaptation to various conditions, still make this form of dock very satisfactory, and in most cases these docks will show a larger return on the investment than other so-called permanent forms of construction. The life of these structures will be from seven to ten years, depending on the quality of the timber and climatic conditions. Oftentimes the superstructure may be rebuilt on original foundation piles where there are no marine borers and the variation of water level is small. When the water is infested with the teredo, the use of untreated piling is a poor investment, therefore this form of dock is now used only on fresh water lakes or in harbors where the presence of fresh water or sewage is enough to destroy the teredo.

(2) Treated Pile and Timber Structures.

Of late years great progress has been made in the creosoting of timber, and on account of the greatly increased life obtained and the great resistance given to the work of marine borers, much treated timber is now being used in wharf construction. Sufficient time has not yet lapsed to determine with any degree of accuracy the life of a thoroughly creosoted timber dock, but observation warrants the conclusion that a life of twenty-five years will not be unusual. When taking into consideration the fact that our transportation service is in a rapidly changing and developing condition, and that a lapse of twenty-five years sees most of our structures obsolete, it would seem that only very peculiar conditions would warrant more expensive structures than well-built creosoted timber docks. Combinations of pile structures with filled centers using timber sheet piling or low reinforced concrete retaining walls often fit certain locations very economically and give very satisfactory results.

(3) Timber and Concrete Combination—Filled.

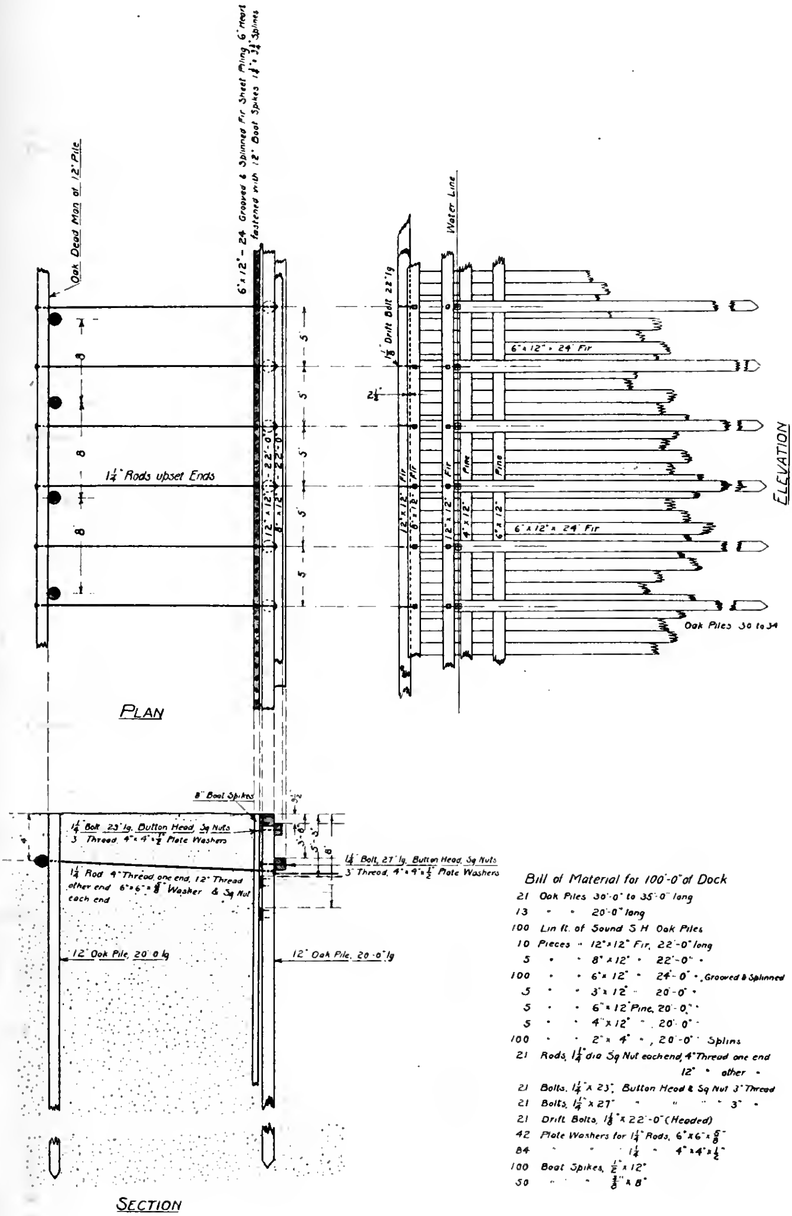
Along our Great Lakes and inland waters, where there is no change of water elevation, there have been built many variations of the filled dock. Some forms use the timber sheet pile front tied back with rods, this surmounted by a gravity concrete wall resting on piling. The conditions warranting this construction are: Shallow water at dock site, cheap filling placed by hydraulic dredges, large area of dock surface for storage of bulk freight, safety from fire loss and ease of use for track terminals. Most of the large coal-handling docks on the Great Lakes are of this pattern and are giving very satisfactory results and showing good economy.

(4) Steel and Concrete Dock.

Of late years some very permanent and expensive forms of docks have been constructed, using steel or concrete sheet piling capped with concrete retaining walls. Structures of this kind are warranted where the area of dock surface is large, water is shallow, not requiring heavy fill, filling material cheap and removed from adjacent slips by hydraulic dredge, and where it is proposed to use the dock surface for a railroad terminal, conditions must be such that a practically permanent layout may be designed so that capital cost could be spread over a period of forty or fifty years. Maintenance cost is, of course, low on this style of dock and should also be given careful consideration.

In the effort to obtain permanent forms of construction, economy is often lost sight of and larger and heavier expenditures are made than a careful consideration of all the facts and conditions would warrant.

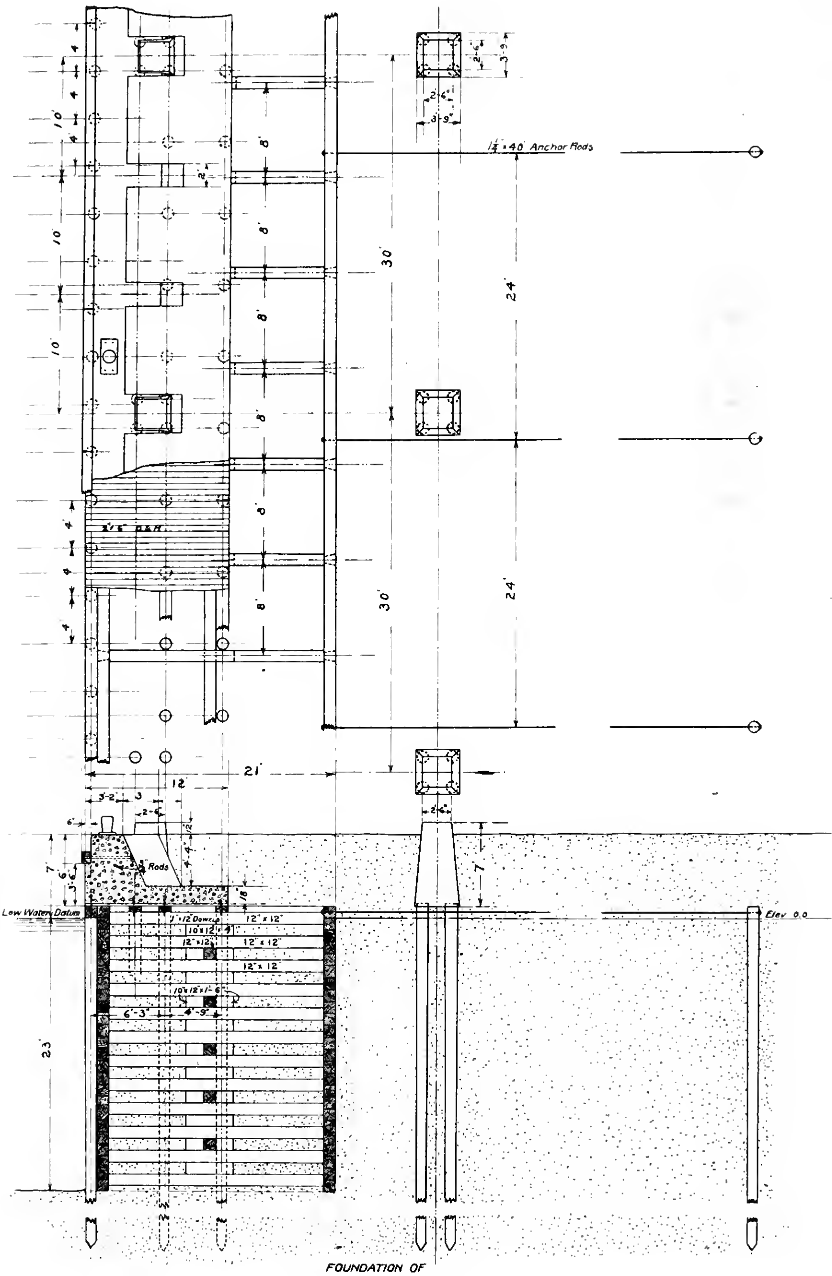
Your Committee has submitted a few typical designs that cover the general points considered and hope, by farther study of the subject, to present comparative cost figures.



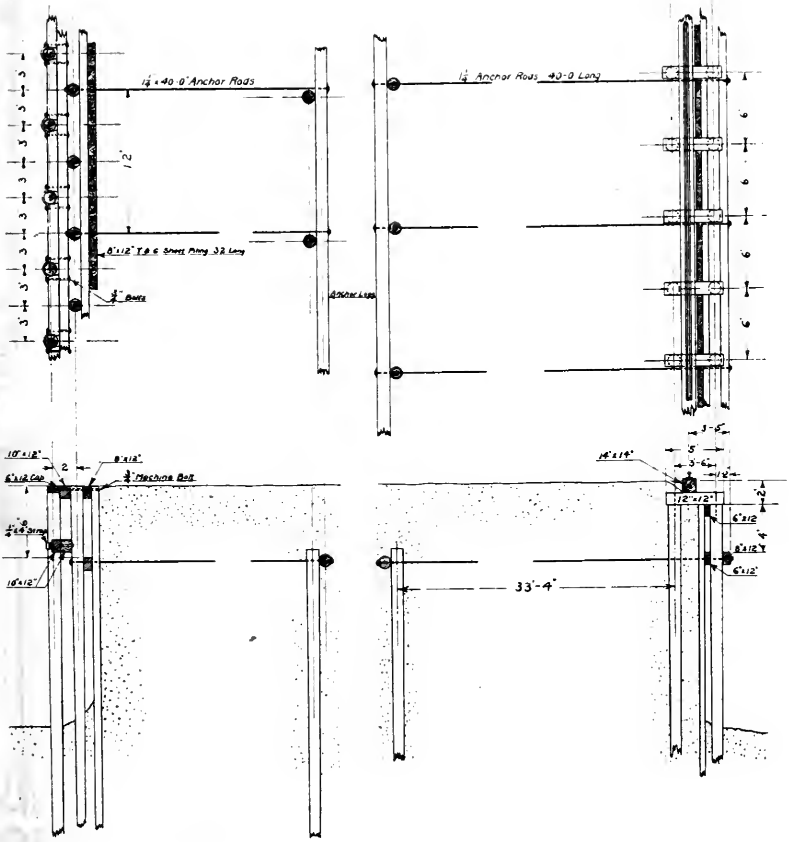
Bill of Material for 100'-0" of Dock

21	Oak Piles 30'-0" to 35'-0" long
13	" " 20'-0" long
100	Lin ft. of Sound S H Oak Piles
10	Pieces " 12"x12" Fir, 22'-0" long
5	" " 8"x12" " 22'-0" "
100	" " 6"x12" " 24'-0" " Grooved & Splinned
5	" " 3"x12" " 20'-0" "
5	" " 6"x12" Pine, 20'-0" "
5	" " 4"x12" " 20'-0" "
100	" " 2"x4" " 20'-0" Splins
21	Rods, 1¼" dia Sq Nut each end, 4" Thread one end 12" " other "
21	Bolts, 1¼"x23", Button Head & Sq Nut 3" Thread
21	Bolts, 1¼"x27" " " " " 3" "
21	Drift Bolts, 1⅛"x22'-0" (Headed)
42	Plate Washers for 1¼" Rods, 6"x6"x⅝"
84	" " " 1¼ " 4"x4"x½"
100	Boat Spikes, ½"x12"
50	" " ⅜"x8"

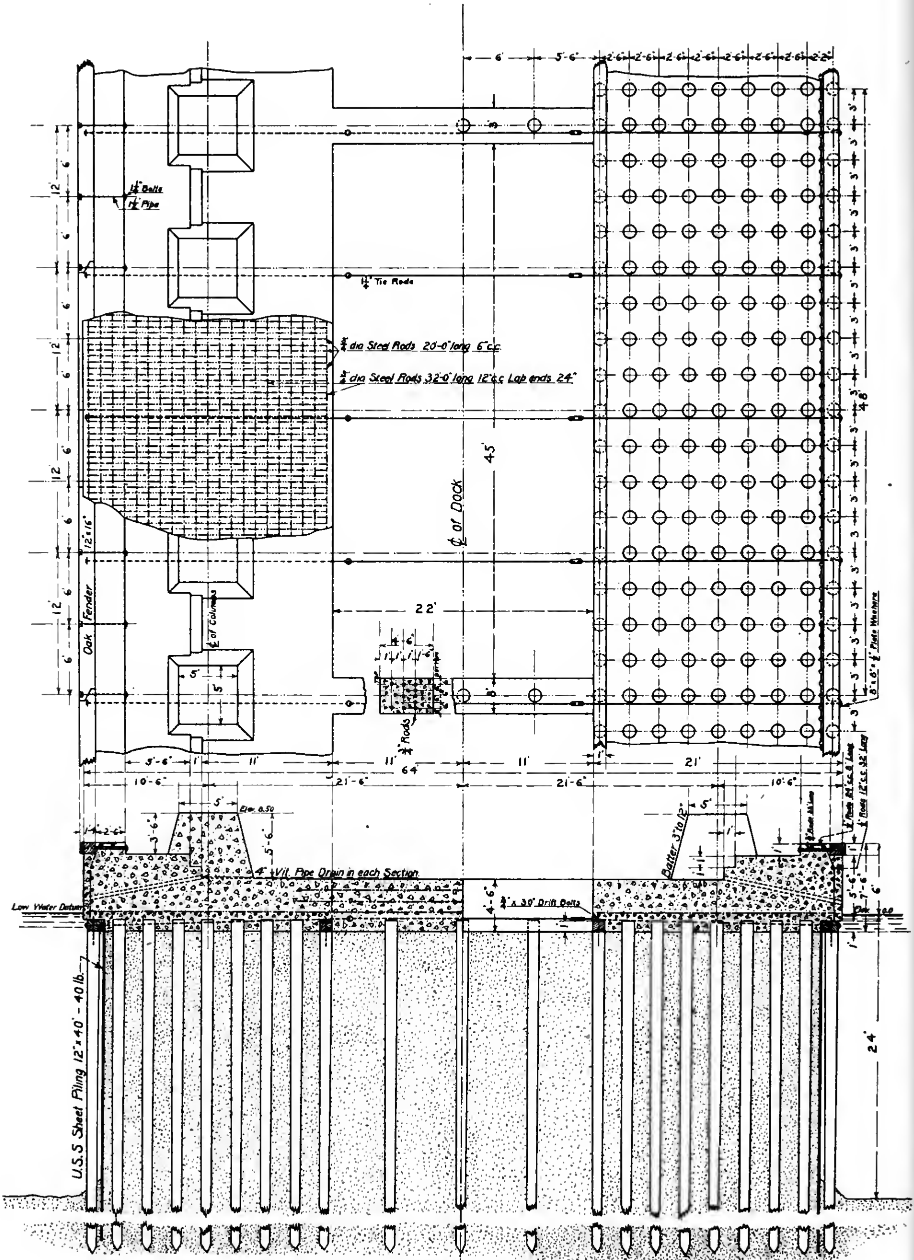
FOUNDATION OF
DOCK ON CHICAGO RIVER
CHICAGO, MILWAUKEE & ST PAUL RAILWAY



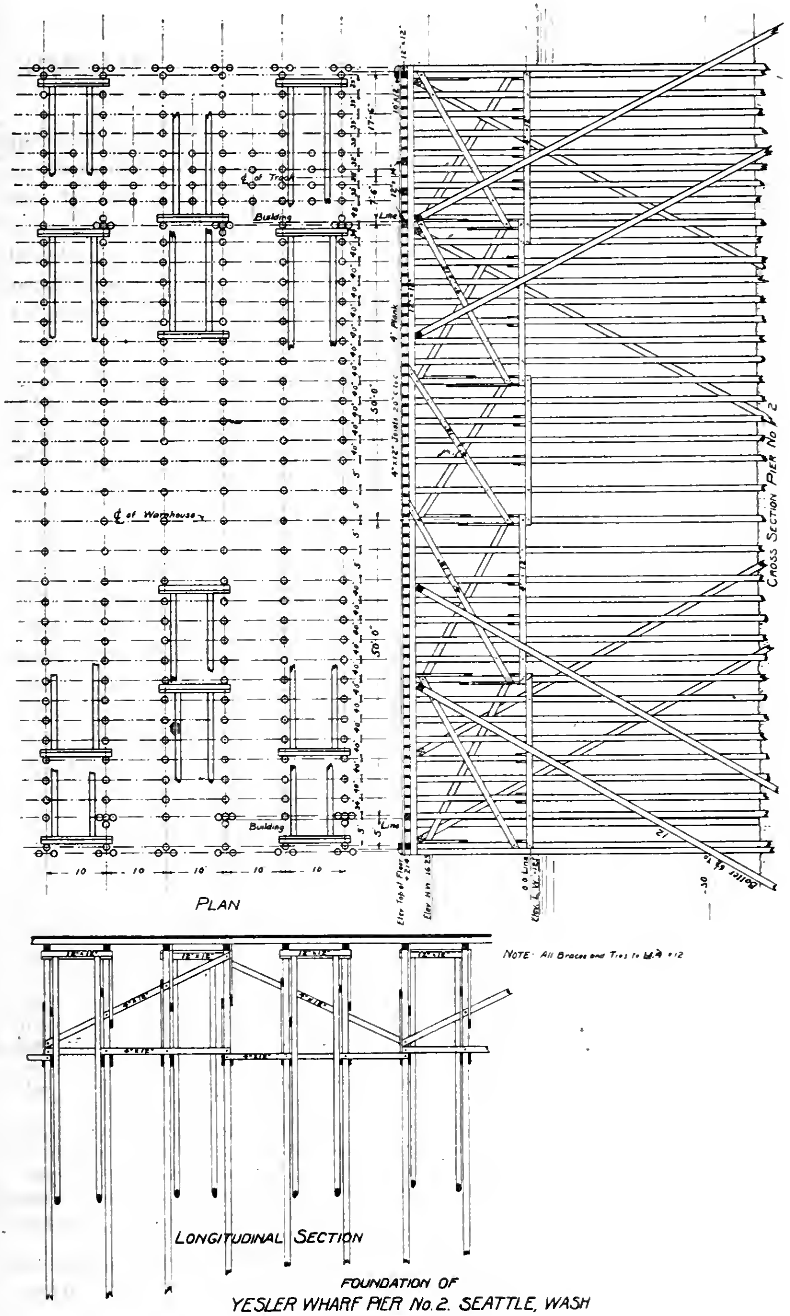
FOUNDATION OF
DULUTH COAL DOCK



FOUNDATION OF
DULUTH COAL DOCK



FOUNDATION OF
STEEL ORE DOCK *5
DULUTH, MISSABE AND NORTHERN RAILWAY



NOTE · All Braces and Ties to be 4 × 12

FOUNDATION OF
YESLER WHARF PIER No. 2. SEATTLE, WASH
NORTHERN PACIFIC RAILWAY

(2) COMPARATIVE MERITS OF BALLAST DECK AND REINFORCED CONCRETE TRESTLES.

Since the subject assigned to the Committee for investigation seems to encroach somewhat on the field of activity of the Masonry Committee, the matter under consideration was referred to the Chairman of that Committee in an effort to ascertain the extent of pertinent information as to reinforced concrete trestles which might have been collected thereby. We find that the Masonry Committee is not in possession of material data suitable for our work, and have therefore been conducting investigations on our own behalf.

Inquiries have been transmitted to about seventy-five of the more important railways in the United States and Canada, aggregating 225,550 miles of line. To these inquiries forty-seven of the lines have responded, and we have, therefore, received replies from 143,557 miles of road. The questions submitted and a very brief abstract of answers to a portion thereof appear below.

It is the sense of the Committee that, since there are so many factors of both an engineering and economic nature to be thoroughly considered before intelligent conclusions can be reached, it cannot submit a completed report at this time. Many of the attendant questions and problems of which disposition must be made are not susceptible of mathematical solution, and while the Committee can report the work well in hand and progressing satisfactorily, though slowly, it begs to request a continuation of final report until next year.

On October 19th the Committee sent out to seventy-five of the largest and most important railways of the United States and Canada the following circular letter:

DEAR SIR:

In the preparation of a "Report on Comparative Merits of Ballast Deck and Reinforced Concrete Trestles," to be submitted to the American Railway Engineering Association by its Committee on Wooden Bridges and Trestles, the Committee finds it necessary to collect certain data not now in its possession, and to this end respectfully requests that, if possible or consistent with other demands upon your time, you furnish, in as much detail as you may elect or in any form best suited to your convenience, available recorded information or your personal views and experience pertaining to the several phases of the subject in hand as indicated in following outline, sending such reply as you may deem advisable to the undersigned:

(1) Owing to the difficulty of securing definite maintenance costs of ballast deck timber trestles or dependable figures as to their length of serviceable life, it has not been possible thus far to present a comprehensive and reliable statement of the relative economy of the two types of bridges, and in view of this fact thorough consideration must be given to other affecting elements. May we not therefore ask:

(a) What, in your opinion, is the probability of destruction by fire of ballast deck timber trestles, furnishing, if available, actual figures in support thereof?

(b) What is the relative danger of loss and damage of the two types by reason of flood?

(c) What value should be placed on the vastly greater inertia of the reinforced concrete trestle in producing desirable riding qualities in the track?

(d) To what extent should "appearance" be considered in the adoption of either type?

(e) With the numerous large-sized sticks in a timber trestle, together with their probable length of life when creosoted, on the one hand, and the absolute waste of form lumber on the other, should any consideration be given to the theory of "conservation of natural resources?"

(f) To what extent, if at all, should "depreciation" of way and structures have an influence in deciding as between the two types?

(g) Are legal requirements or orders of public authorities in municipalities or communities through which your lines are operated mandatory in any degree as to installation of concrete structures, and if so just to what extent?

(2) What general conditions, natural or artificial, would exert a controlling influence, in your decision, as to the adoption of a ballast deck creosoted timber trestle or a reinforced concrete trestle for any particular bridge or locality?

It is perhaps needless to add that the Committee will greatly appreciate any assistance in its efforts to formulate sound conclusions.

A brief abstract of such replies to the different subdivisions of Question No. 1, as have thus far been received, is shown in the accompanying tabular statement.

ABSTRACT OF REPLIES RECEIVED TO INQUIRIES, "COMPARATIVE MERITS OF BALLAST DECK AND REINFORCED CONCRETE TRESTLES," FEBRUARY 1, 1916.

	"A" Fire Hazard.	"B" Relative Flood Hazard	"C" Relative Riding Qualities
Atlantic Coast Line	Excessive	Less in concrete	Concrete preferable
Boston & Albany	No opinion	No opinion	Concrete preferable
Baltimore & Ohio	Considerable	Favorable to concrete	Of doubtful value
Central of Georgia	Considerable	Generally inconsiderable	Concrete preferable
Central of New Jersey	Considerable	Inconsiderable	Immaterial
Chicago & Eastern Illinois	Inconsiderable	Inconsiderable	Difference of doubtful value
Chicago & Northwestern	No opinion	No opinion	No opinion
Chicago, Burlington & Quincy	Dependent on location	Inconsiderable	Little or no difference
Chicago, Rock Island & Pacific	Probable fire loss, 1:100	Inconsiderable	No opinion
Chicago, St. Paul, Minneapolis & Omaha	Very great	Inconsiderable	Practically indeterminate
Delaware, Lackawanna & Western	No opinion	No opinion	No opinion
Duluth, Missabe & Northern	No opinion	No opinion	No opinion
Duluth, South Shore & Atlantic	35% of open trestle	1:2 favor concrete	4:5 favor concrete
El Paso & Southwestern	Probable fire loss, 1:1000	Favorable to concrete	Of doubtful value
Grand Trunk	No opinion	No opinion	No opinion
Grand Trunk Pacific	No opinion	No opinion	No opinion
Hocking Valley	No opinion	Favorable to concrete	4:5 favor concrete
Lehigh Valley	Inconsiderable	Favorable to concrete	Favorable to concrete
Louisville & Nashville	Inconsiderable	No opinion	No opinion
Michigan Central	Little hazard	Dependent on location	Negligible
Minneapolis & St. Louis	25% of open trestle	Inconsiderable	Of indeterminate value
Missouri, Kansas & Texas	No opinion	No opinion	No opinion
Missouri Pacific	Very small	Equal, considering cost	Slight difference indeterminate
Mobile & Ohio	Inconsiderable	Favorable to concrete	Negligible
Nashville, Chattanooga & St. Louis	Not great	Favorable to concrete	No appreciable difference
New York Central	Possible hazard	Favorable to concrete	Favorable to concrete
New York, New Haven & Hartford	Considerable	Slightly favorable to concrete	Favorable to concrete
Norfolk Southern	No opinion	No opinion	No opinion
Norfolk & Western	Slight	Slightly favorable to concrete	No opinion
Northern Pacific	No definite information	Practically equal	Dependent on traffic
Oregon Short Line	No opinion	No opinion	No opinion
Oregon-Washington	Slight	Favorable to concrete	Favorable to concrete
Pennsylvania Lines West	No opinion	No opinion	No opinion
Pennsylvania	Great hazard	Greatly favorable to concrete	Favorable to concrete
Philadelphia & Reading	No opinion	No opinion	No opinion
Pittsburgh & Lake Erie	No opinion	No opinion	No opinion
Queen & Crescent	Slight	Favorable to concrete	Favorable to timber
St. Louis & San Francisco	Great	Favorable to concrete	No opinion
St. Louis Southwestern	Very slight	Inconsiderable	No opinion
San Pedro, Los Angeles & Salt Lake	Very slight	Favorable to concrete	No difference
Seaboard Air Line	Inconsiderable	Favorable to concrete	Favorable to timber
Southern	Slight	Inconsiderable	Little or no difference
Southern Pacific	Slight	No opinion	No opinion
Union Pacific	No opinion	No opinion	No opinion
Vandalia	No opinion	No opinion	No opinion
Wabash	Slight	Favorable to concrete	No difference
Western Maryland	No opinion	No opinion	No opinion

ABSTRACT OF REPLIES RECEIVED TO INQUIRIES, "COMPARATIVE MERITS OF BALLAST DECK AND REINFORCED CONCRETE TRESTLES," FEBRUARY 1, 1916.

"D" Appearance	"E" Conservation	"F" Depreciation	"G" Legal Requirements
Not to be considered	Not to be considered	Only as to ultimate cost	None
No opinion	No opinion	No opinion	
Dependent on location	No opinion	No opinion	None
Dependent on location	Little consideration	Considerable influence	None
Little consideration	Little consideration	Only as to safety and cost	None
Dependent on location	Not to be considered	Important factor	None
No opinion	No opinion	No opinion	
Dependent on location	Favorable to concrete	Difficult of application	Dependent on location
Undue expense unwarranted	Favorable to concrete	Only as to ultimate cost	Dependent on location
Not to be considered	Favorable to concrete	Important influence	None
No opinion	No opinion	No opinion	
No opinion	No opinion	No opinion	
Minor consideration	Favorable to concrete	Decided influence	None
Concrete preferable in cities	Favorable to concrete	Fundamental as to ultimate cost	None
No opinion	No opinion	No opinion	
No opinion	No opinion	No opinion	
4:5 favor concrete	Not to be considered	Favorable to concrete	None
Dependent on location	Not to be considered	Favorable to concrete	None
No opinion	No opinion	No opinion	
Dependent on location	Not to be considered	Only as to ultimate cost	None
Little consideration	Eventually demand concrete	Only as to ultimate cost	None
No opinion	No opinion	No opinion	
Only in special cases	Not to be considered	Not a factor at present	None
Only in communities	Not material factor	Only as to ultimate cost	None
Only in cities	Not to be considered	Not to be considered	None
Generally favorable to cement	Probably of no influence	Considerable influence	Dependent on location
Generally negligible	No opinion	Large influence	None
No opinion	No opinion	No opinion	
No opinion	No opinion	No opinion	
Dependent on traffic	Not to be considered	Only as to ultimate cost	Only in special cases
No opinion	No opinion	No opinion	
Dependent on location	Little or no consideration	Only as to ultimate cost	Dependent on location
Only in municipalities	No opinion	No opinion	
Dependent on location	Favorable to concrete	Favorable to concrete	Dependent on location
No opinion	No opinion	No opinion	
No opinion	No opinion	No opinion	
Dependent on location	Favorable to concrete	Only as to ultimate cost	None
Dependent on location	Not to be considered	No influence	None
Little consideration	Little consideration	Only as to ultimate cost	None
Dependent on location	Not to be considered	Only as to ultimate cost	None
Dependent on location	Not to be considered	Only as to ultimate cost	None
Not to be considered	Not to be considered	Not to be considered	None
No opinion	No opinion	No opinion	
No opinion	No opinion	No opinion	
No opinion	No opinion	No opinion	
Favorable to concrete	Favorable to concrete	Only as to ultimate cost	None
No opinion	No opinion	No opinion	

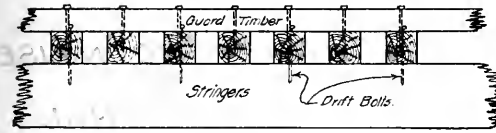
(3) USE OF LAG SCREWS FOR FASTENING GUARD TIMBERS.

During the year 1914 the Committee began the investigation of the use of lag screws to fasten guard timbers to ties on wooden and metal bridges. A goodly number of replies were received to a circular which was sent to the various roads throughout the country, but owing to the small number of roads using lag screws, another circular was prepared and sent to such roads as reported having had no experience with them. In this last circular one of the queries was whether the road communicated with would be willing to give lag screws a trial on some of its bridges on the recommendation of the Committee. Thirty-three roads indicated their willingness to make this trial, and the Committee recommended that the trial be made.

The work for this year has been to formulate plans and methods of procedure for further investigation. A plan was prepared (Diagram A) illustrating the practice of several of the railway systems having had success in the use of lag screws. There is also shown on the plan the general ideas of the Committee relative to such construction, so that investigation and experiment might be carried on along similar lines and results compared.

A circular was prepared and a copy of the plan attached. This communication was sent to the thirty-three roads indicating their willingness to make a trial of lag screws, and in the circular it was urged that the road addressed make the trial, following in a general way the ideas of the Committee. Replies to a later communication (see Appendix A) indicate that four roads have already begun the experiment and fourteen others expect to make the experiment as soon as opportunity presents itself or work now in progress develops to that stage where the trial can be made.

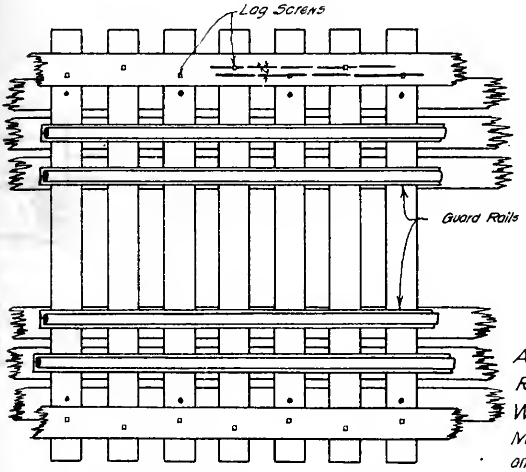
A table has been prepared from replies received to circulars of July, 1914, and January, 1915 (see Appendix B), showing what roads have used or are using lag screws successfully; and what roads are making or planning to make a further trial of this method. In spite of the very general satisfaction expressed by the roads using lag screws, and in view of the fact that comparatively few roads have used them, and that a few of the roads using them report adversely and have abandoned their use; your Committee does not yet feel justified in recommending the adoption of lag screws for fastening outer guard timbers as good practice. Your Committee, however, believes that more time should be given for the trials now in progress; and for others which it is hoped can be arranged for; and therefore submits this as a progress report only and recommends the continuation of the subject for next year's study.



ELEVATION

Note:-

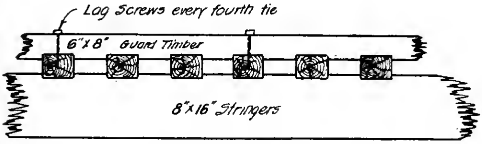
Ties and Guard Timbers to be sized one dimension, omit dapping of Guard Timbers and Ties.
Use Lag Screws in every tie, holes to be bored for Lag Screws one inch deeper than penetration of Lag Screw
Fasten alternate ties to stringers.
Lag Screws to be staggered 2 in in guard timbers.



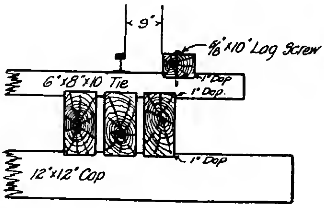
PLAN

DIAGRAM A.

AMERICAN RAILWAY ENG. ASSOCIATION
Recommendations of Committee VII
WOODEN BRIDGES AND TRESTLES
Method of fastening Guard Timbers to Ties on Decks of Wooden Trestles.



ELEVATION



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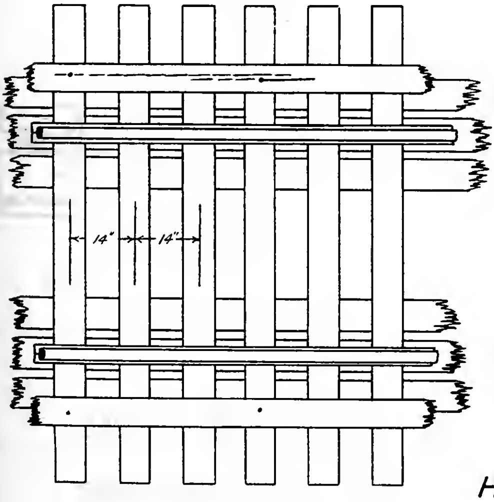
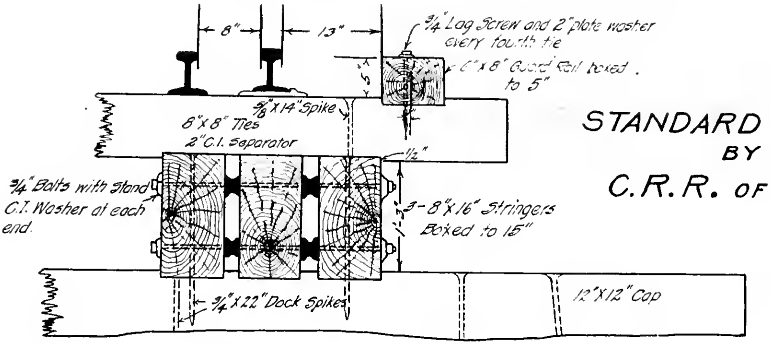


PLAN

Note:-
Four Stringers to be used under each rail on all main line trestles.

STANDARD IN USE
BY
HOCKING VALLEY RY.

STANDARD IN USE BY C.R.R. OF N.J.



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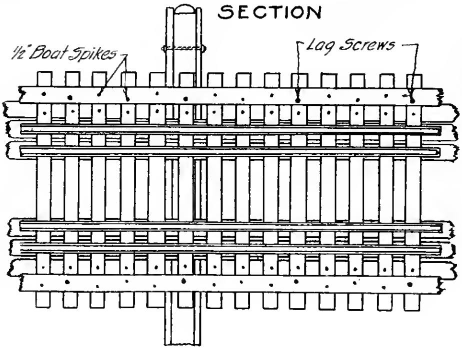

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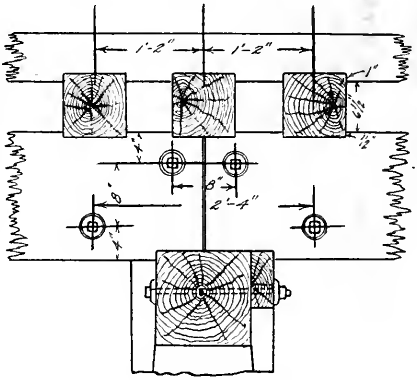

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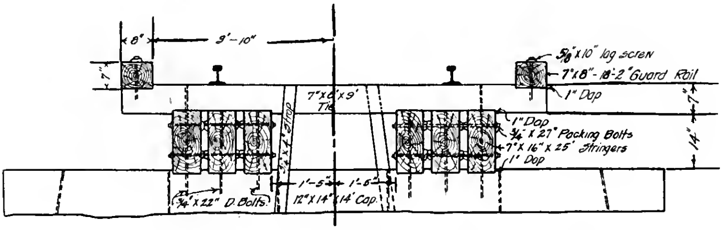

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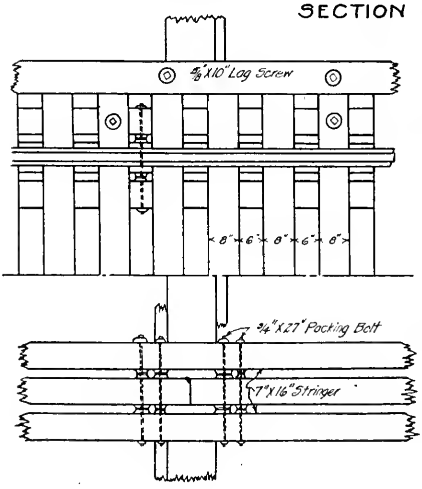
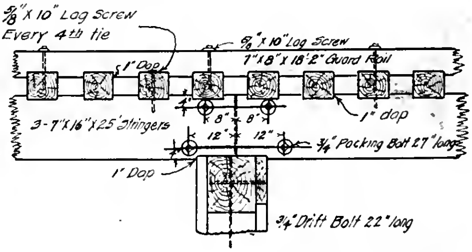
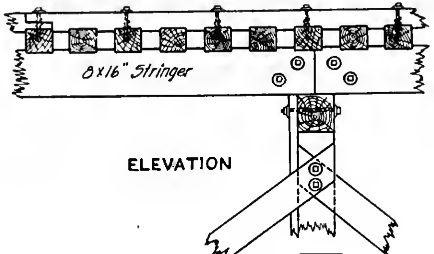


PLAN



ELEVATION

STANDARD IN USE BY MOBILE & OHIO R.R.



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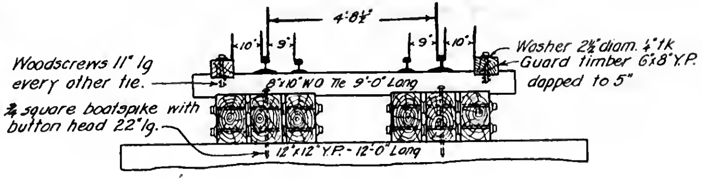

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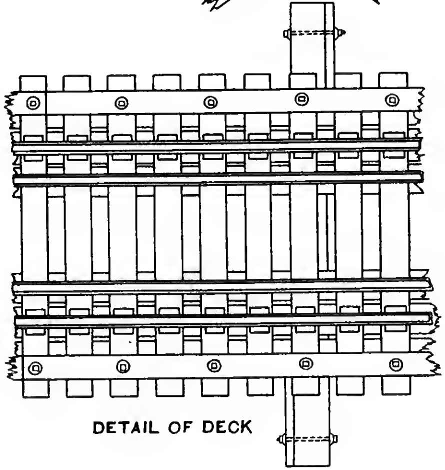


DETAIL OF DECK

DETAIL OF WOOD SCREW

DIMENSIONS OF STRINGERS

Span C-C Bents	For H6b or E3d. Engines	For Engines Heavier than H6b or E3d.
10'-0"	2 pcs 10"x16" Y.P. per rail	2 pcs 10"x16" Y.P. per Rail.
12'-0"	3 pcs. 8"x16" " " "	3 pcs 10"x16" " " "
14'-0"	3 pcs 10"x16 " " "	Steel Stringers to be used in this span.

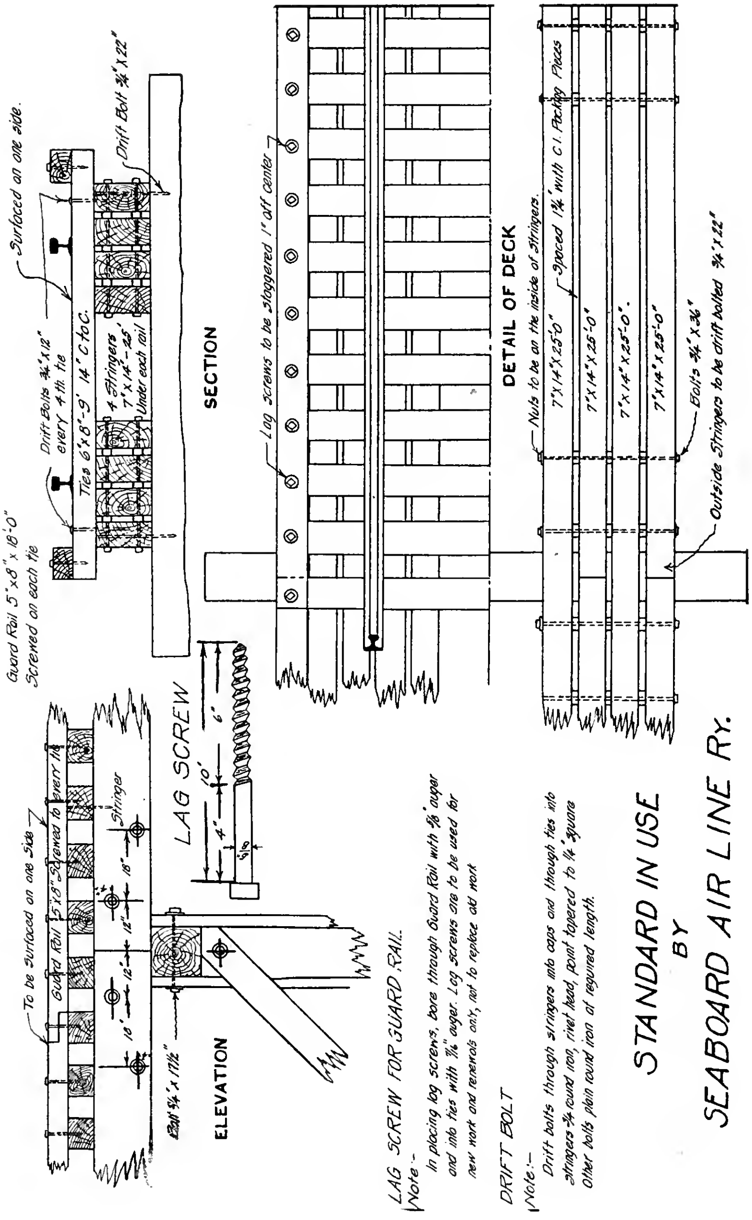
Notes:–

Where trestle is 10'-0" high or less, transverse bracing to be used on curves only.

All surfaces in contact and all surfaces disturbed by saw, axe or adze, also screw holes in ties, to be coated with hot dead oil of tar creosote before assembling.

All bolts ¾" diam. with 3" diam. washer ¼ thick under head and nut.

STANDARD IN USE
BY
PENNSYLVANIA RAILROAD



LAG SCREW FOR GUARD RAIL.

Note:-

In placing lag screws, bore through Guard Rail with 5/8" auger and into ties with 7/16" auger. Lag screws are to be used for new work and renewals only, not to replace old work.

DRIFT BOLT

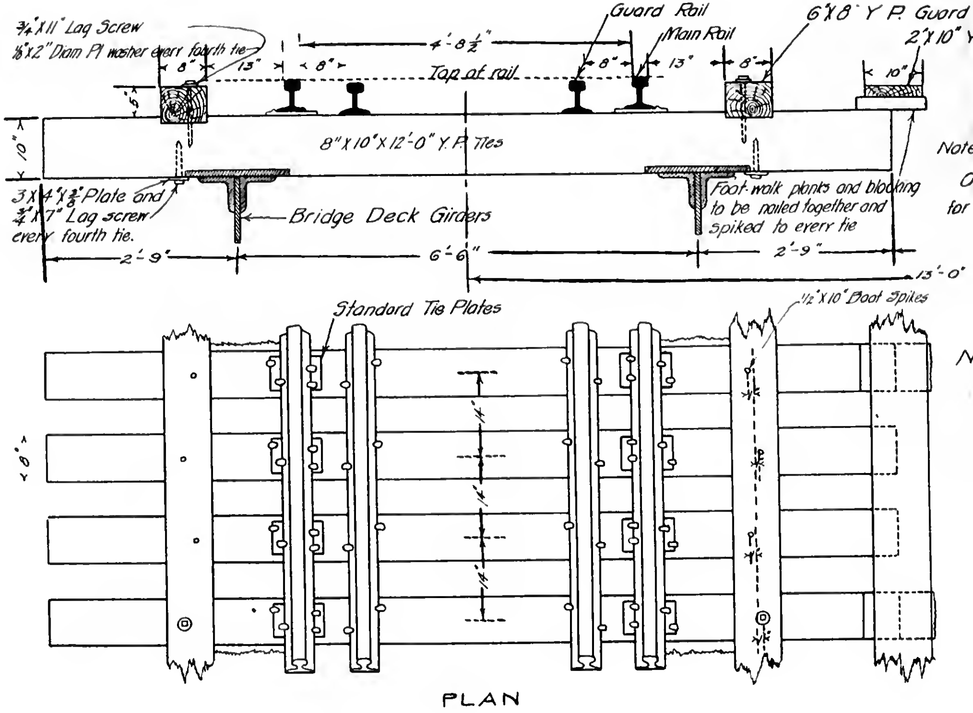
Note:-

Drift bolts through stringers into caps and through ties into stringers ¾" round iron, rivet head, point tapered to ¼" square. Other bolts plain round iron of required length.

STANDARD IN USE

BY

SEABOARD AIR LINE RY.



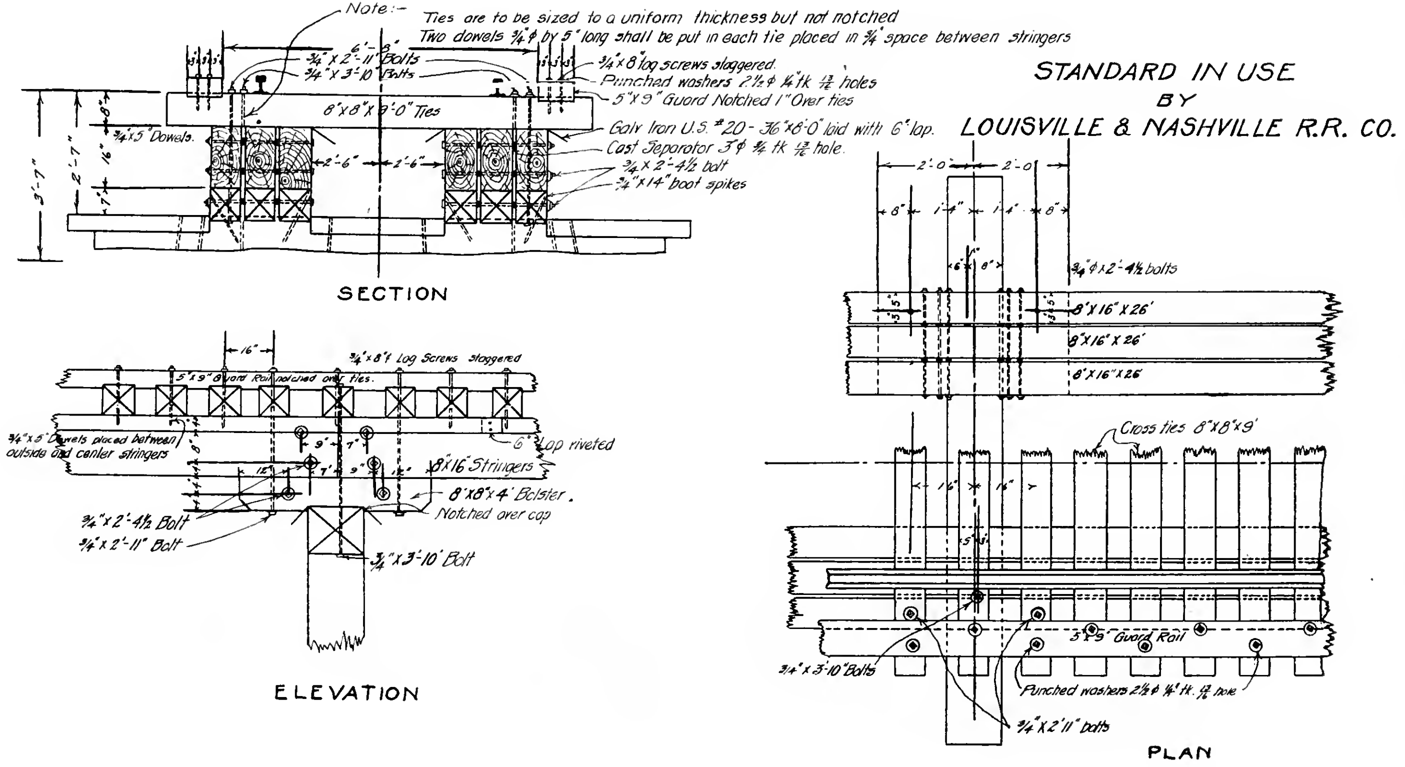
Note:-

One track of double track construction of floor for steel bridge.

Note:-

Lag screws and boat spikes to be of the sizes indicated on the plan and of lengths to give at least 6" hold in the ties. Lag screws and boat spikes in guard rails to be 1" off center.

STANDARD IN USE
BY
PHILA. & READING RY.


STANDARD IN USE
BY
LOUISVILLE & NASHVILLE R.R. CO.
Note:- Ties are to be sized to a uniform thickness but not notched
Two dowels 3/4"ϕ by 5" long shall be put in each tie placed in 3/4" space between stringers
3/4" x 2'-11" Bolts
3/4" x 3'-10" Bolts
6'-8"
3/4" x 8" log screws staggered.
Punched washers 2½ϕ 1/4" tk 13/16 holes
5" x 9" Guard Notched 1" Over ties
8" x 8" x 9'-0" Ties
3/4" x 5" Dowels.
Galv Iron U.S. #20 - 36" x 8'-0" laid with 6" lap.
Cast Separator 3"ϕ 3/4 tk 13/16 hole.
3/4 x 2'-4½ bolt
3/4" x 14" boot spikes
2'-6"
2'-6"
3'-7"
2'-7"
8"
16"
7"
SECTION
16"
3/4" x 8" ϕ Log Screws staggered
5" x 9" Guard Rail notched over ties.
3/4" x 5" Dowels placed between outside and center stringers
6" Lap riveted
8" x 16" Stringers
8" x 8" x 4' Bolster.
Notched over cap
3/4" x 2'-4½ Bolt
3/4" x 2'-11" Bolt
3/4" x 3'-10" Bolt
9"
7"
12"
ELEVATION
2'-0"
2'-0"
8"
1'-4"
1'-4"
8"
6"
8"
3/4"ϕ x 2'-4½ bolts
8" x 16" x 26'
8" x 16" x 26'
8" x 16" x 26
Cross ties 8" x 8" x 9'
16"
16"
5" x 9" Guard Rail
3/4" x 3'-10" Bolts
Punched washers 2½ϕ 1/4" tk. 13/16 hole
3/4" x 2' 11" bolts
PLAN

Appendix A.

TABULATION OF REPLIES TO CIRCULARS OF AUGUST 5, 1915, AND OCTOBER 12, 1915, RELATIVE TO EXPERIMENTAL TESTS ON USE OF LAG SCREWS.

Railroad.	Are Now Making Test	Will Make Test for Report.	Remarks.
Akron, Canton & Youngstown	No	No	Not yet, doubtful.
Buffalo, Rochester & Pittsburgh	Yes		3 plate girders fastened.
Boston & Albany	No	Yes, soon	On one span of Ware River Bridge.
Central of Georgia	Yes	No	Think they are all right.
Chicago, St. Paul, Minneapolis & Omaha	No	Yes	5 bridges, one on each district being tried.
Chicago, Indianapolis & Louisville	No	No	Don't think it advisable to make test.
Canadian Government Railways	No	Yes, soon	One bridge, will report.
Chicago Junction	No	No	Did not put them on. No report.
Canadian Pacific	No	Yes, soon	Soon as opportunity presents itself.
Denver & Rio Grande	No	Yes, soon	Several girders and perhaps trestle.
Duluth, South Shore & Atlantic	No	Yes, now applying	2 important bridges this fall.
El Paso & Southwestern	No		Prefer drift bolts.
International & Great Northern	No	No	Much experience and don't like them.
Indiana Harbor Belt	No	Yes, soon	Lags ordered.
Illinois Central	No	Yes, soon	1 trestle ½ each way.
Long Island	Yes		Fear test will not be favorable.
Lake Superior & Ishpeming	No	Yes, not soon	No report until next year.
Michigan Central	Yes		Looks very good and holding.
Northern Pacific	No	Yes, soon	This fall sometime. One bridge.
Norfolk Southern	No	No	Can't see any advantage in them.
St. Louis & Southwestern	No	No	Not in favor of lag screws.
Spokane, Portland & Seattle	No	Yes, one trestle	About January 15th.
Western Maryland	No	Yes, soon	100 ft. of bolts and lags and report.
Watauga & Yadkin River	No	Yes, but not soon	Report doubtful.
Spokane International	No	Yes, soon	One trestle being built 500 ft. long.

Appendix B.

TABLE SHOWING ROADS WHICH ARE NOW USING, MAKING TEST OF OR PREPARING TO TEST LAG SCREWS FOR FASTENING GUARD TIMBERS.

No.	Railroad.	Remarks.
1.	Akron, Canton & Youngstown	Not yet prepared to test. Doubtful when.
2.	Aransas Pass Terminal	Entirely satisfactory. Best method.
3.	Boston & Albany	Will soon make test on one span of bridge.
4.	Boston & Maine	In use on trestles and steel. Standard for 25 years.
5.	Buffalo, Rochester & Pittsburgh	Are now making test.
6.	Cleveland, Cincinnati, Chicago & St. Louis	In use on trestle and steel, alternately with bolts; considering use of lags only.
7.	Chicago Great Western	Not using. Will likely make test.
8.	Central of Georgia	Have had good success, think they are O. K.
9.	Canadian Government Railways	Not yet used. Will test on one bridge and report.
10.	Chicago, Indianapolis & Louisville	Doubtful, but may make test.
11.	Canadian Northern	In use 20 years on trestle and steel, better than bolts.
12.	Canadian Pacific	Not yet used. Will make test soon.
13.	Central of New Jersey	In use on trestles and steel in connection with bolts.
14.	Chicago, St. Paul, Minneapolis & Omaha	Not yet used. Are testing them on five bridges.
15.	Chicago Junction	Not yet used. Will probably make test.
16.	Cuban Central	Never used them. Will make test.
17.	Chicago, Burlington & Quincy	Practice is to use them. Satisfactory.
18.	Delaware & Hudson	In use on trestle and steel. Preferable to bolts.
19.	Duluth & Iron Range	Worthy of trial. Will accept results of other roads.
20.	Denver & Rio Grande	Will test on several girders and perhaps trestle.
21.	Duluth, South Shore & Atlantic	Now testing on two important bridges.
22.	Elgin, Joliet & Eastern	Will make test.
23.	El Paso & Southwestern	Will probably make test.
24.	Grand Rapids & Indiana	Worthy of trial. Have used them on steel with success.
25.	Gulf & Ship Island	Worthy of trial. Will test.
26.	Hudson Bay	Worth trial. May make test.
27.	Hocking Valley	In use for years. Satisfactory.
28.	Illinois Central	Limited use. Will test one trestle half each way.
29.	International & Great Northern	Successful on steel bridges. Will test on trestle.
30.	Indiana Harbor Belt	Worth a trial. Will test.
31.	Indiana Harbor Belt	Material ordered for a test.

32. International & Great Northern	Have tried them and don't like them.
33. J. P. Snow, Consulting Engineer	Have used. Highly recommend them.
34. Kansas City Terminal	In use on trestle and steel.
35. Kanawha & Michigan	In use on trestle and steel. Better than bolts.
36. Louisiana & Arkansas	In use on trestles. Prefer them to bolts.
37. Louisville & Nashville	In use on trestle and steel. Very successful.
38. Long Island	Making test. Recommend large shoulder and omit washer.
39. Lake Shore Electric	Worth trial. May make test.
40. Lake Superior & Ishpeming	Worth trial. Will test next year.
41. Maine Central	Now using them with good success.
42. Michigan Central	Are making test. Test looks good and is holding.
43. Missouri Pacific	Standard for wooden bridges.
44. MacKenzie, Mann & Co	Intend to try them on first opportunity.
45. Mobile & Ohio	In use on trestles. Very satisfactory.
46. Mississippi River & Bonne Terre	In use on trestle and steel. Perfectly satisfactory.
47. New York, New Haven & Hartford	In use on trestle and steel. Better than bolts, will not loosen.
48. Northern Pacific	Will test on one bridge soon.
49. Nashville, Chattanooga & St. Louis	In use on trestle and steel. Satisfactory.
50. Norfolk & Western	Doubt merit, but think it worthy of trial.
51. Pennsylvania	In use on trestle and steel. Preferable to bolts or boat spikes.
52. Philadelphia & Reading	In use on trestle and steel. Very good.
53. Puget Sound	In successful use.
54. San Pedro, Los Angeles & Salt Lake	Worth trial, but doubtful if test will be made.
55. Seaboard Air Line	In use on trestle only. Very successful.
56. Spokane International	Will test on 500-ft. trestle now building.
57. Spokane, Portland & Seattle	Not used. Will test on one trestle this year.
58. Toledo & Ohio Central	Have found them unsatisfactory.
59. Terminal Association of St. Louis	Not used, probably will test.
60. Wabash	In use on trestle only. Satisfactory.
61. Waddell & Harrington	Worth a trial.
62. Western Maryland	Not used, worth trial. Will test 100 ft., lags and bolts.
63. Wheeling & Lake Erie	Worth a trial. Probably will test.
64. Watauga & Yadkin River	Intend to try, but not soon.

Note.—Table compiled from replies to circulars.

Roads now using lag screws for trestle or steel	27
Roads now testing, planning to test or recommend test	37
Total number of roads replying	131

REPORT OF COMMITTEE VIII—ON MASONRY.

F. E. Schall, *Chairman;*	F. L. Thompson, *Vice-Chairman;*
R. Armour,	W. S. Lacher,
John C. Beye,	C. P. Richardson,
H. A. Cassil,	R. A. Rutledge,
T. L. Condron,	G. H. Scribner, Jr.,
J. K. Conner,	F. P. Sisson,
L. J. Hotchkiss,	Job Tuthill,
Richard L. Humphrey,	J. J. Yates,

Committee.

To the Members of the American Railway Engineering Association:

The Committee on Masonry, during the past year, held one meeting of the whole Committee on December 6, 1915, at Chicago. Meetings of the various Sub-Committees were held at different points; most of the committee work, however, was carried on through correspondence between the members of the Sub-Committees.

The following Sub-Committees were appointed to deal with the subjects assigned by the Board of Direction:

Sub-Committee "A"—*"Make critical examination of the subject-matter in the Manual, and submit recommendations for changes."* T. L. Condron, Chairman; L. J. Hotchkiss, W. S. Lacher, G. H. Scribner, Jr.

Sub-Committee "B"—*"Report on cost and method of constructing concrete piles."* F. L. Thompson, Chairman; John C. Beye, C. P. Richardson, F. P. Sisson.

Sub-Committee "C"—*"Report on appearance, wearing qualities and cost of surface finish of concrete."* Job Tuthill, Chairman; H. A. Cassil, J. K. Conner, R. A. Rutledge.

Sub-Committee "D"—*"Report on design of foundations for piers, abutments, retaining walls and arches in various soils and depth of water (not including pneumatic foundations)."* J. J. Yates, Chairman; R. Armour, Richard L. Humphrey, F. E. Schall.

Joint Committee on Standard Specifications for Cement. H. A. Cassil, J. K. Conner, F. E. Schall, F. P. Sisson, J. J. Yates.

Joint Committee on Concrete and Reinforced Concrete. H. A. Cassil, F. E. Schall, F. P. Sisson, J. J. Yates.

REVISION OF MANUAL.

The Sub-Committee, on account of the new Manual being in print, prepared its report, and, after written discussion between the members of the Masonry Committee, the report was forwarded to the Secretary.

COST AND METHOD OF CONSTRUCTING CONCRETE PILES.

This Committee made further study of the data collected and presents a report on the subject.

The Committee also submits general specifications for the construction of pre-molded concrete piles and the driving of such piles. Typical designs of pre-molded reinforced concrete piles were submitted in last year's Proceedings. The so-called cast-in-place concrete piles being of patented designs or method of construction, were not considered by the Committee.

APPEARANCE, WEARING QUALITIES AND COST OF SURFACE FINISH OF CONCRETE.

This Committee presents a final report on the subject and submits general specifications for different surface finishes of concrete used in general railroad construction.

The Committee also presents certain conclusions on the subject for adoption and publication in the Manual.

DESIGN OF FOUNDATIONS FOR PIERS, ABUTMENTS, RETAINING WALLS AND ARCHES IN VARIOUS SOILS AND DEPTH OF WATER (NOT CONSIDERING PNEUMATIC FOUNDATIONS).

This Committee confined its activity to the searching of records as to the general practice of investigating the carrying capacity of foundation soils. A number of questions relative to the method of testing foundations in general were submitted to members of the Association and others; the answers to the questions are presented in the progress report of the Committee in tabulated form. The work of this Sub-Committee embraces a very large and important field for investigation and study and its work will necessarily extend over a number of years and the reassignment of the subject is requested.

The Committee will, in the near future, prepare a form showing in what manner records of tests of foundation soils may be kept, as a guide to the Engineer making such tests, and to facilitate the work of your Committee.

It is most earnestly hoped that the members of the Association will co-operate in this matter, having tests of foundation soils recorded and copies of such records furnished to the Masonry Committee.

JOINT COMMITTEE ON SPECIFICATIONS FOR CEMENT.

(COMMITTEE C-1, AMERICAN SOCIETY FOR TESTING MATERIALS.)

The Joint Committee held several meetings during the past year.

The report of the Joint Conference, appointed to reconcile differences between the specifications of the American Society for Testing

Materials and the United States Government Specifications for Cement, presented its long-looked-for report on June 15, 1915. The report is very complete, but in addition to reconciling the differences existing at the time the Joint Conference was appointed, the Committee undertook to make a number of changes in the specifications. This action, by reason of not being represented on the Joint Conference, was resented by the manufacturers of cement and at the meeting on June 15th at Philadelphia, as well as at the meeting held on June 24, 1915, at Atlantic City, forced the adoption of a motion to suppress the report of the Joint Conference until thoroughly investigated, and caused the adoption of a motion to submit the report to a number of sub-committees to determine the value of the specifications as presented and the effect the specifications will have on the cement manufacturing interests. These sub-committees are supposed to report within one year to Committee C-1 of the American Society for Testing Materials. The representatives of the American Railway Engineering Association are represented on the sub-committees to investigate the proposed specifications.

The Sub-Committee on Accelerated Tests of Cement held one meeting during the past year and decided that until such tests have received a more complete investigation and until the value and purpose of the accelerated test is more fully established, the existing requirements as to constancy of volume of cements should govern.

JOINT COMMITEE ON CONCRETE AND REINFORCED CONCRETE.

The Joint Committee held several meetings during the past year, at which the members from the Masonry Committee assigned to the Joint Committee participated under a ruling by the Board of Direction.

The subjects under consideration at these meetings comprised the presentation of formulas for design of reinforced concrete floors supported by columns for buildings and also the quality of reinforcing steel, more particularly the use of reinforcing bars rolled from steel rails.

The general opinion of a number of the members of the Joint Committee is that the Committee has outlived its usefulness and an early closing of its affairs may be looked for. It is thought that a committee with new members can be appointed whenever the conditions seem to require such action.

The question of a contribution to the extent of $250 by the American Railway Engineering Association as its proportionate share of the expenses during the past years of the Joint Committee will be presented to this Association, and, inasmuch as the members from this Association participated in the work of the Joint Committee, favorable action as to some contribution is recommended, understanding that a sufficient number of copies of the report of the Joint Committee are furnished to the American Railway Engineering Association.

Your members assigned to the Joint Committee request action by this Association on the following points:

(1) Are steel reinforcing bars rolled from steel rails recommended for general use in reinforced concrete construction?

(2) Are steel reinforcing bars rolled from steel rails recommended for general use in reinforced concrete construction, provided such bars are used only when the bars do not require to be bent?

(3) Are steel reinforcing bars rolled from steel rails recommended for general use in reinforced concrete construction under the same conditions as steel reinforcement bars rolled from billets under the requirements of the specifications for high carbon steel of the American Society for Testing Materials? (See Year Book 1914, American Society for Testing Materials, pages 87-89.)

NEXT YEAR'S WORK.

It is recommended that the subject of cost and method of constructing concrete piles be reassigned to the Committee for further consideration; the Committee to present additional typical designs for such piles for different loading and rules for the driving of such piles under various conditions and loading. The subject of certain typical designs of foundations for piers, abutments, retaining walls and arches in various soils and depths of water (not including pneumatic foundations) to be reassigned to the Committee.

Respectfully submitted,

COMMITTEE ON MASONRY.

COST AND METHOD OF CONSTRUCTING CONCRETE PILES.

Your Committee, in its progress report last year, presented typical designs for concrete piles and tables showing the cost and use of such piles.

No further information was requested from the membership of the Association on this subject, your Committee confining its work to further study of the data presented last year.

The typical designs for concrete piles, illustrated in last year's Proceedings, furnish, in the opinion of your Committee, a sufficient variation to give information in regard to designs of piles that may be suitable for certain classes of work.

It is to be understood that the load which a concrete pile is to carry, the nature of the soil into which it is to be driven, whether the pile will act as a column on the hard bottom or whether the pile receives support from the soil through skin friction, are factors that enter into the question as to size, design and amount of steel reinforcement required.

The question as to whether square, octagon or hexagon-shaped concrete piles should be used, depends upon the style of the structure the piles are to carry; the question as to whether tapered or straight concrete piles should be used depends upon the soil in which they are to be driven and whether the piles act as a simple column or whether skin friction may be obtained; these questions must be decided by the designer. The hexagon-shaped pile, either tapered or straight, by reason of its comparative constant diametric section, seems to present the most suitable shape for general conditions. A square pile, if twisted in driving, may cause the enlargement of the supporting cap in case of narrow work, while under the same conditions the hexagon-shaped pile, which does not materially change in diameter, may not cause such enlargement.

The cost of constructing concrete piles depends upon the number, length and size of the piles required at a given point, the load that a pile is to carry, the amount of steel reinforcement required, the design of the pile (either as a free column for soft ground or a supported column for harder ground), the shape of the pile and the nature of the soil in which a concrete pile is to be driven. The available space for manufacturing and storage for seasoning of piles, and the distance of such storage ground from the site of the structure have a large bearing on the cost of constructing concrete piles.

No exact cost data can be set up by reason of the varying conditions, both as to structures and localities. A fair idea, however, can be obtained by examining the tables published in last year's Proceedings.

Concrete piles, to obtain good results, should be seasoned not less than 30 to 40 days before handling and driving, depending upon the amount of driving expected and the season of the year when the piles are made.

Your Committee considered only the pre-molded concrete pile, as that style of pile was understood to be covered by the instructions to the Committee.

SPECIFICATIONS FOR CONSTRUCTING CONCRETE PILES.

1. The piles shall be made in accordance with the dimensions shown on the plans.

2. The workmanship and materials shall be in accordance with the Specifications for Plain and Reinforced Concrete and Steel Reinforcement as embodied in the Manual, with the following modifications:

3. The coarse aggregate shall consist of material such as crushed stone or gravel varying in size from ¼-inch to ¾-inch; it shall be clean, hard, durable and free from all deleterious matter.

4. The proportions of the concrete shall be 1 part cement, 2 parts fine aggregate and 4 parts coarse aggregate.

5. The forms for concrete piles shall be made under the requirements for forms of concrete and reinforced concrete as published in the Manual; they must rest upon supports spaced not over 4 feet centers; forms are generally collapsible, the bottom left under the piles until the piles have seasoned sufficiently to permit turning upon the supports.

6. Concrete piles shall not be handled on the supports under 10 days or moved to the site for driving, unless they have seasoned 30 to 40 days; all concrete piles must be handled carefully, avoiding all drops or heavy jarring.

SPECIFICATIONS FOR DRIVING CONCRETE PILES.

1. Piling shall be protected during driving with an approved cushion cap.

2. The driving or jetting of piles shall be governed by "Pile Driving—Principles of Practice," given in the Specifications for Workmanship for Pile and Frame Trestles in the Manual of the Association.

3. In driving, preference will be given to a steam hammer. Where a drop hammer is permitted a heavy hammer with a short drop shall be used; where jetting and driving are employed a steam hammer is preferred.

4. Any pile injured in driving or driven out of place shall either be pulled out, cut off or replaced by a new pile, as may be directed by the Engineer.

5. On sloping ground and where necessary, a suitable hole shall be dug at the location of each pile to aid in holding it in proper position.

6. Before driving the piles shall be carefully located and set to the line called for on the plan, and the pile-driver leads held in proper position by means of guy lines.

7. Unless otherwise called for on the plans, piles shall be driven in a plumb position as near as possible; any pile out of plumb more than one-half inch per foot, or out of position more than one foot, shall

be pulled and re-driven or cut off and replaced by a new pile, if so required by the Engineer.

8. All reasonable efforts shall be made to drive the concrete piles to plan cut-off, the lengths of piles having been determined by borings or test piles; driving will be continued until this point is reached or until the following conditions are met. (Cases where driving is through soft soil to hard bottom or rock excepted.)

9. Piles which are to carry a load of .... net tons shall have a penetration for the last 6 blows not exceeding .... inch per blow by the following hammers:

(a) Steam hammer weighing ...... lbs., weight of plunger .... lbs., height of drop .... feet, or steam hammer of equal mechanical effect.

(b) Drop hammer weighing ...... lbs., height of drop .... feet, or drop hammer of equal mechanical effect.

10. In selecting the weight of the hammer, the size and weight of the pile should be considered.

CUTTING OFF PILES.

1. Where it is not possible to drive concrete piles to plan cut-off, it will be necessary to remove a portion of the pile above this point, and, unless otherwise specified, a variation of 4 inches will be allowed above the plan cut-off for the inequalities of the tops of the piles. All shaken or loosened parts of the head of cut-off piles shall be removed.

2. Where reinforcement has to be cut off it shall be done by a hack saw or oxy-acetylene torch.

APPEARANCE, WEARING QUALITIES AND COST OF VARIOUS METHODS OF SURFACE FINISH OF CONCRETE.

APPEARANCE.

The appearance of the surface of concrete is dependent upon the materials of which the concrete is composed, the forms in which the concrete is placed and the treatment given the surface after the forms are removed. Without special treatment the color is due almost entirely to the cement, the sand ordinarily used affecting it only to a minor extent. When treated mechanically the colors of the aggregates have a large influence upon that of the surface, the size of the grains of the sand and of the stone modify the texture, and a variety of color and texture can be obtained in pleasing effects by a careful selection and proportioning of the aggregates. The appearance is also influenced by the amount of water used, as this affects the density of the concrete and the time of setting and thereby the color. If the surface is allowed to dry rapidly the color will be lighter than if kept damp and allowed to dry slowly.

DURABILITY.

The durability of a finish depends mainly upon the resistance of the surface of the concrete to the penetration of moisture. A skin of mortar is produced against the form and the more non-absorbent the form material the richer in cement will this outside coating be and therefore the more impervious to moisture. When this skin of mortar is removed by any process, the resulting surface is more susceptible to the influence of the weather and with a porous concrete the action of frost may produce serious disintegration. The quality of the concrete should therefore be taken into consideration in deciding upon the treatment for the surface, a richer mixture and greater density being desirable if the outer coating is to be removed. A roughened surface is more susceptible to discoloration from dust and smoke and in general the smooth natural surface left by the forms is the most durable, both as to wearing qualities and color.

METHODS OF FINISHING.

The following methods are those generally used for finishing concrete surfaces:

Spading or Working the Coarse Aggregate Away from the Form.

1. As the concrete is deposited, the coarse aggregate is carefully worked back from the forms into the mass of the concrete with spades, fine stone forks or other tools, leaving only mortar next to the forms. All holes or voids appearing after the removal of the forms should be filled with a mortar made of the same proportions of cement and sand as the mortar of the concrete and rubbed smooth and even with the surface with a wooden float.

This method is generally used and where decorative treatment is not required, produces the best finish for the least expense. The resultant surface should be as smooth as the forms against which it is made, is nearly impervious to moisture and its wearing qualities are equal, if not superior, to those of any other method. By using dressed lumber for forms, careful workmanship, and coating the inside with raw paraffin, very smooth surfaces, free from grain marks, can be obtained.

Forms of metal or wooden forms lined with metal give a smoother surface than bare wood, but being non-absorbent, an excess of cement is brought to the form, producing a thin skin of rich mortar on the surface of the concrete, that later may develop unsightly hair cracks and checks.

Coating with a Wash of Cement.

2. After the forms are removed a wash usually of one part cement and one part sand is applied to the surface with a brush. This fills up the pores, covers the small inequalities and wood grain marks and produces a smooth and more even finish and color. The film of mortar thus put on usually develops checks and hair cracks and later scales and flakes off.

Rubbing.

3. This method consists in rubbing the surface of the concrete to the desired degree of smoothness with carborundum bricks, cement bricks or with wooden floats in the manner described below. The rubbing smooths inequalities, fills the pores and small cavities and forms a surface of uniform finish and appearance that does not flake or scale. The earlier the rubbing is done the better are the results.

SPECIFICATIONS FOR RUBBING WITH CARBORUNDUM OR CEMENT BRICKS.

1. As the concrete is deposited, the coarse aggregate shall be carefully worked back from the forms with spades, fine stone forks or other proper tools so as to bring a layer of mortar against the face of the forms.

2. The forms shall be removed as early as practicable from the surfaces to be finished, joint marks, projections and inequalities removed and all cavities filled with mortar. These surfaces shall then be thoroughly wet with water and rubbed to a smooth uniform finish with a flat stone, a cement brick made of one part Portland cement to two or two and one-half parts sand; or first with a No. 8 carborundum brick, followed by a No. 30, as may be necessary to obtain the desired degree of smoothness.

3. No mortar or cement shall be applied except to fill distinct holes or cavities. Uneven places shall be smoothed by rubbing down and not by plastering. The surface shall not be washed after the rubbing but shall be protected by moist canvas or other suitable means for three days after the rubbing is completed.

SPECIFICATIONS FOR RUBBING WITH WOODEN FLOATS.

1. As the concrete is deposited, the coarse aggregate shall be carefully worked back from the forms with spades, fine stone forks or other proper tools, so as to bring a layer of mortar against the face of the forms.

2. The forms shall be removed from the surfaces to be finished while the concrete is green; joint marks, projections and inequalities removed and all cavities filled with mortar. The surfaces shall then be rubbed with soft wood floats and kept well flushed with clean water during the rubbing. When the desired finish is obtained the whole surface shall be thoroughly washed.

3. No mortar or cement shall be applied except to fill holes or cavities. Uneven places shall be smoothed by chipping and rubbing down and not by plastering.

4. All work shall be finished free from discolorations, streaks, or other imperfections that injure the appearance or life of the work.

Removing the Outside Mortar and Exposing the Aggregate.

5. This method requires a coating or layer of specially prepared aggregate on the outside of the concrete where the surface is to be treated. By carefully selecting and combining the aggregates a variety of color and textures can be obtained. A combination of gravel and crushed stone, for instance, gives a more varied effect than either alone. The color and texture depend upon the color, size and proportions of the aggregates used, therefore accurate measurement of materials, gaging with the proper amount of water and careful mixing for each batch are necessary for uniform results. Where the surfaces are too large to concrete in one day, the forms must be constructed so that the face forms can be readily removed from the sections as they are ready for treatment. Good form material and careful construction are also essential.

The surface coating prepared to produce the desired appearance is placed against the form as the concrete is deposited and after removing the forms the surface is finished by:

(a) Washing or scrubbing with brushes and water.
(b) Treating with acids.
(c) Removing the mortar with a sand blast.

SPECIFICATIONS FOR WASHED OR SCRUBBED SURFACES.

1. The outside layer for the finished surface shall be composed of one (1) part cement to two (2) parts coarse sand and two (2) parts granolithic grit (or whatever aggregate is desired), mixed to stiff mortar. The aggregate shall be (description of aggregate) crushed to pass a sieve of .... mesh and screened free of dust. For vertical surfaces the mixture shall be placed by skilled workmen against the face of the forms in a layer not less than one and one-half (1½) inches thick, as

the concrete is placed so that it shall form a part of the body of the work. Care shall be taken to prevent air spaces or voids in the surface.

2. As soon as the concrete has sufficiently hardened, but is still quite green, the forms shall be removed from the surfaces to be finished and all voids be filled with the surface mixture.

3. The surface shall then be washed with water and brushes of stiff fiber or wire until the grit (or other aggregate) is sufficiently exposed and projects slightly, but not enough to injure its adhesion to the mass. The whole surface shall then be rinsed thoroughly clean and kept moist and protected from the sun for not less than three (3) days.

4. For horizontal surfaces the surface mixture shall be not less than one and one-half (1½) inches thick, placed immediately after the concrete is deposited and before it has set, troweled or floated to an even surface and after it has set sufficiently hard shall be washed as above until the grit (or the aggregate) is exposed.

Treatment with Acid.

The surface layer is washed with acid and scrubbed as above, commercial hydrochloric or nitric acids are used, diluted usually one part to two or three parts of water, according to the age of the concrete as determined by experiment on the work. Great care must be taken to remove completely all traces of the acid, otherwise its action will continue and the surface be permanently discolored.

This treatment is sometimes used after the washing or scrubbing method, to clean thoroughly all traces of cement from surface of the aggregate and better bring out its natural color. The surface is washed with a dilute solution of hydrochloric acid with an ordinary calcimine brush and rubbed while wet with a stiff vegetable fiber brush. The acid should not be left on more than thirty minutes and should then be thoroughly and carefully washed off.

Treatment with Sand Blast.

Removing the mortar with the sand blast has not generally proved successful, because of the varying density or hardness of ordinary concrete, and consequent difficulty in removing the mortar to a uniform depth. The nozzle should not be larger then one-eighth (⅛) inch diameter and be held close to the surface to be cut and a very hard sand with angular grains must be used.

Tooling the Surface.

5. Concrete may be cut or dressed similar to natural stone with a crandall, bush hammer rotary or other tools. This treatment carried to the extent of cutting slightly into the aggregate produces attractive surfaces and bush hammering is considered by many to give the best possible appearance at a reasonable cost. For the best results thoroughly spaded surfaces or surfaces composed of special aggregate are necessary. The aggregate and the mortar should be as nearly of equal hardness as possible, and the smaller and more uniform the size of the aggregate, the more nearly will the resulting surface resemble natural stone.

Scoring or Blocking the Surface.

. 6. The effect of courses can be produced by placing "V"-shaped battens, properly arranged, horizontally on the inside face of the forms. Vertical battens should be limited to construction joints rather than used to imitate stone work. The marks or scorings thus produced break the flat appearance of large surfaces, render expansion joints less prominent and obscure the lines between different days' work. They are quite as effective in rubbed or scrubbed surfaces and prevent the marks so difficult to avoid between two pieces of finishing.

Sidewalk and Floor Finishes.

7. Sidewalks should be finished with a wearing surface not less than one-half an inch thick of mortar composed of one part cement to two parts of hard sand laid at the same time as the base to secure a thorough bonding. A better wearing surface is produced by increasing the thickness to one inch and using one and one-half parts cement, one part coarse sand and two parts granite grit laid at the same time as the base. This top surface should be well troweled and where necessary to prevent slipping, finished with a wood float, a bristle or coarse broom or roughened by small prick marks. All edges and joints should be rounded and finished with a smoothing iron and proper provision made for expansion.

Concrete floors do not stand hard trucking without considerable wear and dust. The wearing surface should be mortar mixed with carborundum, granite grit or other hard aggregate and troweled hard. Some patented combinations of sal-ammoniac and finely divided iron have proved fairly durable.

COST.

Very little reliable data on the cost of the various kinds of finish has been found available. It is generally conceded that the cost of spaded surfaces is practically inappreciable. Costs of some of the other methods from various sources are as follows:

Rubbing with carborundum, 1c to 4c per square foot.
Rubbing with wood floats, 1c to 4c per square foot.
Sand blast, 2c per square foot.
Bush hammering or tooling, 3c to 10c per square foot.

CONCLUSIONS.

SURFACE FINISH OF CONCRETE.

1. For all work not requiring decorative treatment spaded finish is recommended as the most durable, the most readily applied and the most economical.

2. Coating with a wash of cement is not recommended.

3. Rubbing with carborundum bricks or wood floats is next to spading in ease of application and cost.

4. The most pleasing appearance can be obtained by bush hammering or other tool work and where ornamentation is desired this method or scrubbing is recommended.

DESIGN OF FOUNDATIONS FOR PIERS, ABUTMENTS, RETAINING WALLS AND ARCHES IN VARIOUS SOILS AND DEPTHS OF WATER (NOT INCLUDING PNEUMATIC FOUNDATIONS).

Your Committee has confined itself to the collection of information bearing on the methods of design of foundations as reported by various railroad companies and members of the Association.

With the view to continuing the study another year no recommendations are made, but the Committee submits the following as information:

The bearing power of soil for the support of structures is a subject that has not been as thoroughly investigated as the determination of the strength of materials composing structures which are placed on the soil; while investigations have been made for specific cases, no extended tests for determining the pressure that the various soils may safely carry have been made in the past.

The American Society of Civil Engineers have appointed a Special Committee, of which Robert A. Cummings is chairman, to investigate and codify the present practice on the bearing values of soils. This Special Committee in a progress report, February, 1915, to the American Society of Civil Engineers, gives as an appendix a bibliography of publications having to do with the physical properties and bearing values of soils; the Committee states that this is not complete, although it covers over 250 references and it is evident that a vast amount of work is necessary to cover the subject thoroughly.

The work of your Committee embraces this difficult and lengthy problem, and, in order to accomplish something of value to the engineering profession, it is incumbent upon every member of the American Railway Engineering Association, in making investigations and tests of the carrying capacity of soils for specific structures, to keep an accurate account of such investigations, its results and determinations, and furnish such information to your Masonry Committee.

For the purpose of properly recording soil data, the Committee will submit later a form which will not only serve as a guide to the Engineer in making tests, but will also greatly aid the Committee in collating the information obtained.

In the preparation of this and other data your Committee will, in so far as practicable, co-operate with other organizations having the subject under consideration.

The thirty-one (31) answers received from a circular letter sent to the members of the Association are hereinafter given in table form:

TABLE I. METHODS OF PRELIMINARY INVESTIGATIONS.

Atlantic Coast Line	Usually drive a pile, as most of our foundations are pile supported.
Baltimore & Ohio	Borings or test pits.
Canadian Government	Wash borings, diamond drills, test pits, test loads and test piles.
Canadian Pacific	Wash borings, diamond drills, test pits, test loads and test piles.
Central of New Jersey	Wash borings, soft material. Important structures, core borings. Drill at least 10 feet in solid rock. Test pits, test loads and test piles.
Chicago & Northwestern	Hand borings, 2-inch-3-inch augers. Also diamond drills. Sounding rod, test pits, test loads and test piles.
Chicago, St. Paul, Minneapolis & Omaha	Wash borings in more important work, sounding rod, test piles.
Duluth & Iron Range	Augers, borings, test pits and test piles.
Elgin, Joliet & Eastern	Hand borings or well drilling machine, test pits.
Grand Trunk Railway System	Auger to rock. Core drill borings. Drill 5 feet to 10 feet into rock. Sounding rod, test pits, test loads and test piles.
Hocking Valley	Borings, test loads.
Illinois Central	Borings, test pits, test loads and test piles.
Long Island	Wash borings. Soil is universal glacial deposit.
Louisville & Nashville	Borings in rock, test pits, soundings and test piles.
Michigan Central	Wash borings. Well boring machines. Test pits, test loads and test piles.
Missouri, Kansas & Texas	Borings.
Nashville, Chattanooga & St. Louis	Test piles and test pits to determine kind of soil.
New York Central	Core drills or wash borings. Sometimes test pits, test loads and test piles.
Norfolk & Western	Records of old structures and test piles.
Northern Pacific	Wash borings, test pits.
New York, New Haven & Hartford Railroad	Wash borings, test pits, test loads and test piles.
Pennsylvania	Drop or core borings. Borings 50 feet to 100 feet apart. Test loads and test piles.
Pennsylvania Lines West of Pittsburg	Augers, test pits, test loads and test piles.
Public Service	Borings, test pits, test loads and test piles.
Queen & Crescent	Churn drills. Diamond drills, important work. Test pits.

Seaboard Air Line	In difficult work, well drills. Sounding rod.
Southern Pacific	Bore test wells not less than 6 inches diameter, also test piles.
Toronto Harbor Commission	Borings to deep rock. Test pit for shallow rock.
Toronto Terminals	Borings, test pits and test piles.
Westinghouse, Church, Kerr & Co.	Augers and wash borings in soft material. Diamond, calyx or similar drills. Test pits, test loads and test piles.
Lehigh Valley	Borings, test pits, test loads, test piles or other means.

21 railroads have used test pits.

14 railroads have used test loads in connection with test pits.

1 railroad used cofferdams in constructing test pits for important work.

23 railroads have used test piles to determine depth to drive, length of pile required and bearing power.

6 railroads have used sounding rods for preliminary determination of soil conditions.

BEARING VALUE OF SOILS FOR FOUNDATIONS.

The carrying capacity of soils in foundations is dependent on many factors, such as the character and uniformity of the material, the thickness and general strata of the layers and the behavior of the soil against the action of the elements.

The general formation, density, uniformity and thickness of strata of soil vary so much that the testing of the foundation soil and the depth of underlying strata are absolutely necessary for the determination of the safe load that may be placed upon the soil encountered.

For all structures, not only the immediate location for a structure should be investigated, but the surrounding structures, natural conditions of the vicinity and any influence the future development of surrounding property may have on the design of the foundations should be carefully studied.

The following soils are generally considered suitable for foundations:

Solid Rock, 10 to 12 feet in thickness, with nearly horizontal layers or veins, is generally considered sufficient support for most structures. If the rock, however, contains cavities and is not sufficiently homogeneous, the foundation is of questionable value.

Not infrequently the rock strata overlies beds of clay, which may, through exposure to the elements, either by artificial or natural causes, become softened with water. In such cases settlement is likely to occur or if the beds are in an inclined position a sliding or side movement of the courses might be experienced.

It is also possible that through water supply construction the softer strata may be gradually washed or sucked out, causing settlement.

In mining districts the support of the rock may be lost by mining operations. Where mining chambers occur the rock strata must be artificially supported by carefully filling these chambers.

The influence of the elements upon rock structure must also be considered, as certain rock formations are subject to disintegration when exposed.

Gravel Deposits 8 to 10 feet in thickness make a good foundation bottom.

Gravel foundation should not be subject to strong action of water, since such action might loosen the formation of the gravel.

Sand properly confined against lateral movement is considered an excellent support for foundations. The bearing value of sands increases in proportion to the thickness of the bed and the depth to which the foundation is carried.

Sand particles distribute pressures and layers of sand are often employed to distribute the weight over a larger area of a less stable foundation soil.

Clay, usually a tough, more or less compressed mass, if found in deposits of not less than 10 feet in thickness and when practically impervious to water, is considered good foundation soil for ordinary structures.

Clay even if found in hard condition is subject to slight compression, which, while uniform, may not be of much consequence.

Through absorption of water clay is softened and made less strong and compact and loses the elements of good foundation soil.

The carrying capacity of clay bottom may be increased by ramming into it stone or gravel, thus compacting the soil of a softer nature, understanding, however, that the underlying strata of soil form a sufficient support for the loading proposed.

Mixtures of Sand and Loam, considering the ratio in which they are found, may have fairly good bearing values. These values vary in proportion to the quality of the clay and sand encountered and are dependent on special conditions. Such soils must be thoroughly tested.

Top Soil, Peat or Marsh are considered poor foundation soils. Soils of a greasy nature, especially when combined with sand and an abundance of water are considered very poor foundation soils.

Artificial Soils, such as made embankments and fills, except specially prepared foundations of sand, gravel or broken stone, are not considered as safe foundations.

ALLOWABLE PRESSURE ON FOUNDATION SOILS AND ON PILES.

The weight for which a foundation soil can permanently and safely be used depends upon the strength of the material encountered. The same pressure which is imposed upon the foundation soil is naturally also sustained by the underside of the material used in the construction of the foundations, therefore the load upon the foundation soil will never exceed the strength of the building material placed upon it.

Table 2 gives a summary of answers to the circular letter on the allowable bearing pressures on different soils and on piles.

TABLE 2. ALLOWABLE BEARING PRESSURES ON DIFFERENT SOILS AND ON PILES.

Tons per Square Foot.

	Solid Rock	Sand and Gravel	Sand	Clay	Loam and Clay	Top Soil, Peat and Marsh	Piles (Tot. load)
Chicago, Milwaukee & St. Paul	5–30	8–10	2–6	4–8	1–2	0.5–1	15
Chicago & Northwestern	....	....	3	2.5	0.5–2	....	17.5–22.5
Central of New Jersey	4–up	....	2.5	2.5	....	....	12–15
Elgin, Joliet & Eastern	....	....	....	....	....	....	10
Hocking Valley	5–up	10	4–6	4–6	1–2	1–1.5	....
Louisville & Nashville	....	3	1.5–2	2.25	1.5	....	....
Nashville, Chattanooga & St. Louis	10	6	....	2–4	....	1	....
Norfolk & Western	....	....	....	2–5 Ton	s on soil	....	....
Pennsylvania	3.5	....	....	1–2.5	1–2.5	....	....
Public Service	5–200	8–10	2–6	2–6	1–2	0.5–1	....
Queen & Crescent	....	....	....	1.5–2 on	Tons soil	....	....
Southern Pacific	5–200	8	2–4	4	1	5	....

UPLIFT OR BUOYANCY.

The answers to the circular letter of the Committee indicate that the majority are in favor of considering uplift in designing foundations in water.

The following report their practice:

Reported by	*Remarks.*
New York Central	Consider uplift.
Southern Pacific	Consider uplift only when the substructure is on pile or other supports and not directly upon the soil.
Elgin, Joliet & Eastern	Consider uplift.
Nashville, Chattanooga & St. Louis	Consider uplift.
Louisville & Nashville	Design foundations so that they will be stable without the uplift, considering uplift as a factor of safety.
Queen & Crescent	Consider uplift.
Northern Pacific	Consider uplift.
Michigan Central	Consider uplift.
Central of New Jersey	Consider uplift when on pile foundations and in calculating overturning moments.
New York, New Haven & Hartford	Consider uplift except where structure is founded on rock.
Illinois Central	Consider uplift in deep water.
Public Service Railway	If uplift increases safety factor it is neglected. If safety factor is reduced it should be considered.
Chicago, St. Paul. Minneapolis & Omaha	Consider uplift only in computing the overturning moment.
Toronto Harbor Commission	Consider uplift but not always uniform or in full amount.
Baltimore & Ohio	Consider uplift except on ordinary foundations.
Pennsylvania Lines West of Pittsburg	Consider uplift.

Reported by	*Remarks.*
Grand Trunk	Consider uplift except on foundations on solid rock.
Westinghouse, Church, Kerr & Co.	Consider uplift.
Canadian Pacific	Consider uplift.
Norfolk & Western	Consider uplift.
Duluth & Iron Range	Consider uplift.
Atlantic Coast Line	Do not consider uplift.
Canadian Government Railways	Do not consider uplift.
Missouri, Kansas & Texas	Do not consider uplift.
Pennsylvania Railroad	Do not consider uplift.
Toronto Terminals	Do not consider uplift.
Chicago & Northwestern	Do not consider uplift.
Long Island	Do not consider uplift ordinarily, as most of our structures are not large enough to make any substantial difference.
Seaboard Air Line	Do not consider uplift.
Lehigh Valley	Do not consider uplift except for overturning moments.

FORMULAS FOR DETERMINING PRESSURES ON FOUNDATIONS.

Much information has been collected on formulas for determining the pressures on foundations, but there has not been sufficient time to make a careful study of the subject. From the data compiled it is evident that Rankine's formula as outlined in Volume 10, Part 2, 1909, page 1317, American Railway Engineering Association, are most frequently used.

PILE CUT-OFF. PROPER DEPTH OF FOUNDATION TO AVOID FROST ACTION.

The representative practice of the various railroads in fixing elevation of pile cut-off and of proper depth of foundation to avoid frost action, is summarized in Tables 3 and 4, respectively.

TABLE 3. PILE CUT-OFF.

Reported by	*Height in Reference to Mean Low Water.*
Atlantic Coast Line	M. H. W.
Baltimore & Ohio	M. L. W.
Central of New Jersey	1 ft. above M. L. W.
Canadian Government	Below M. L. W. Some cases just below M. H. W.
Chicago & Northwestern	1 ft. above M. L. W.
Grand Trunk	M. L. W.
Hocking Valley	M. L. W.
Long Island	1 ft. above M. L. W.
Louisville & Nashville	Level of bottom of river or bay. Teredo present.
Lehigh Valley	Near mean tide.
New York Central	M. L. W. to 2 ft. above M. L. W.
Norfolk & Western	Below mud line. Marine borers present.
New York, New Haven & Hartford	M. L. W.
Pennsylvania	1 ft. below M. L. W.
Public Service	1 ft. below M. L. W.
Southern Pacific	Below mud line. Teredo present.
Toronto Harbor Commission	M. L. W.
Westinghouse, Church, Kerr & Co.	M. L. W.

TABLE 4. DEPTH OF FOUNDATIONS IN ORDER TO AVOID FROST ACTION.

Reported by	*Depth in Feet.*	*Locations.*
Atlantic Coast Line	......	Not encountered.
Baltimore & Ohio	4 ft.	General.
	5 ft.	Northern parts.
Canadian Government	5 to 6 ft.	Canada.
Canadian Pacific	5 to 6 ft.	E. Can. and Pacific Coast, Central Canada.
Central of New Jersey	4 ft.	New Jersey and Eastern Pennsylvania.
Chicago & Northwestern	4 ft.	Chicago.
	5 ft.	North Michigan and Wisconsin.
Chicago, St. Paul, Minneapolis & Omaha	5 ft.	......
Duluth & Iron Range	7 ft.	Northern Minnesota.
Elgin, Joliet & Eastern	4 to 5 ft.	Northern Illinois and Indiana.
Grand Trunk	4 ft.	Michigan and Southern Ontario.
	5 ft.	Northern Ontario and Quebec.
Hocking Valley	3 ft.	Ohio.
Illinois Central	4 to 6 ft.	North of Ohio River.
	......	Neglected south of Ohio River.
Long Island Railroad	4 ft.	Long Island, New York.
Louisville & Nashville	2 ft.	......
Michigan Central	4 ft.	Michigan and Ontario.
Missouri, Kansas & Texas	3 ft.	......
Nashville, Chattanooga & St. Louis	2 ft.	......
New York Central	4 to 5 ft.	New York.
Norfolk & Western	3 ft.	Virginia, West Virginia and Ohio.
Northern Pacific	5 to 6 ft.	Minnesota.
	4 to 5 ft.	Washington.
New York, New Haven & Hartford	4 ft.	New York and New England States.
Pennsylvania	4 to 6 ft.	Pennsylvania.
Pennsylvania Lines West of Pittsburgh	4 ft.	Territory as far north as Chicago and Toledo.
Public Service	3 ft. 6 in. to 4 ft.	In vicinity of New York.
Queen & Crescent	2 ft.	......
Seaboard Air Line	......	......
Southern Pacific	......	Not encountered.
Toronto Harbor Commission	4 to 5 ft.	In vicinity of Toronto.
Toronto Terminals	4 to 6 ft.	......
Westinghouse, Church, Kerr & Co.	3 to 5 ft.	Pennsylvania and New York.
	4 to 5 ft.	New York.
	7 to 9 ft.	Winnipeg, Canada.
	2 to 3 ft.	Vancouver, B. C.
Lehigh Valley	4 ft.	Pennsylvania.
	5 ft.	Northern New York State.

REPORT OF COMMITTEE III—ON TIES.

L. A. Downs, *Chairman;*	F. R. Layng, *Vice-Chairman;*
C. C. Albright,	J. B. Myers,
M. S. Blaiklock,	A. J. Neafie,
W. J. Burton,	J. V. Neubert,
W. A. Clark,	R. J. Parker,
S. B. Clement,	J. G. Shillinger,
E. D. Jackson,	I. O. Walker,
E. P. Laird,	H. S. Wilgus,
E. R. Lewis,	Louis Yager,

Committee.

To the Members of the American Railway Engineering Association:

The following subjects were assigned your Committee by the Board of Direction:

(*a*) *Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.*

(*1*) *Report on the effect of tie plates and track spikes on life of cross-ties.*

(*2*) *Specifications for cross- and switch-ties.*

(*3*) *Metal, composite and concrete ties.*

The work was divided into Sub-Committees as follows:

(1) F. R. Layng, Chairman; R. J. Parker, Vice-Chairman; A. J. Neafie, J. V. Neubert, W. J. Burton, C. C. Albright.

(2) E. R. Lewis, Chairman; W. A. Clark, M. S. Blaiklock, E. D. Jackson, I. O. Walker, Louis Yager.

(3) H. S. Wilgus, Chairman; S. B. Clement, J. B. Myers, J. G. Shillinger.

THE EFFECT OF TIE PLATES AND TRACK SPIKES ON THE LIFE OF CROSS-TIES.

Your Committee reports progress on this subject and submits the following report as information:

The data collected shows that the practice of the railroads is anything but uniform: the fact is that the methods of properly protecting the tie are going through rapid changes, which make it difficult for the railroads to say definitely as to the effect on the tie of any particular part of the design. A study of the situation leads to the conclusion, however, that this subject is one of the important problems that confronts the maintenance engineer to-day. It is felt that no definite practice can be presented to the Association as having been developed to such an extent that it should be adopted, and the present purpose of the Committee is to illustrate tendencies of good practice and to call particular attention to the necessity of reducing or eliminating, if possible, movement between the tie plate and the tie.

The primary purpose or function of the tie plate is to protect the tie from mechanical wear and all other functions should be subordinated to this. Assuming that the tie plate will be of sufficient area to properly distribute the loads imposed, and that it is of sufficient thickness so that it will not buckle, it is necessary that the movement between the plate and the tie be reduced to a minimum or eliminated, if possible. If this is not done this movement will defeat the purpose of the plate. Of the different methods in use to accomplish this the following are illustrated:

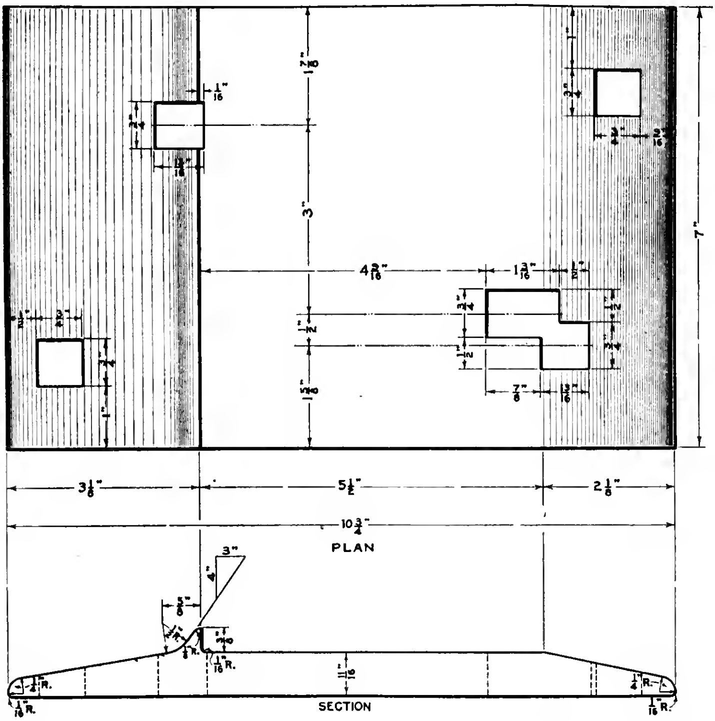


Fig. 1. Standard Tie Plate, P. R. R.

First, by using cut spikes independent of those that secure the rail, as shown in Fig. 1.

Second, by using screw spikes or lag screws independent of the fastenings securing the rail. Fig. 2 makes use of cut spikes to secure the rail and lag or screw spikes to secure the plate.

In Fig. 3, screw spikes secure the rail while lag screws secure the plate, and in Fig. 4, the plate is secured to the tie by screw spikes, and the rail is secured by a hook on the plate on one side and by a screw or cut spike on the other.

Third, by using a flat plate bolted through the tie, as is shown by the experiment illustrated in Fig. 5. Another method to reduce the movement between the tie and the plate is to provide for more or less movement between the fastenings and the rail, as shown in Fig. 3; the free distance being about $\frac{1}{16}$-inch.

The general tendency at the present time seems to be towards a flat-bottom plate, or at least plates that have no deep ribs or projections on the bottom. The report will not present any data bearing on this feature, as it is felt that the practice at the present time has not yet progressed far enough to reach definite conclusions.

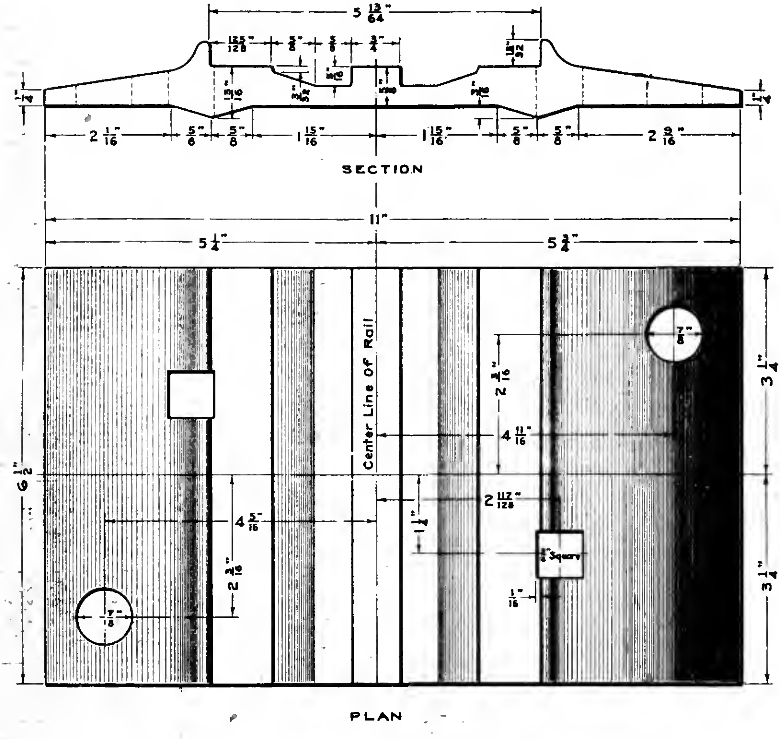


Fig. 2. Standard Tie Plate, P. & L. E. R. R.

Attached to this report is a tabulation showing the practice as to tie plates and fastenings on a number of railroads.

Your Committee wishes to again emphasize the importance of the question assigned them, and to suggest that the study be continued in next year's work.

SPIKES IN USE ON VARIOUS RAILROADS

RAILROAD.	CUT SPIKE						SCREW SPIKE								CLIPS USED
	Total Length		Size		Point		Total Length		Thread		Diameter				
	Over All	Under Head	Shank	Under Head	Kind	Length	Over All	Under Head	Length	Pitch	Neck	Shank	Thread	Head	
Lehigh & Hudson River	6"	5¼"	⅝"x⅝"	¾"x⅝"	Chisel	1¼"	6¾"	5½"	4 27/64"	15/32"	⅞"	⅝"	⅞"	2"	None.
Lehigh Valley	6"	5⅜"	⅝"x⅝"	¾"x⅝"	Chisel	1¼"	....	....	....	....	....	....	....	....	
Long Island	6"	5 7/16"	⅝"x⅝"	¾"x⅝"	Chisel	1¼"	7 5/16"	6"	5¼"	½"	29/32"	⅝"	29/32"	2"	None.
Norfolk & Western	6"	5¼"	⅝"x⅝"	⅝"x¾"	Chisel	1¼"	....	....	....	....	....	....	....	....	
N. Y. C.—Lines East	6 1/16"	5½"	⅝"x⅝"	11/16"x⅝"	Chisel and Goldie	1¼"	....	....	....	....	....	....	....	....	
N. Y. C.—Lines West	6 1/16"	5½"	⅝"x⅝"	11/16"x⅝"	Chisel	1¼"	....	....	....	....	....	....	....	....	
N. Y. N. H. & H.	....	....	....	....	....	....	6 25/32"	5½"	4 3/16"	½"	⅞"	21/32"	15/16"	2 5/16"	None.
N. Y. O. & W.	6"	5½"	⅝"x⅝"	23/32"x⅝"	Chisel	1⅛"	....	....	....	....	....	....	....	....	
N. P.	6¼"	6"	9/16"x9/16"	9/16"x⅝"	Chisel	1⅛"	....	....	....	....	....	....	....	....	
Penna.—Lines East	....	....	....	....	....	....	8¼"	6¼"	5"	½"	1"	¾"	1"	1¾" Hex.	None.
Penna.—Lines West	6½"	5⅞"	⅝"x⅝"	11/16"x⅝"	Chisel	1¼"	....	....	....	....	....	....	....	....	
P. & L. E.	....	....	½"x½"	....	....	....	....	....	....	....	9/16"	....	....	....	
R. F. & P.	5⅝"	5"	⅝"x⅝"	11/16"x⅝"	Chisel	1½"	....	....	....	....	....	....	....	....	
Southern	5 13/16"	5⅛"	9/16"x9/16"	9/16"x11/16"	Chisel Rounded.	1¼"	....	....	....	....	....	....	....	....	
S. L. S. F. R. R.	5 25/32"	5 9/32"	9/16"x9/16"	¾"x9/16"	Chisel	1⅛"	....	....	....	....	....	....	....	....	
So. P. (Corrugated)	6¼"	5⅞"	⅝"x⅝"	⅝"x11/16"	Chisel	1¼"	....	....	....	....	....	....	....	....	
do	6¼"	5⅞"	⅝"x⅝"	⅝"x11/16"	Chisel	1¼"	7 1/16"	6⅛"	4¾"	½"	⅞"	⅝"	⅞"	2"	2" Clips—(Use Liner).
Vandalia	6½"	5⅞"	⅝"x⅝"	¾"x⅝"	Chisel	1¼"	....	....	....	....	....	....	....	....	

SPIKES IN USE ON VARIOUS RAILROADS

RAILROAD.	CUT SPIKE						SCREW SPIKE								CLIPS USED
	Total Length		Size		Point		Total Length		Thread		Diameter				
	Over All	Under Head	Shank	Under Head	Kind	Length	Over All	Under Head	Length	Pitch	Neck	Shank	Thread	Head	
A. T. & S. F.	6"	5½"	9/16"x9/16"	9/16"x9/16"	Chisel	1¼"	7⅛"	6"	4⅝"	½"	⅞"	⅝"	⅞"	2"	None
Boston Elevated							6 9/16"	5¼"	4⅜"	½"	⅞"	⅝"	15/16"	2 3/16"	None with this Spike.
do							6⅞"	5⅝"	4⅜"	½"	⅞"	⅝"	15/16"	1 9/16"	2"x2"x11/16" to fit Contour of Head.
Boston & Albany	6 1/16"	5½"	⅝"x⅝"	11/16"x⅝"	Chisel	1¼"									
B. R. & P.	5 15/16"	5 5/16"	⅝"x⅝"	⅝"x11/16"	Goldie	1⅛"									
B. & O.	6"	5⅜"	⅝"x⅝"	⅝"x11/16"	Chisel	1¼"	7¼"	6"	4 59/64"	15/32"	⅞"	⅝"	⅞"	2¼"	None.
do	5¾"	5¼"	9/16"x9/16"	9/16"x⅝"	Chisel	1⅛"									
Canadian Northern	5¾"	5 3/16"	9/16"x9/16"	¾"x⅝"	Chisel	1⅛"									
Canadian Pacific		5¾"	⅝"					6"			⅞"				
C. R. R. of N. J.	6"	5 5/16"	⅝"x⅝"	¾"x⅝"	Chisel Rounded	1⅜"									
do	7"	6 5/16"	⅝"x⅝"	¾"x⅝"	Chisel Rounded	1⅜"									
C. C. C. & St. L.	6 1/16"	5½"	⅝"x⅝"	11/16"x⅝"	Chisel	1¼"									
C. B. & Q.	6"	5½"	⅝"x⅝"	⅝"x¾"	Chisel	1¼"									
do	6"	5½"	9/16"x9/16"	9/16"x9/16"	Chisel	1⅛"									
C. R. I. & P.	5⅞"	5½"	9/16"x9/16"	9/16"x9/16"	Chisel	1⅛"	6¾"	5½"	5"	½"	⅞"	⅝"	⅞"	1⅞"	None.
do	6½"	6"	⅝"x⅝"	⅝"x¾"	Chisel	1¼"									
D. L. & W.		6"	⅝"x⅝"		Chisel	1¼"	7¼"	6"	4 59/64"	15/32"	⅞"	⅝"	⅞"	2¼"	None.
Grand Trunk	6⅛"	5½"	9/16"x9/16"	9/16"x9/16"	Chisel	1¼"									

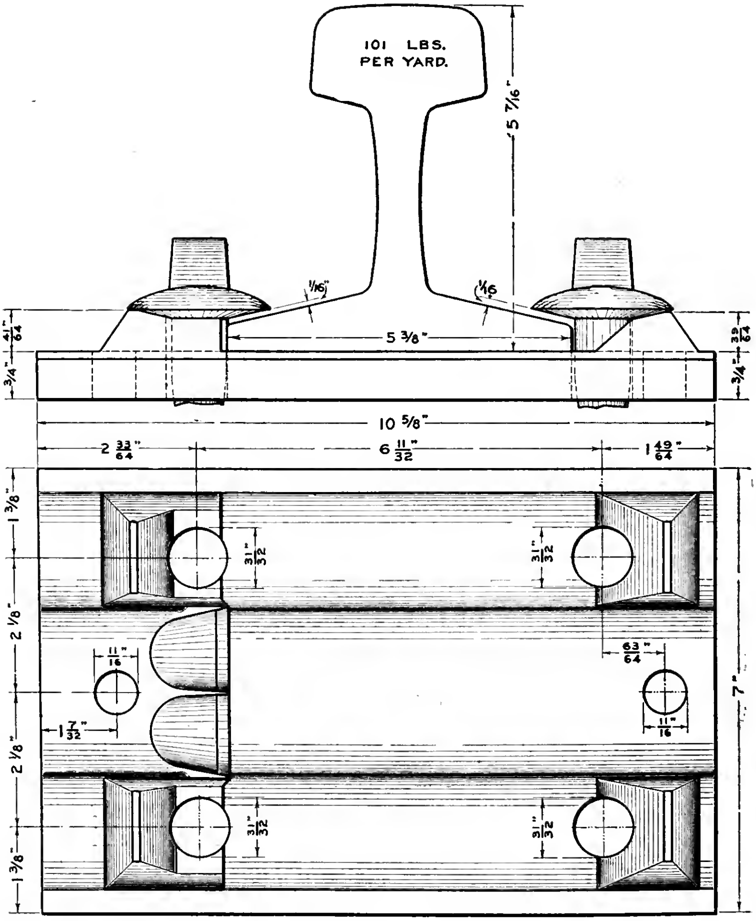


FIG. 3. SCREW SPIKE TIE PLATE WITH RAIL, D. L. & W. R. R.

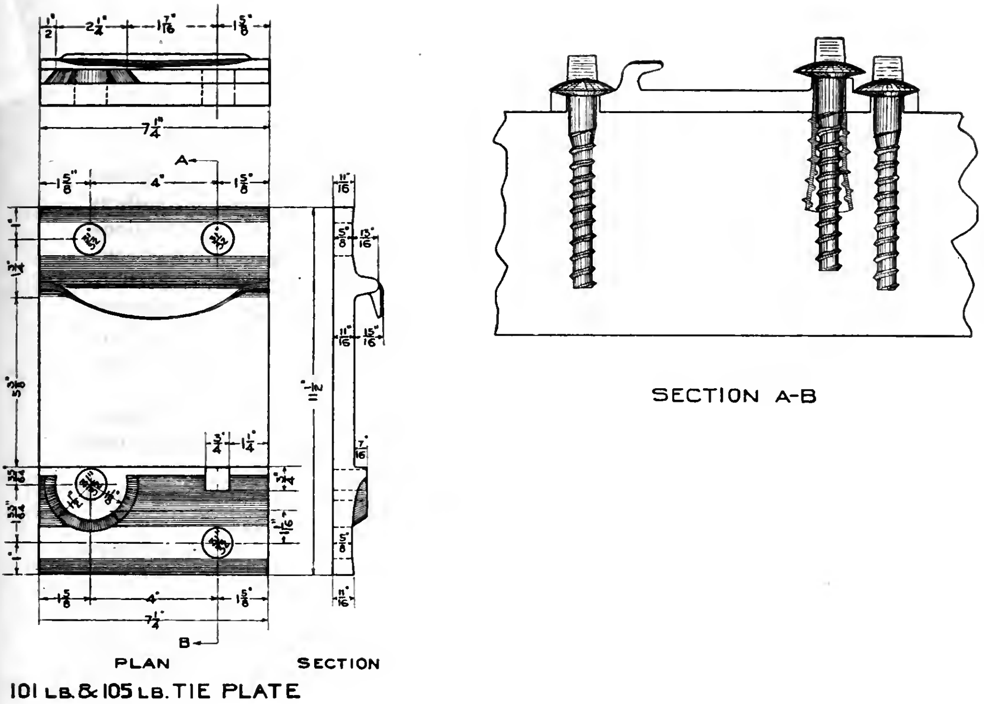


FIG. 4. HOOK SHOULDER TIE PLATE FOR 5⅜ RAIL BASE, D. L. & W. R. R.

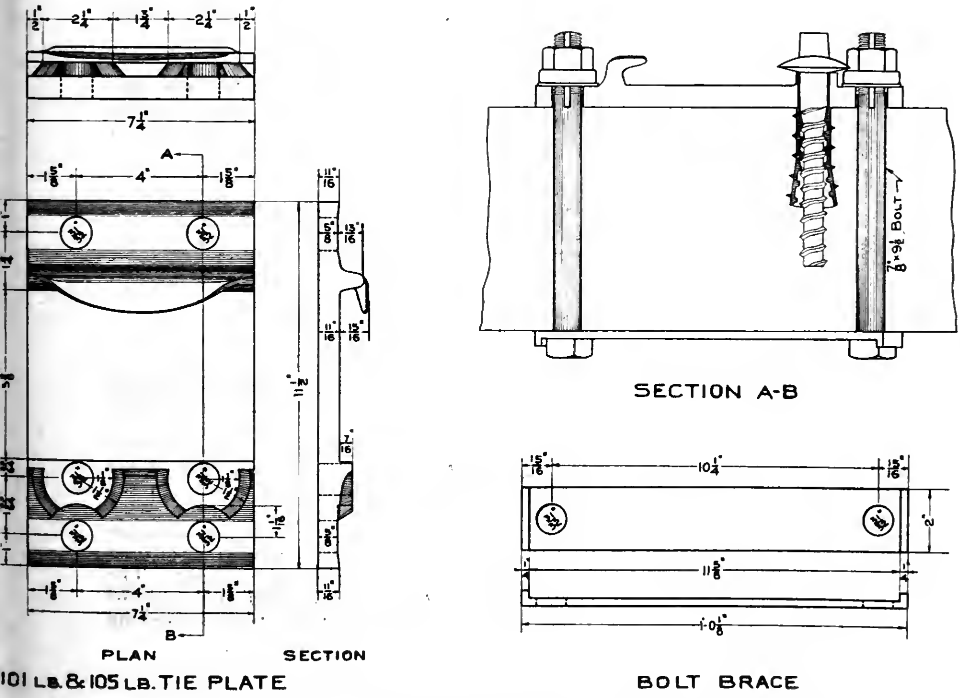


FIG. 5. HOOK SHOULDER TIE PLATE FOR 5⅜ RAIL BASE, D. L. & W. R. R.

SPECIFICATIONS FOR CROSS- AND SWITCH-TIES.

At the first meeting the year's procedure was outlined and a request made that the Association Secretary send a circular letter to railway companies asking for copies of their cross- and switch-tie specifications.

Specifications were received from some seventy-five railway companies, most of which sent copies of both cross- and switch-tie specifications. These were tabulated alphabetically as to the more important stipulations as reference to current practice; and used as a basis for revision of the Association's cross-tie specifications, as well as a basis from which to formulate switch-tie specifications.

Percentages (according to Poor's Manual) of mileage of all tracks represented by the railway companies submitting cross-tie specifications were computed as to dimensions of ties used.

Information was also collected on the subject of various woods used for ties, notably Douglas Fir and Tamarack, with a view to criticism of lists of woods to be used treated and untreated in the manufacture of ties.

List of "Woods to be used untreated" and "Woods to be treated" (see page 52, Manual, 1911) being under discussion, it was decided to delete the terms "Walnut" and "Black Cherry" from list No. 1, because few railway ties of these woods are now available.

"Birch" was added to list No. 2, because ties of this wood are available in considerable numbers for treatment.

"Pines other than longleaf, strict heart yellow pine" is inserted instead of "Loblolly, etc.," because of the multiplicity of local names of the various varieties.

"Douglas Fir" is substantiated for "Red Fir" as a more proper term.

"There is a great deal of misunderstanding about Douglas Fir, due principally to the various names it goes under in the different localities where it is found. The most common of these names and the states in which they are used are:

Douglas Fir—Utah, Oregon, Colorado, Montana.
Red Fir—Oregon, Washington, Idaho, Utah, Montana, Colorado.
Douglas Spruce—California, Colorado, Montana.
Yellow Fir—Oregon, Montana, Idaho, Washington.
Spruce—Montana.
Oregon Pine—California, Washington, Oregon.
Fir—Montana.
Red Pine—Utah, Colorado, Idaho.
Puget Sound Pine—Washington.

"The name Douglas Fir has been adopted by the Forest Service and by various trade and technical associations and is coming into general commercial use.

"The Douglas Fir is in reality not of the Fir family, but is what is known as a Pseudotsuga, or false Hemlock, so-called on account of the resemblance its leaf stems, habits and character its cones bear to the Hemlock.

"The wood varies widely in character and grain, which may be very coarse, medium or fine. Coarse-grained wood is generally of a distinct reddish brown color from which it derived the name of Red Fir. The fine-grained wood is of a yellowish brown color, from which it derived the name of Yellow Fir. The botanical characters of trees furnishing these two qualities of wood are the same, and there is no foundation for the popular belief that these woods come from two different varieties or species of trees. The two grades are sometimes found in the same tree."*

After investigation it is decided to leave unaltered the term "Tamarack" in list No. 2. Though in common with all conifers the heartwood of Tamarack is exceedingly refractory and practically impossible to penetrate, unless subjected to severe steaming,* yet treatment of the sapwood and tie ends seems desirable, as a life of fifteen years is indicated as thus obtainable.

The wording and intent of the proposed revision of cross-tie specifications was the subject of much discussion among members of the Committee. These discussions were carried on by correspondence and at the second and third meetings, as were also the discussions relating to switch-tie specifications.

The term "flatted" as synonymous with "pole," as applied to the railway tie, is inserted because of its wide use by railway companies and tie contractors.

On account of the difference in the methods of piling untreated as compared with treated ties, it is considered advisable to insert the word "untreated" at the beginning of paragraph 6, page 53, Manual, 1911, as well as between the words "fifty" and "ties" in the title to Fig. 1, diagram on the same page. It is intended that the diagram shall be retained otherwise unaltered.

The Committee submits the following revised specifications for cross-ties as shown on the right-hand pages of the following sheets; the left-hand pages giving the wording of specifications according to the Manual of 1911, while the underscored words on the right-hand pages denote changes:

---

*Extracts from letter of Mr. Lowry Smith, Superintendent Timber Preservation, Northern Pacific Railway, Brainerd, Minn.

Present Form.

SPECIFICATIONS FOR CROSS-TIES.

Woods to Be Used Untreated.

1. The following woods may be used for tie timber without preservative treatment:

White Oak family.
Longleaf strict heart yellow pine.
Cypress, excepting the white cypress.
Redwood.
White Cedar.
Chestnut.
Catalpa.
Locust, except honey locust.
Walnut.
Black Cherry.

Woods to Be Treated.

2. The following woods shall preferably not be used for tie timber without a preservative treatment approved by the purchaser:

Red Oak family.
Beech.
Elm.
Maple.
Gum.
Loblolly, shortleaf, lodgepole, Western yellow pine, Norway, North Carolina pine and other sap pines.
Red Fir.
Spruce.
Hemlock.
Tamarack.

Material and Manufacture.

3. Cross-ties shall be well and smoothly hewed or sawed out of straight, growing timber of specified dimensions and out of wind, sawed ends, with straight and parallel faces, the minimum width of either face to be not less than that given in the table of dimensions. Ties shall have bark entirely removed before being delivered on the company's ground. They shall be free from splits, shakes, loose or decayed knots, or any other imperfections which may impair their strength or durability.

Dimensions.

4. Except in pole ties with rounded sides, or in half-round ties, none shall be less than eight (8) in. width of face, and in no tie shall the thickness be less than six (6) in. A variation in size will be permitted of one-half (½) in. over in thickness, two (2) in. over in width and one (1) in. over in length.

Allowable Variation in Pole Ties.

5. In pole ties with rounded sides and half-round ties, the width of face may be less than that given in the table of dimensions, but the

Proposed Form.

SPECIFICATIONS FOR CROSS-TIES.

Woods to Be Used Untreated.

1. The following woods may be used for tie timber without preservative treatment:

White Oak family.
Longleaf strict heart yellow pine.
Red Cypress.
Redwood.
White Cedar.
Chestnut.
Catalpa.
Locust, except honey locust.

Woods to Be Treated.

2. The following woods shall preferably not be used for tie timber without a preservative treatment approved by the purchaser:

Red Oak family.
Beech.
Birch.
Elm.
Maple.
Gum.
All pines, except longleaf strict heart yellow pine.
Douglas Fir.
Spruce.
Hemlock.
Tamarack.
Yellow and White Cypress.

Material and Manufacture.

3. Cross-ties shall be *manufactured* out of straight, *sound, live trees, cut in the winter months when the sap is down. They shall be hewed or sawed to the* specified dimensions and out of wind, with straight and parallel faces *and ends sawed square. The* minimum width of either face *shall be* not less than that given in the table of dimensions. They *must* be free from *such score marks,* shakes, loose or decayed knots, *rot,* splits *or checks,* or any other imperfections as may impair their strength or durability.

Bark shall be entirely removed before delivery.

Minimum Dimensions.

4. *Cross-ties shall be not less than eight (8) ft. long.*

Squared ties shall be not less than six (6) *in.* thick and eight (8) *in.* in width of face.

Pole (or flatted) ties shall be not less than six (6) *in.* thick and six (6) *in.* in width of face.

Present Form.

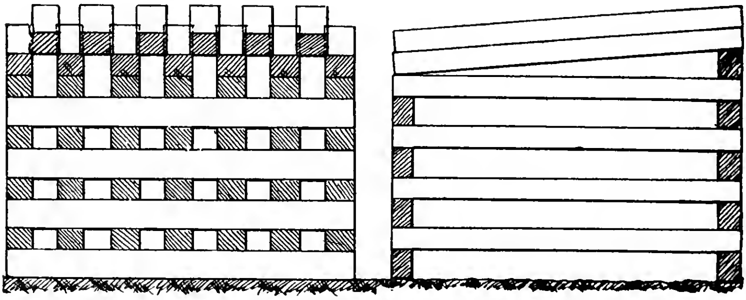
least area of cross-section shall be not less than the area corresponding to the tabular dimensions, and in no case shall the width of face be less than six (6) in.

TABLE OF DIMENSIONS.

Class	Thickness by width of face	Length		
	Inches	Feet	Feet	Feet
A	7 x 10	8	8½	9
B	7 x 9	8	8½	9
C	7 x 8	8	8½	9
D	6 x 9	8	8½	9
E	6 x 8	8	8½	9

Piling Untreated Ties.

6. Ties which are delivered along the right-of-way of the railway shall be piled at station yards or at points between stations designated in the contract not less than ten (10) ft. from the nearest rail; each pile to be of either 25 or 50 ties, built with two ties on the ground and above in alternate courses of 7 and 2, except the top, which shall be placed to form a watershed, as shown in diagram. Each pile shall be plainly marked with the owner's name and date when piled. Three (3) ft. of space shall be left between piles to permit inspection. Sawed ties shall be piled separately from hewed ties.



Piling Diagram for Fifty Ties.

Removal of Rejected Ties.

7. All rejected ties shall be removed from the company's right-of-way within ten (10) days after notice is given.

Piling Treated Ties.

8. Ties treated with a water solution, like zinc-chloride, particularly red oak and beech ties, shall be piled in close piles on well-drained ground, to prevent checking.

Proposed Form.

Allowable Variations in Dimensions.

5. *Variations from the specified dimensions for cross-ties will be permitted of one-half (½) in. over in thickness; two (2) in. over in width, and two (2) in. over in length.*

Pole (or flatted) cross-ties must not exceed twelve (12) in. in width of face. The average width of both faces must not exceed ten (10) in.

TABLE OF DIMENSIONS.

Class	Thickness by width of face		Length		
	Inches		Feet	Feet	Feet
	Squared	Pole (Flatted)			
A	7 x 10	7 x 8	8	8½	9
B	7 x 9	7 x 7	8	8½	9
C	7 x 8	7 x 6	8	8½	9
D	6 x 9	6 x 7	8	8½	9
E	6 x 8	6 x 6	8	8½	9

Piling Untreated Ties.

6. *Ties shall be piled on the right-of-way in strict accordance with the regulations of the railway company. Untreated ties* which are delivered along the right-of-way of the railway company shall *preferably* be piled at station yards or at points between stations designated in the contract, not less than ten (10) *ft.* from the nearest *track* rail; each pile to be of either 25 or 50 ties, built with two ties on the ground and above in alternate courses of 7 and 2, except the top, which shall be placed to form a watershed, as shown in *the* diagram. Each pile shall be plainly marked with the owner's name and date when piled. *At least* three *(3)* ft. of space shall be left between piles to permit inspection.

Removal of Rejected Ties.

7. *All ties piled on the company's property shall be at the owner's risk until inspected and accepted.* Rejected ties must be removed within .... days after notice is given.

Piling Treated Ties.

8. *Treated ties shall be cross piled closely* on well-drained ground to prevent checking.

The Committee presents this revision of cross-tie specifications with the recommendation that they be published in the Manual in place of the present specifications.

The Committee presents the following specifications for switch-ties with the recommendation that they be adopted and published in the Manual:

SPECIFICATIONS FOR SWITCH-TIES.

General.

1. Switch-ties shall preferably be manufactured from hard, firm woods, and shall conform to the specifications for cross-ties, except as to special dimensions.

Minimum Dimensions.

2. The lengths of switch-ties shall be as ordered.

Squared switch-ties shall be not less than seven (7) in. in thickness and nine (9) in. in width of face.

Pole (or flatted) switch-ties shall be not less than seven (7) in. in thickness and seven (7) in. in width of face.

Allowable Variations in Dimensions.

The same variations shall be allowed for switch-ties as are allowed for cross-ties.

Piling.

3. Each set of switch-ties shall be piled separately and must be complete as ordered. The length or number of each tie must be plainly marked on each end.

MILEAGE OF LINES SPECIFYING VARIOUS MINIMUM DIMENSIONS FOR NO. 1 CROSS-TIES.

Lengths.	Miles.		Widths.	Miles.		Thicknesses.	Miles.	
8′ 0″	143,750	63.0%	7″	103,307	45.3%	7″	168,418	70.4%
8′ 6″	82,424	36.7%	8″	82,608	36.3%	6″	58,416	29.6%
9′ 0″	652	0.3%	9″	25,356	11.6%			
7′ 0″	8		10″	14,711	6.4%			
			5″	852	0.4%			
Totals,	226,834	100%		226,834	100%		226,834	100%

NUMBER OF RAILROADS AND AGGREGATE MILES OF TRACK SPECIFYING SIMILAR MINIMUM DIMENSIONS FOR NO. 1 CROSS-TIES.

Dimensions. T	W	L	Number of Railroads.	Aggregate Mileage.	Percentage of Total Mileage.
7″	7″	8′	10	53838	23.6
6″	8″	8′	22	52362	23.0
7″	7″	8½′	13	44275	19.4
7″	9″	8½′	8	24704	11.3
7″	8″	8′	4	16793	7.4
7″	10″	8′	1	14711	6.4
7″	8″	8½′	8	13445	5.9
6″	7″	8′	4	5194	2.3
6″	5″	8′	1	852	0.4
7″	9″	9′	1	652	0.3
6″	8″	7′	1	8	
Total			73	226834	100%

THE USE OF METAL, COMPOSITE AND CONCRETE TIES.

The work of the Sub-Committee includes the following:

(1) The obtaining of a progress report from each railroad on which substitute ties are in service.

(2) A careful search of the Bulletins of the International Railway Congress, and other sources of information, as to the use of substitute ties on foreign railways.

(3) An inspection of substitute ties in service on the following railways: Bessemer & Lake Erie, Pennsylvania, Pennsylvania Lines West, Pittsburgh & Lake Erie and Union. The Sub-Committee desires to make no detailed report.

I. SUMMARY OF PROGRESS REPORT ON SUBSTITUTE TIES.

(The references are to the Proceedings of the A. R. E. A., in which last reference is made.)

Atchison, Topeka & Santa Fe Railway:

Baird Steel Ties, Newton, Kan., Vol. 16, page 525.
Carnegie Steel Ties, Newton, Kan., Vol. 16, page 525.
Universal Steel Ties, Florence, Kan., Vol. 16, page 525.

R. J. Parker, General Superintendent: "The Baird tie is in good condition, as are also the Universal ties, in eastbound main track, in front of passenger depot at Florence. The Baird tie shows a little more corrosion than the Universal, however. It has been in the track about three years longer, and the ballast largely composed of cinders, while the ballast is largely, in fact altogether crushed stone, where the Universal tie is laid.

"Neither tie has caused any extra labor at the present writing, and it is hard to express preference. Both apparently good for a great many years to come."

Baltimore & Ohio Railroad:

Metal Tie Co.—Cast Steel Tie, Martinsburg, W. Va., Vol. 16, page 525.—J. B. Myers, District Engineer: "The metal ties are the ties made by the Metal Tie Co., which were installed in the eastbound main track near Martinsburg, W. Va., and are still in track, none of them having been removed. Some few of the wooden blocks, however, have been renewed since report made last year, otherwise conditions are the same as last year's report.

Boughton Steel Ties, Akron, Ohio, Vol. 10, page 509.—The Boughton ties which were installed near Akron; report shows that nine of them are still in track. Four of these, however, will have to come out shortly. It was reported to me that these ties are found particularly hard to tamp."

Bessemer & Lake Erie Railroad:

Carnegie Steel Ties.—F. R. Layng, Engineer of Track: "During the year 1915, the Bessemer & Lake Erie Railroad ordered and will receive from the mills, 30,000 10-in. base and 50,000 8-in. base ties. The section has been changed from that formerly used. For the purpose of securing a stockier section, the changes are principally in a thicker web and in more generous fillets at the intersection of the web and the top and bottom tables of the tie. The 8-in. tie is known as the Carnegie Steel Co. M-29; weight, 24 lbs. per foot; and 8 ft. 6 in. tie, 204 lbs., as against 181 lbs. for the M-21 section formerly used. The new 10-in. tie is Carnegie Steel Co. M-28A; weight, 29.8 lbs. per foot; an 8 ft. 6 in. tie is 253.3 lbs. We have started to use this year a two-bolt, 4½-in. wide clip, designed to give additional strength on curves and further to make impossible the slewing of the tie where the steel runs, thus acting in a much more effective manner than the 2-in., one-bolt clip which has been used heretofore. The inside part of this 2½-in. clip is Carnegie Steel Co. section No. 118, and the outside part No. 118-A. It is not the intention to discontinue altogether the use of the small clip; the larger clip will be used at certain points.

"We have no further information to give in regard to the steel tie other than to say that it continues to give satisfaction"

Buffalo, Rochester & Pittsburgh Railway:

CARNEGIE STEEL TIES, Colden, N. Y., Vol. 16, page 528.—E. F. Robinson, Chief Engineer: "We have nothing further to advise regarding the Carnegie steel ties installed in our track in Colden in 1905."

Chicago & Alton Railroad:

SIMPLEX STEEL TIE, Chicago, Ill., Vol. 16, page 528.—H. T. Douglas, Jr., Chief Engineer: "I regret to advise you that I have no additional information which I could offer relative to the Simplex ties in our northbound main line track about ten miles south of Chicago. These ties are still in our track and are giving us most excellent service and, in all respects, have proven altogether good."

Chicago, Burlington & Quincy Railroad:

UNIVERSAL STEEL TIES, Chicago, Ill., Vol. 16, page 528.—T. E. Calvert, Chief Engineer: "These ties were installed in freight track about 300 ft. west of Western Avenue, in Chicago, in March, 1911. There were 100 of these put in as manufactured by the Universal Metallic Tie Company of Salt Lake City. They were spaced 21 in. centers, ballasted with gravel; traffic was light freight. We used oak ties at the joints, as no steel ties were furnished for this purpose.

"These ties were made of ⅜-in. channel irons, 8 in. x 4 in., with a wooden block under each rail. This block is held in place by means of a clamp which fastens to the base of the rail and a bolt running through the clamp and the wood block.

"While these ties are still in good condition, they are beginning to scale off considerably, and on some of them the rust scale reaches quite deep, both on the inside and outside of top of tie.

"The soil and climate of Chicago are both hard on steel metal used in this way, and our people think, and judging by their general appearance at this time after about four years of service, that they will rust out in the near future to such an extent as to weaken them and that they will not prove in the place we are using them any economy over a tie plated treated wood tie. The cost of relaying with these ties would be considerably greater than it would be with a wooden tie."

Chicago & Northwestern Railway:

BUHRER COMPOSITE TIE, Allis, Ill., Vol. 10, page 515.—W. H. Finley, Chief Engineer: "These ties were removed from the track in 1914. The steel plates on top of them were badly worn as well as the clips and bolts. The ties themselves were in fairly good condition, and are still on hand at Milwaukee, but cannot be used in their present condition. The removal in 1914 was occasioned on account of track elevation work at that point."

Cleveland, Cincinnati, Chicago & St. Louis Railway:

CARNEGIE STEEL TIES, Greensburg, Ind., Vol. 16, page 528.—Paul Hamilton, Engineer of Track and Roadway: "We have no further information to furnish in regard to Carnegie steel ties, as there have been no changes in the condition of the ties during the past year."

TIE PLATES IN USE ON VARIOUS RAILROADS.

TIE PLATES IN USE ON VARIOUS RAILROADS

CUT SPIKE PLATES

RAILROAD	Weight of Rail	Dimensions of Plate				RIBS						Cant	Outside Shoulder	Inside Shoulder	SPIKE HOLES FOR							Projection Outside of Rail Base	Rolled or Cast
		Width	Length	Thickness	Area	Transverse No	Size	Longitudinal No	Size	Cross	Type				Plate Fastening No	Size	Position	Rail Fastening Outside No	Size	Inside No	Size		
Atlantic Coast Line	80	6"	8½"					2	⅞"				¾"					2	[illegible]	2	⅝"x[illegible]	1⅝"	Rolled
do	75	5"	8"	⅝"	40"			2	⅞"				¾"					2	[illegible]	2	[illegible]	1¼"	Rolled
A. T. & S. F.	75 90	7½"	9"	½"	67½"	2	¼"						⅞"					2	[illegible]	2	9/16"x⅝"	2¼"	Rolled
do																							
Boston & Maine	100	5"	9"	½"	45"			2	⅞"				½"					2	¾"x⅝"	2	¾"x⅝"	1¼"	Rolled
do	85	5"	8¼"	½"	41¼"			2	⅞"				⅝"					2	¾"x⅝"	2	¾"x⅝"	1¾"	Rolled
do	75 80	5"	8"	½"	40"			2	⅞"				½"					2	¾"x⅝"	3	¾"x⅝"	1½"	Rolled
Boston & Albany	95 105	6½"	9"	½"	58½"						Flat Bottom	⅛"	[illegible]					2	¾"x¾"	2	¾"x¾"	2⅝"	Rolled
Boston Elevated																							
B. R. & P.	90	7"	9¾"	[illegible]	68¼"						Goldie		⅜"					2	¾"x¾"	2	¾"x¾"	2½"	Rolled
Baltimore & Ohio	100 100	6"	9"	½"	54"						4 Ribs or Sellers Bottom		Not shown					1	¾"x¾"	2	¾"x¾"	1⅝"	Rolled
do	90	6"	8½"	½"	51"						4 Ribs or Sellers Bottom		Not shown					1	¾"x¾"	2	¾"x¾"	1½"	Rolled
do	85	6"	8½"	⅝"	51"						4 Ribs or Sellers Bottom		Not shown					1	¾"x¾"	2	¾"x¾"	1⅞"	Rolled
Canadian Pacific	7[illegible] 85	6"	8½"	[illegible]	55¼"			4	½"			1⅜"	⅞"					2	¾"x⅝"	2	¾"x⅝"	2	Rolled
C. R. R. of N. J.	100	7½"	10½"	½"	78¾"					¾"x2¾"	Channel Across Center		⅞"					2	¾"x¾"	2	¾"x¾"	2⅝"	Cast
do	75 90 & Less	6"	9"	½"	54"					¾"x2¾"	Channel Across Center		⅝"					1 Hole 1 Slot	¾"x¾"	2	¾"x¾"	2	Cast
C. C. C. & St. L.	90	6"	8½"	½"	51"	[illegible]	¼"			Diagonal ⅝"	Sellers Anchor Bottom		⅞"					2	¾"x¾"	2	¾"x¾"	1⅝"	Rolled
do	80	6"	8½"	½"	51"								⅝"					2	¾"x¾"	2	¾"x¾"	2"	Rolled
C. R. I. & P.	100	7½"	9"	½"	67½"	2	¼"						⅞"					2	⅝"x⅝"	2	⅝"x⅝"	2½"	Rolled
	100	6⅝"	8¾"	½"	56⅞"			4	⅛"				⅞"					2	⅝"x⅝"	2	⅝"x⅝"	1⅝"	Rolled
	85	6½"	8¾"	½"	56⅞"			4	⅛"				¼"					2	⅝"x⅝"	2	⅝"x⅝"	2⅛"	Rolled
[illegible]	90 60	6⅝"	8¾"	½"	53⅝"	[illegible]	¼"						⅞"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Rolled
do	90 60	6⅝"	8¾"	½"	56[illegible]			4	⅛"				¼"					2"	⅝"x⅝"	2	⅝"x⅝"	2⅛"	Rolled
C. B. & Q.	100	6"	9"	½"	54"	4	⅝"						⅜"					None Shown				2¼"	Cast
do	90 & Less	6"	8½"	½"	51"					Diagonal ⅝"	Sellers Anchor Bottom	⅛"	⅝"					None Shown				2"	Cast
Chicago & Alton	90	6"	8½"	[illegible]	51"	4	⅜"					⅛"	⅝"					2	¾"x¾"	2	¾"x¾"	2"	Rolled
C. M. & St. P.	100	6"	9½"	[illegible]	57"						Flat Bottom		¼"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Cast & Rolled
[illegible]	100	6"	9"	[illegible]	54"						Flat Bottom		¼"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Cast & Rolled
[illegible]	100	6"	9"	[illegible]	54"	2	⅝"x1⅝"	4	⅝"				¼"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Cast
[illegible]	100	6"	9"	[illegible]	54"					Diagonal ⅝"	Sellers Anchor Bottom		¼"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Rolled
do	100	6"	9½"	[illegible]	57"					Diagonal ⅝"	Sellers Anchor Bottom		¼"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Rolled
do	100	6"	9"	½"	54"	4	⅜"						⅝"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Rolled
	90	6"	8½"	½"	51"					Diagonal ⅝"	Sellers Anchor Bottom		¼"					[illegible]	⅝"x⅝"	2	⅝"x⅝"	2"	Rolled
do											Flat Bottom		¼"					[illegible]	¾"x⅝"	1 1	⅝"x⅝" ¾"x⅝"	2"	Cast & Rolled
do	90 85	6"	8½"	½"	51"	2	⅛"x1¾"	4	⅜"				¼"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Cast
do	90 85	6"	8½"	½"	51"	4	⅜"						¼"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Rolled
do	90 85	6"	8½"	½"	51"	4	⅜"						¼"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Rolled
do	90 75	6"	8¼"	½"	49½"						Flat Bottom		¼"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Cast
do	75	6"	8½"	½"	51"						Flat Bottom		¼"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Rolled
do	75	6"	7¾"	⅝"	46½"	2	⅛"x2"	4	½"				¼"					2	¾"x⅝"	2	¾"x¾"	1⅝"	Cast
do	75	6"	8¼"	⅝"	49½"					Diagonal ⅝"	Sellers Anchor Bottom		¼"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Rolled
do	75	6"	8½"	⅝"	51"	4	⅜"						¼"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Rolled
C. G. W.	85	8"	8¾"	½"	70"						Flat Bottom	⅛"	¼"					2	⅝"x⅝"	2	⅝"x⅝"	2"	Rolled
D. L. & W.	91	7"	9⅛"	⅝"	63⅞"			5	⅞"				Inf ½"					2	¾"x¾"	2	¾"x¾"	2"	Rolled
do	80	6"	8"	½"	48"			5	⅞"				Inf ½"					2	⅝"x¾"	2	⅝"x¾"	1½"	Rolled
do																							
E. P. & S. W.	90	8½"	8¾"	½"	74⅜"						Flat Bottom		⅜"					2	⅝"x⅝"	1	⅝"x⅝"	1⅝"	Rolled
Grand Trunk	100	6"	8¾"	½"	52½"						Flat Bottom		⅜"					2	¾"x⅝"	2	¾"x⅝"	1¾"	Rolled
do	90	6"	8⅜"	½"	50¼"						Flat Bottom		⅜"					2	¾"x⅝"	2	¾"x⅝"	1⅞"	Rolled
do	80	6"	8½"	⅝"	51"						Lundie	1 in 20	⅝"					2	¾"x⅝"	2	¾"x⅝"	2"	Rolled
Illinois Central	85 90	7½"	8½"	⅝"	63¾"					Diagonal ⅝"	Sellers Anchor Bottom		⅝"	2	⅝"	1 Each End	2	⅝"x⅝"	2	⅝"x⅝"	1⅝"	Rolled
L. & H. R.	100	7"	10¾"	¾"	75¼"						Lundie	1 in 20	¾"					2	¾"x⅞"	2	¾"x⅞"	3¼"	Rolled
Lehigh Valley	90 100	8"	9½"	½"	76"	2	¼"						½"					1	¾"x⅞"	2	¾"x⅞"	2⅝"	Rolled
Long Island	100	7"	10"	½"	70"					Diagonal	Sellers Anchor Bottom		¾"					2	¾"x⅝"	2	¾"x⅝"	2⅜"	Cast
Norfolk & Western	100	6"	9½"	½"	57"			2 2	⅝" ¼"				Inf ½"					2	¾"x¾"	2	¾"x¾"	2¼"	Cast
Northern Pacific	90	7"	9"	⅝"	63"						4 Prongs 1"x⅝"x1¼" Deep	⅛"	⅝"					2	¾"x⅝"	2	¾"x⅝"	2¼"	Rolled
do	90	6"	8½"	⅝"	51"						4 Prongs 1"x⅝"x1¼" Deep	⅛"	⅝"					2	¾"x⅝"	2	¾"x⅝"	2"	Rolled
do	90	7"	9"	⅝"	63"	4	⅜"					⅛"	⅝"					2	¾"x⅝"	2	¾"x⅝"	2¼"	Rolled
do	90	6"	8½"	½"	51"	4	⅜"					⅛"	⅝"					2	¾"x⅝"	2	¾"x⅝"	2"	Rolled
do	85	6"	8½"	½"	51"						4 Prongs 1"x⅝"x1¾" Deep	⅛"	⅝"					2	¾"x⅝"	2	¾"x⅝"	2"	Rolled
do	85	7"	9"	⅝"	63"	4	⅜"					⅛"	⅝"					2	¾"x⅝"	2	¾"x⅝"	2¼"	Rolled
do	85	6"	8½"	⅝"	51"	4	⅜"					⅛"	⅝"					2	¾"x⅝"	2	¾"x⅝"	2"	Rolled
do	85	7"	9"	⅝"	63"						4 Prongs 1"x⅝"x1¼" Deep	⅛"	⅝"					2	¾"x⅝"	2	¾"x⅝"	2¼"	Rolled
N. Y. C. Lines—East	100 105	7"	9½"	⅝"	66½"			2	¼"				½"					1	¾"x¾"	2	¾"x¾"	2⅝"	Rolled
do	80	7"	9"	⅝"	63"			2	¼"				½"					1	¾"x¾"	2	¾"x¾"	2⅞"	Rolled
N. Y. C. Lines—West	100	6"	9"	⅝"	54"			1	⅞"		Sides Flashed		⅝"					1	¾"x¾"	2	¾"x¾"	1⅞"	Rolled
N. Y. N. H. & H.																							
Penna Lines—East	100	7"	10¾"	⅝"	75¼"						Flat Bottom		⅜"		2	¾"x¾"	Staggered	1	¾"x⅝"	1	¾"x1⅝"	3⅛"	Rolled
Penna Lines—West	85 100	7"	9"	⅝"	63"						4 Prongs 1"x⅜"x1¼" Deep		⅞"					2	¾"x¾"	2	¾"x¾"	2⅜"	Rolled
do	85 100	7"	9"	⅝"	63"						Flat Bottom		⅞"					2	¾"x¾"	2	¾"x¾"	2⅜"	Rolled
do	85	7"	8¼"	½"	57¾"						With or Without Claws		⅜"					2	¾"x¾"	2	¾"x¾"	1¾"	Rolled
P. & R.		7"	10"	⅝"	70"																		
P. & L. E.	100	6½"	11"	⅝"	71½"	2	⅜"						1⅛"	1⅛"	2	⅞"	Staggered	1	¾"x¾"	1	¾"x¾"	3⅛"	Rolled
R. F. & P.	100	6"	9¼"	½"	55½"	4 1	⅝" ⅛"						⅝"					2	¾"x¾"	2	¾"x¾"	2"	Rolled
S. L. & S. F.	90	6½"	9"	½"	58½"	2	¼"						⅝"					2	⅝"x⅝"	2	⅝"x⅝"	2¼"	Rolled
do	75 85	6½"	8¾"	½"	56⅞"			4	⅛"				¼"					2	¾"x¾"	2	¾"x¾"	2⅜"	Rolled
Southern Pacific	90	10"	10"	⅝"	100"						Flat Bottom		¼"					2	¾"x¾"	2	¾"x¾"	2⅝"	Rolled
do	90	8"	8¾"	⅞"	70"						Flat Bottom		¼"					2	¾"x¾"	2	¾"x¾"	1⅝"	Rolled
Southern	85 80	6"	8¾"	½"	51½"	4	⅛" Diagonal	4	⅛"				½"					2	¾"x¾"	1	¾"x¾"	2¼"	Rolled
Vandalia	100	6"	9"	¾"	54"			1	½"				⅝"					2	¾"x⅞"	2	¾"x⅞"	2"	Rolled
do	100	6"	9"	¾"	54"			1	½"				⅝"					2	¾"x⅞"	2	¾"x⅞"	2"	Rolled

SCREW SPIKE PLATES

RAILROAD	Weight of Rail	Dimensions of Plate				RIBS					TYPE	Cant	LUGS				Outside Shoulder	Inside Shoulder	SPIKE HOLES FOR							Projection Outside of Rail Base	Rolled or Cast	Free Play	REMARKS
		Width	Length	Thickness	Area	Transverse No	Size	Longitudinal No	Size	Cross			Outside No	Height at Hole	Inside No	Height at Hole			Plate Fastening No	Size	Position	Rail Fastening Outside No	Size	Inside No	Size				
A. T. & S. F.	90	7½"	8¾"	½"	65⅝"	2	¼"						2	[illegible]	2	[illegible]	¼"	½"				2	9/16"	2	9/16"	1⅝"	Rolled	⅛"	Screw Spike Plates Circular Lugs Experimental
do	90	7½"	9"	½"	67½"	2	¼"						2	[illegible]	2	[illegible]	¼"	½"				2	9/16"	2	9/16"	1⅝"	Rolled	⅛"	1" Lug Outside Spike Hole Experimental
Boston Elevated	85	6"	8¾"	[illegible]	52½"			1	⅛"								⅛"					2	[illegible]	2	[illegible]	1¼"	Rolled	Allowed	
Baltimore & Ohio	100	8"	9"	½"	72"						Flat Bottom		2	[illegible]	2	[illegible]	⅜"					2	1"	2	1"	1⅝"	Rolled	None	
do	90	8"	9"	½"	72"						Flat Bottom		2	[illegible]	2	[illegible]	[illegible]					2	1"	2	1"	2⅛"	Rolled	None	
do	85	8"	9"	½"	72"						Flat Bottom		2	¼"	2	¼"	¾"					2	1"	2	1"	1⅝"	Rolled	None	
C. R. R. of N. J.																													Wrought Iron
do																													Wrought Iron
C. R. I. & P.	100	6¾"	9¾"	½"	62⅞"						Flat Bottom			⅞"		¾"	⅞"					[illegible]	[illegible]	2	⅝"	2⅝"	Rolled	⅛"	Screw Spike Plate Spike Shoulders Across Ends of Plate
C. B. & Q.																													Wrought Iron or Steel
do																													Wrought Iron
Chicago & Alton																													Wrought Iron or Steel
[illegible] (Flat Bottom, 100, 6", 9")																													Wrought Iron or Steel
[illegible] (100, 6", 9", 2 ⅝"x1⅝")																													Malleable Iron
do (Flat Bottom, Cast & Rolled)																													Wrought Iron or Steel
do (90/85, 2 ⅛"x1¾")																													Malleable Iron
do (90/85, 4 ⅜", second)																													Inside Holes Staggered
do (90/75, Flat Bottom)																													Wrought Iron. Inside Holes Staggered
do (75, Flat Bottom)																													Steel Inside Holes Staggered
do (75, 2 ⅛"x2")																													Malleable Iron.
do (75, 4 ⅜")																													Inside Holes Staggered
C. G. W.																													Holes Staggered
D. L. & W.	101 105	7"	10⅛"	¾"	71⅛"						Flat Bottom		2	1¾"	2	1¾"	Inf ½"		2	⅝"	1 Each End	2	1¼"	2	1¼"	3"	Rolled	⅛"	
do	91	7"	10½"	¾"	74¼"						Flat Bottom		2	1½"	2	1½"	Inf ½"		2	⅝"	1 Each End	2	1¼"	2	1¼"	[illegible]	Rolled	⅛"	
do	80	7"	10¼"	⅝"	71¾"						Flat Bottom		2	1½"	2	1½"	Inf ½"		2	⅝"	1 Each End	2	1¼"	2	1¼"	⅝"	Rolled	⅛"	
Illinois Central																													Holes Staggered
L. & H. R.	80 100	7"	10¾"	⅝"	75¼"						Flat Bottom		2	1¾"	2	1¾"	Inf ½"					1 1	1⅛" ¾"x¾"	1 1	1⅛" ¾"x¾"	2¼"	Rolled	None	Screw Spike Plate R and L Comb Holes Staggered.
Long Island	100	5⅝"	8⅞"	⅝"	50¼"								2	1½"	2	1½"	Inf ½"	Inf ½"				2	⅝"	2	⅝"	1⅛"	Rolled	None	Cut Spike Plates Wrought Iron.
Norfolk & Western																													Wolhaupter Shoulder Flange Plate No. 67
Northern Pacific (last do)																													Right or Left Plates
N. Y. C. Lines—East (do)																													Right or Left Plates
N. Y. C. Lines—West																													Right or Left Plates
N. Y. N. H. & H.	100	7"	10½"	⅝"	73½"	2	⅜"										¼"					2	1"	2	1"	2⅝"	Rolled	1/16"	Spike Shoulder Both Sides
Penna Lines—East	100	7"	13½"	⅝"	94½"						Flat Bottom		1	1⅛"	1	1⅛"	1¼"		1	⅝"	2 Each End	1	1⅛"	1	1⅛"	4¼"	Rolled	1/16"	Cut Spike Plate Spike Holes Staggered Screw Spike Plates Spike Shoulder Both Sides
P. & L. E.																													Spike Holes Staggered.
R. F. & P.																													Holes Slightly Staggered
Southern Pacific																													Spike Holes Staggered.
do																													Spike Holes Staggered.

Cornwall & Lebanon Railroad:

SNYDER STEEL TIES, Mt. Gretna, Pa., Vol. 16, page 528.—A. D. Smith, President: "With regard to the 150 Snyder steel ties installed in our track near Mt. Gretna, beg to advise that there seems to be no change in the condition of these ties since last year, having received very little attention since my last letter."

Denver Union Terminal Railway:

SHANE STEEL TIES, Denver, Colo., Vol. 16, page 534.—J. Keating, Manager: "Please note following from our track foreman, dated Oct. 6, 1915: 'In regard to the Shane steel ties, which were installed in track at the Union Depot Terminal between 18th and 19th streets, on the old line, are still in service and are giving better satisfaction than any other ties in this yard.

" 'They have held the surface in the track during the wet season last spring and summer better than any other track in the yard.' "

These ties were formerly reported on by the Union Pacific Railroad, A. F. Vick Roy, Superintendent.

Duluth & Iron Range Railroad:

CARNEGIE STEEL TIES, Vol. 16, page 528.—W. A. Clark, Chief Engineer: "In regard to the Carnegie steel ties which were installed in track in 1905, I beg to advise that there is nothing new to report, as these ties continue to give good service."

Duluth, Missabe & Northern Railway:

CARNEGIE STEEL TIES, Vol. 16, page 530.—H. L. Dresser, Chief Engineer: "We have not put in any more of these ties since the first installment of about seven miles in 1908. Every one of these ties is still in the service and, for all I can see, is just as good as the day it was put in. They have given us very good satisfaction. About five miles of them are laid in a track across a big muskeg swamp, which used to cause us much trouble when using wooden ties. On account of the shaky foundation, the rails used to spread even when using tie plates until the track would have to be line spiked every year to keep it in shape, but we have nothing of this kind to bother with now.

"Of course, we do some light surfacing occasionally, but not as much as we did with the wooden ties when it was necessary to keep continually changing out old ties and putting in new and thus loosening up the roadbed under the track. If we had put in new wooden ties at the time we put in these steel ties, we would have found it necessary to change out at least 75 per cent. of them before this time, and another year or so would have seen them all changed."

Elgin, Joliet & Eastern Railway:

BATES TIE, Whiting, Ind., Vol. 16, page 530; Carnegie Steel Ties, various locations, Vol. 16, page 530; Campbell Concrete Ties.—A Montzheimer, Chief Engineer: "We now have 14,028 Carnegie steel cross ties in our track, put in as follows:

1907	50	ties
1909	3 600	"
1910	7,000	"
1911	500	"
1912	1,000	"
1913	1,638	"
1914	240	"
	14,028	"

"We also have 893 sets of Carnegie steel switch ties, put in as follows:

1912	154 sets
1913	494 "
1914	85 "
1915	160 "
	893 "

"All of these steel ties are in excellent condition, and giving good satisfaction.

"In addition to the above steel ties, we have 62 Bates reinforced concrete ties, located in eastbound main track, near Whiting, Ind. These ties were placed in our track in 1912, and are in first-class condition. As far as they can be seen, they are in the same condition as when first placed in track.

"In reference to Campbell reinforced concrete ties which were placed in our track September 7, 1914. These ties have all been removed through failure. The ties cracked, due to insufficient reinforcement. The concrete also shattered considerably underneath the rail. The most service we got out of these ties was eleven years, and some of them did not last that long."

Erie Railroad:

Carnegie Steel Ties, Croxton, N. J., and Jamestown, N. Y., Vol. 14, page 749.—F. B. Lincoln, General Manager: "The only switch ties of this character on East Grand Division were installed in track at Croxton, N. J., in 1909, and this installation consists of 57 switch ties. Below please find information requested by you:

Weight of rail on ties:	90-lb. ASCE
Spacing of ties:	20 in., C to C
Kind of ballast:	Stone
Kind of traffic over ties:	Freight
Amount of traffic over ties:	700 cars per 24 hours
Locomotive axle loads over ties:	60,000 pounds
Are ties insulated or non-insulated?	Non-insulated
What type of clip used to hold rail?	Bridge lugs and bolts
Do passenger trains pass over ties at high speed?	Do not pass over this switch
How do you close gage of worn rail?	Unable to correct wide gage

"We are not in a position to express any opinion as to merits of these ties."

Mr. R. S. Parsons, General Manager: "Two hundred and eighty steel ties of the Carnegie type were installed in track through station platform at Jamestown, in September, 1909. The ties which were placed under the street railway crossing just east of the station were taken up in November, 1914, on account of being broken and badly bent.

"The steel ties in the platform are still in service. We have, however, had some trouble with the ties, due mainly to bending and breaking directly under the rail through the holes by which the rail clips are fastened to the ties."

Florida East Coast Railway:

Percival Concrete Ties, St. Augustine, Fla., Vol. 16, page 530.—C. S. Coe, Engineer Maintenance of Way: "So far as the ties themselves are concerned, I beg to advise that my last report, of August 26, 1914, still holds good; no defects have developed, a recent examination showing the ties to be in as good condition in all respects as when first installed in our track in March, 1906, the 16 concrete ties being under one 70-lb. ASCE rail.

"The fastenings held well and were never touched previous to June, 1915, when it was found necessary to replace some of the gum wood cushions between the rail and the ties, which were beginning to split after the remarkable long service of nine years. We were obliged to replace these gum cushions with oak, as Mr. Percival, the inventor of the ties, was unable to obtain the gumwood at the time. It is not expected that the lasting qualities of the oak cushions will be anything near that of the gum, in this climate, Mr. Carter stating in a letter to Mr. Percival that the lasting qualiies of the gum originally furnished had outworn anything of a similar character that he had ever used."

Galveston, Harrisburg & San Antonio Railroad:

Percival Concrete Ties, Vol. 16, page 530.—I. A. Cottingham, Assistant General Manager: "In regard to the Percival concrete ties which we have in our track, I wish to advise that about the only additional information besides that which was furnished you last year is as follows:

"Bayou Sale—97 ties installed in 1910, no ties renewed to date. All ties sound and in good condition. No cracks, excepting one tie, which was made by screwing spike into socket that had a stone in it.

"Twenty-six of the original creosoted cushions were replaced with cypress cushions.

"Eighty-five of the old creosoted cushions cracked lengthwise with the tie and across the spike hole.

"Twelve of the old cushions completely burned off on the inside of the rail, leaving spikes exposed. This caused by the continued practice of cleaning fires in locomotives on track.

"Forty cushions partly burned on inside of rail.

"Two cushions show slight signs of decay.

"Twenty-nine cushions badly split, cracks ¼ in. to ½ in. wide.

"Nine ties have ½ in. to 1 in. of corner chipped off.

"All spikes well down.

"Line, surface and gage good.

"Clifton—One renewal in past year on account of screw spikes being broken off in tie. There are 21 ties remaining, this set in fair shape.

"San Leon—There have been two renewals during this year in this set, due to one tie being broken and the other tie with seven broken spikes. There are 50 ties remaining in this set."

Hocking Valley Railway:

International Steel Ties, Columbus, O., Vol. 16, page 531.—Wm. Michel, Chief Engineer: "Will advise that the 16 International steel ties which have been in our track for several years were removed June 17, 1915. These ties failed on account of cracking and disintegration of the concrete. They were put in the track December 22, 1911."

Huntington & Broad Top Mountain Railroad:

Stoneback Concrete Tie. No report received. Tie will not be described until report is submitted.

Lake Champlain & Moriah Railroad:

Carnegie Steel Ties, Vol. 11, page 891.—M. Moore, Superintendent: "With reference to the Carnegie steel ties that we have in use, beg to advise that I have nothing further to report concerning these ties. They have not, as yet, been removed from the track for any cause, and appear to be giving satisfactory service."

Lake Erie & Western Railroad:

Buhrer Composite Ties, Tipton, Ind., Vol. 10, page 515.—J. K. Conner, Chief Engineer: "In regard to the Buhrer composite ties which are in this company's track. My file indicates that 20 Buhrer ties were placed in the main track west of Tipton in 1903. There are 14 ties still in the track, six having been taken out. The condition of three of the 14 ties indicates that it will be necessary to replace them in 1916."

Lake Terminal Railroad:

CARNEGIE STEEL TIES, Lorain, Ohio, Vol. 16, page 531.—G. M. Ferguson, Superintendent: "In reference to our experience with Carnegie steel ties, would state that the Carnegie steel ties are used by us exclusively, we having started their use in the year 1907. We recently made some tests as to the loss from corrosion in track, taking ties from track where boiler house ashes had been used, with fair drainage, and found that the average loss was 86/100 of 1 per cent. per year. We also checked these results with ties which had been installed in 1910, which showed a loss of 82/100 of 1 per cent. per year, and, as a result, we believe that we will secure an average of at least 25 years' service from steel ties. Where the drainage is good, we believe this can be considerably increased, by reason of the fact that ties taken from points where the drainage was good showed a loss of but 1 pound in 5 years. All of the ties tested were taken from tracks which were subject to heavy traffic of large capacity loaded cars, such as coal, ore, etc.

"The use of steel ties has also enabled us to secure a longer life on our old wooden ties, by installing the steel ties every third tie and holding the rails to gage, thus avoiding the necessity of respiking and disturbing the old, wooden ties.

"We are securing excellent results from their use and would not now use anything else, as they have proved very satisfactory in every particular."

Midvale Steel Company:

SNYDER COMPOSITE TIES, Midvale, Pa., Vol. 14, page 755.—Newell C. Bradley, Assistant Superintendent: "In regard to our Snyder composite ties, which we have in these works, would say that they have not been sufficiently stiff to stand the loads on our main tracks and we have put them on tracks where the traffic is lighter and less frequent. For this reason we do not believe that they are a paying proposition for us."

New York Central Railroad:

BUHRER COMPOSITE TIES and UNIVERSAL STEEL TIES, Vol. 16, page 531.—G. W. Vaughan, Engineer Maintenance of Way: "In regard to the Buhrer steel ties, all of these ties are now out of our main track and we are putting them in sidings approaching the main track, where the wooden ties last but a very short time on account of burning them out in cleaning fires on engines.

"We have not yet given up to adopting or using this type of tie for main-track conditions.

"In regard to the Universal tie, which is a steel tie with wooden blocks for support of the rail. We had these in track at a place known as Washington Cut, between Spuyten Duyvil and 72d Street Yard, on the West Side, New York City, where there is mostly freight service.

"We have track circuits through this point, and we found it very difficult to maintain the insulation, due to oxidation of the metal clips which hold the rail to the tie, as well as the wood itself, also the wooden blocks crushed down. We are having these ties removed and put in slow-speed track, where there are no circuit conditions.

"These ties were sent us about four years ago for experiment, but on account of their first cost, oxidation, etc., I doubt if the cost would warrant us in buying any more, and their expense is too great to use them in side tracks."

New York, Chicago & St. Louis Railroad:

Kimball Concrete Ties, Cleveland, Ohio, Vol. 10, page 517.—E. E. Hart, Chief Engineer: "In regard to the six Kimball concrete ties installed near Euclid Avenue, Cleveland. During the grade elimination at this point, the ties were lost in the shuffle, and we have no record of them whatever since the last report that I made to the Tie Committee."

Pennsylvania Railroad:

Standard Steel Tie Company Ties, Parkersburg, Pa., A. C. Shand, Chief Engineer: "We have five hundred steel cross ties in our eastbound freight track at Parkesburg, Pa., manufactured by the Standard Steel Tie Company of Dallas, Tex. These ties, however, have only been in track about two months, and we are unable to give you any report as to their efficiency."

Mr. W. G. Coughlin, Engineer Maintenance of Way, reports as follows:

Mechling & Smith Steel and Wood Ties, Wilkinsburg Yard, Vol. 16, page 531. "Of the 100 Mechling & Smith steel and wood ties laid in Wilkinsburg yard in October, 1910, twenty were removed this fall, the wood blocks being worn so that there was no longer a good bearing for the rail or anchorage for the spikes. The steel is also reported to be in bad condition, and many of the bolts holding the wood blocks are broken. New tie plates were installed on the remaining 80 ties. The steel portion of the ties is reported to be somewhat corroded.

"We are advised that track laid with these ties seems to get out of line more quickly than track laid with wooden ties, and it is impossible to reline them without digging out and spoiling their old bed. It is also reported that these ties are difficult to maintain in proper surface, the apparent reason being insufficient tamping area.

"Morgan Steel Ties, Vol. 16, page 532. During the past year a number of changes have been made in the design of this tie, but none of the ties hitherto submitted proving entirely satisfactory, all Morgan ties remaining in track were removed last month. We have this month installed 56 Morgan ties of a new design, as shown in photographs.

"Carnegie Steel Ties, Vol. 16, page 531. Three thousand installed near Atglen, November, 1913. In October, 1914, it was found that the rivets had become loose on 83 of these ties. The Carnegie Steel Company furnished 100 new ties to replace them. The latter were installed and the 83 defective ones returned to Carnegie Steel Company in December, 1914.

"Snyder Composite Ties, Vol. 16, page 532. A number of the Snyder ties in the Conemaugh Yard and on the Johnstown Branch, Pittsburgh Division, have failed by reason of the rail wearing through the steel shell. Such failure occurred principally at or near joints. Nine hundred and seventy new Snyder ties have been purchased this year and installed in the eastward freight track on the Atglen & Susquehanna Branch, Philadelphia Division, east of Atglen, in July.

"In response to your letter of October 18, we give below the data requested concerning experimental ties, the information being arranged as indicated in your letter, viz.:

1. Plan.
2. Description.
3. Main track or siding.
4. Weight of rail.
5. Character of ballast.
6. Number of ties per 33 ft. rail.
7. Character of subgrade.
8. Total number of ties laid.
9. Date installed.

FIG. 6. LONGITUDINAL VIEW OF THE NEW DESIGN MORGAN TIE IN SERVICE AT ATGLEN ON THE PENNSYLVANIA RAILROAD.

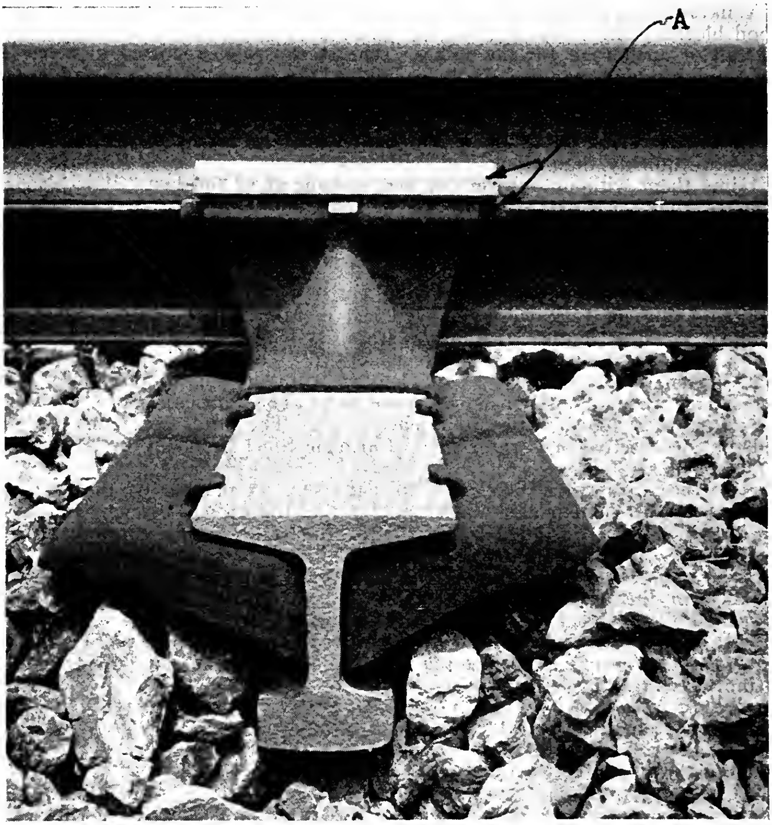


FIG. 7. NEAR VIEW OF NEW DESIGN OF MORGAN TIE.

This shows (1) pan for distributing the load on the ballast, which is illustrated in detail in Fig. 9, and (2) the clips marked "A" in the photograph for fastening the running rail to the tie and as shown in more detail in Fig. 8.

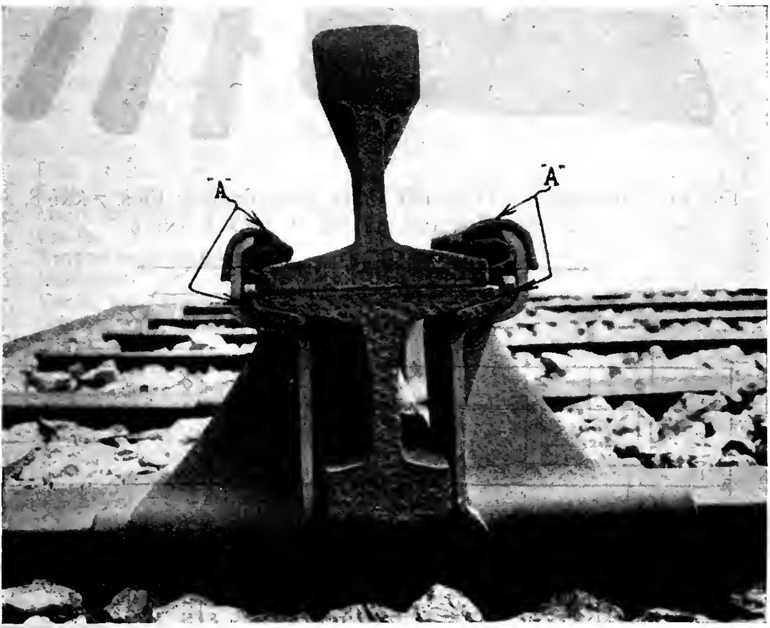


FIG. 8. CROSS-SECTION OF THE RUNNING RAIL ADJACENT TO THE NEW DESIGN MORGAN TIE.

This shows in more detail the clips mentioned in No. 2, which are marked "A" and which are more particularly illustrated in Fig. 10.

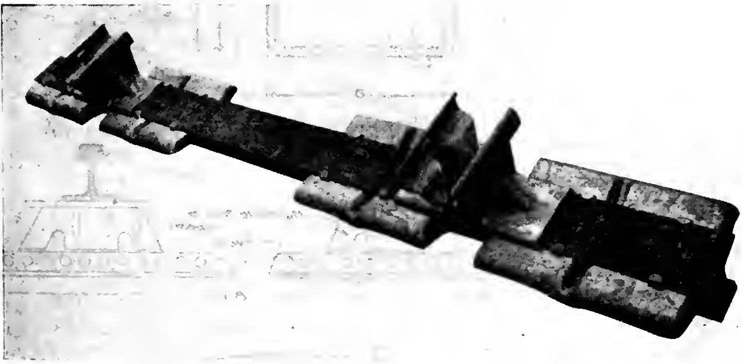


FIG. 9. ANOTHER PERSPECTIVE VIEW OF THE NEW DESIGN MORGAN TIE.

Fig. 10. Photograph (1) of the Clips Mentioned in Figs. 7 and 8, and (2) the Pan Illustrated in Figs. 8 and 9.

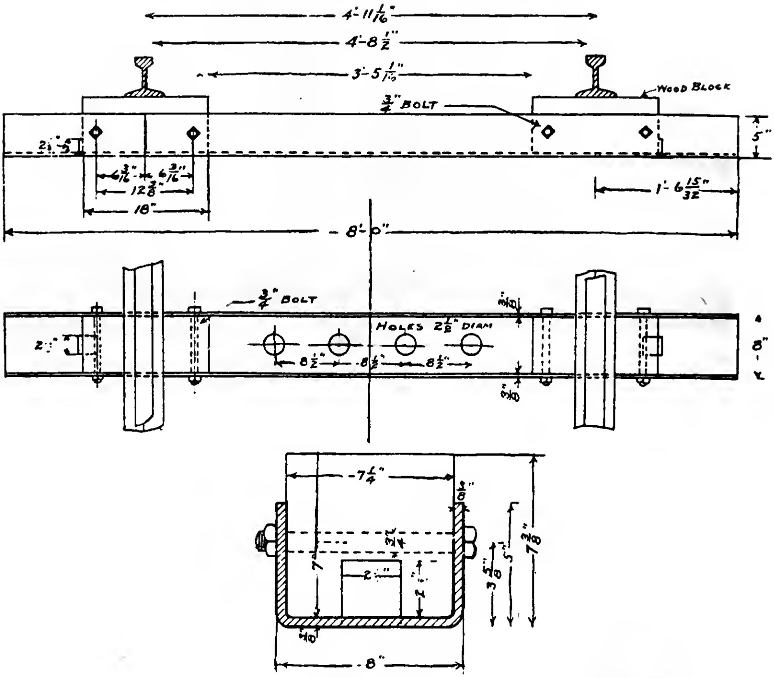


Fig 11. Standard Steel Tie.

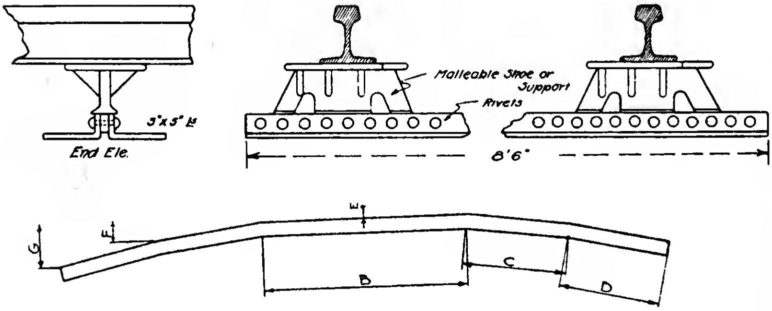


Fig. 12. Pennsylvania Steel Company Tie.

10. Weight of tie.
11. Cost.
12. Point of manufacture.
13. List showing where used, if at more than one point.

STANDARD STEEL TIE.

1. Plan 13, No. A attached.
2. Rolled steel channel with creosoted wooden blocks under rails.
3. Main eastward freight track.
4. 100-lb.
5. Trappe rock and cinder.
6. Eighteen.
7. Earth and stone.
8. 200 of 5-16-in. steel, 300 of ⅜-in. steel.
9. June, 1915.
10. 5-16-in. size, 160 lb.; ⅜-in. size, 205 lb.
11. 5-16-in. steel, $2.00 each; ⅜-in. steel, $3.25 each.
12. Channels, Midland, Pa.; blocks, Long Island City, N. Y.
13. Phila. Div., Atglen & Susquehanna Branch, east of Lenover, Pa.

SNYDER COMPOSITE TIE.

1. (See Vol. 13, 1912, page 352, for plan.)
2. Steel shell filled with asphalt and stone concrete.
3. Main eastward freight track.
4. 100-lb.
5. Trappe rock and cinder.
6. Sixteen.
7. Earth and stone.
8. 970.
9. July, 1915.
10. 494 lbs.
11. $4.00.
12. Pittsburgh, Pa.
13. Phila. Div., Atglen & Susquehanna Branch, east of Lenover, Pa.

MORGAN IMPROVED STEEL TIES.

1. See Figs. 6, 7, 8, 9, 10.
2. Tie is formed by riveting wings on an inverted rail. Chairs are placed on this tie supporting an inverted longitudinal rail, which, in turn, supports the running rail.
3. Main eastward freight track.
4. 100-lb.
5. Trappe rock, 1¼ in. to 3 in.
6. Eighteen.
7. Earth and stone.
8. Fifty-six.
9. October, 1915.
10. Have no data.
11. Unknown. The Morgan Engineering Company makes no charge for manufacture. The railroad company furnishes the old rail.
12. Alliance, Ohio.
13. Phila. Div., Atglen & Susquehanna Branch, east of Lenover, Pa.

PENNSYLVANIA STEEL COMPANY'S STEEL TIES.

1. See Fig. 12.
2. The base is formed by riveting together two "L" bars with web members between them supporting a casting forming an "I" section under the rail, filler plates being used at other points between the bottom "L's."

3. Main eastward freight track.
4. 100-lb.
5. Trappe rock, 1¼ in. to 3 in.
6. Eighteen.
7. Earth and stone.
8. Five.
9. June and July, 1913.
10. 160 lbs.
11. Unknown.
12. Steelton, Pa.
13. Phila. Div., Atglen & Susquehanna Branch, west of Atglen. Two of these ties were removed October 20, 1915, account of failure.

LEONARD CONCRETE TIE.

1. ———.
2. Reinforced concrete, square chamfered section, cored; wooden blocks under rails.
3. Main eastward freight track.
4. 100 lbs.
5. Trappe rock, 1¼ in. to 3 in.
6. Eighteen.
7. Earth and stone.
8. Six.
9. May, 1914.
10. 600 lbs.
11. Unknown.
12. Philadelphia, Pa.
13. Phila. Div., Atglen & Susquehanna Branch, west of Atglen, Pa.

WAPLES CONCRETE TIE.

1. Inventor is unwilling to publish plan as changes are contemplated.
2. Reinforced concrete, wooden wedges under rails; rails secured by adjustable hook rods.
3. Main eastward freight track.
4. 100-lb.
5. Trappe rock, 1¼ in. to 3 in.
6. Eighteen.
7. Earth and stone.
8. Six.
9. August, 1915.
10. 1,000 lbs.
11. Unknown.
12. Philadelphia.
13. Phila. Div., Atglen & Susquehanna Branch, west of Atglen, Pa.

Pennsylvania Lines, Northwest System:

CHAMPION COMBINATION CONCRETE AND STEEL TIE, Emsworth, Pa., Vol. 16, page 532.—R. Trimble, Chief Engineer Maintenance of Way: "This tie was formerly known as New York Steel Tie Company's tie, now known as National steel tie. A recent inspection showed these ties to be in very good condition, with the exception that in probably 50 per cent. the concrete filling had worked out of the steel shell for a distance of about one-half inch. This would indicate that the concrete had broken across the tie, but it has not as yet had any effect on the life of same. The insulation originally supplied with these ties proved very faulty, and a large number of signal failures resulted during melting of heavy snows. During the past summer, new insulation was applied, and it is not anticipated that any further trouble will be had with signal failures from this cause."

Riegler Concrete Steel Ties, Emsworth, Pa., Vol. 16, page 532.—Since the above report was made, the only development with regard to these ties is that they were removed from No. 1 track (in which they had been originally placed) in December, 1914. and were replaced in No. 3 track on May 6, 1915. This change of location was due to the fact that there were a number of experimental devices in No. 1 track, and as there had been some signal failures it was desired to reduce the number of devices, so that the determination of the signal failures could be more readily made. It was found that these failures were due to faulty insulation of another steel tie (New York Steel Company's ties) and were not in any way attributable to the Riegler ties. During the time that the Riegler ties were out of track, a very careful examination was made of them and they were found to be in very good condition. Two of the ties showed some cracks in the concrete, but not of sufficient magnitude to affect the integrity of the ties. These ties have now been in service for over seven years, and apparently are in as good condition as when newly made.

"Rohm Steel Ties, Sewickley, Pa.. Vol. 16, page 532.—A recent inspection showed that these ties were still in good condition, with the exception of one tie, which shows a crack in the holding plate outside of the rail. A great many of the holding plates are loose, and the fiber insulation is working out from between the plates and the rails. The Supervisor is of the opinion that the ties require a little more labor to keep in line than do wooden ties and about the same amount of surfacing. The wedges holding the cover plates require tightening about once a month, and at the present time are driven almost as far as they can go."

Pere Marquette Railroad:

Alfred Concrete Steel Ties, Vol. 10, page 519, A. L. Grandy. Chief Engineer: "Since 1908 these ties have gradually failed by excessive cutting under the rail seat and many have broken entirely through at this point and practically all of them have been removed at this date. We are not replacing any of them with concrete ties."

Pittsburgh & Lake Erie Railroad:

Atwood Steel Tie, McKees Rocks, Pa., Vol. 16, page 533.—J. A. Atwood, Chief Engineer: "The Atwood concrete steel ties that are in No. 4 main track west of McKees Rocks are still in service. Some of them cracked slightly shortly after installation, but have not cracked further. They have been in service since October, 1908. The rail fastening on this tie should be improved upon."

Brukner Reinforced Concrete Tie, McKees Rocks.—"The Brukner concrete steel ties that were in No. 3 main track just west of McKees Rocks station were removed from main track on account of ties being so badly broken that it was not safe to continue them in use."

Carnegie Steel Tie, McKees Rocks.—"The Carnegie steel ties that were placed in No. 3 main track at McKees rocks in September, 1907, failed to such an extent that in May, 1914, 500 (about one-half of them) were removed. This section of tie is not heavy enough for the traffic at this point. The other 500 are still in track where the traffic is comparatively light."

International Steel Tie, Glassport.—"The International concrete steel ties that were in westbound main track east of Glassport station were all removed in February and March, 1915, on account of being so badly broken that it was unsafe to continue them longer in use. The failure occurred in the concrete."

MAXEY STEEL TIE, Glassport.—"The Maxey or United States steel ties that are in westbound main track east of Glassport have cracked so badly that it will soon be necessary to remove them. A better construction of these ties at the rail-bearing parts will, in my opinion, make this a very good tie."

PERCIVAL CONCRETE TIE, McKees Rocks.—"The Percival concrete steel ties that were in No. 1 main track at McKees Rocks station were removed after having been in service twenty months. They were so badly broken that it was not safe to continue them in use."

UNIVERSAL STEEL TIE, Terminal Station. Pittsburgh, Pa.—"The Universal steel ties in westbound main track east of Smithfield Street Bridge at Pittsburgh have been in service since February, 1911, and are still in good condition, except that the rail fastening is poor."

Pittsburgh, Shawmut & Northern Railroad:

CARNEGIE STEEL TIES, Vol. 16, page 534.—H. S. Wilgus, Engineer Maintenance of Way: "These ties are failing rapidly. Some have already been removed and other renewals will follow from time to time. This tie is one of the first type placed on the market.

"Steel ties, I-beam section, require about 12 per cent. more ballast per mile than wood ties."

Union Railroad:

CARNEGIE STEEL TIES, Vol. 16, page 534.—F. R. McFeatters, Superintendent. No report received this year.

(II) USE OF SUBSTITUTE TIES ON FOREIGN RAILWAYS.

(A) A Report on the Use of Metal Railroad Ties, by E. E. Russell Tratman;

(B) Abstract of report on use of metal ties in Germany to the U. S. Government by Dr. W. K. Hatt (heretofore unpublished);

(C) A series of references in connection with dispute among professional German railroad men on the question of substitute ties;

(D) Reference to interesting articles on the use of substitute ties in foreign countries, prepared by A. C. Kaestner, 111 Broadway, New York, N. Y.;

each more fully described as follows:

(A) A Report on the Use of Metal Railroad Ties, by E. E. Russell Tratman.

Bulletin No. 9 of the United States Department of Agriculture, Division of Forestry, published in 1894. This valuable book outlines the use of metal ties in Europe, Africa, Australasia, Asia, South America and North America; the general review of metal track questions is of great value; the preservation of wooden ties; patents relating to metal railroad tracks covering the period from March, 1890, to March, 1894, a summary (page 311) of which is as follows:

Concrete block ties.
Fastenings for metal ties.
Joint for rails on metal ties.
Ties utilizing old rails.
Ties for street railway tracks.
Combination ties of metal and wood.
Longitudinals.

(B) Abstract of report on the use of metal ties in Germany to the U. S. Government, September, 1909. By Dr. W. K. Hatt. (Heretofore unpublished.)

It is quite apparent that conditions in Germany as in this country are changing fast with respect to increased severity of service on track, and that many of the standards used now in the German track, including steel ties and various forms of tie fastenings, are experimental. It is probable that officials have not in possession the information which would show whether or not these standards are successful. It would seem also that the tendency of the German official is to introduce improvements and complications beyond the immediate proven necessity for them. It must not be forgotten that the German railroads are state railroads and that improvements and experiments can be entered into, the value of which may be apparent only after a lapse of many years. This is because of the permanency of the controlling organization.

It appears that the Rueping process is of much more general use in Europe than in America, and is rapidly becoming the standard process in Continental Europe.

The use of steel ties is somewhat a question of geography, being more usually in the vicinity of the large steel works, and is somewhat rare except for switches in the vicinity of Berlin and the northeast. The use of steel ties is also no doubt determined by relations other than those of track economy. The government orders both kinds of ties, partly, no doubt, to keep prices down by competition, but also to keep these well-established industries in operation.

With reference to the advantage of the steel ties and the service they give in the track, my information is that the steel tie and fastenings have been increased in strength and redesigned so often to meet the increased weights of engines and to correct former mistakes in design that the modern steel tie has not been in the track long enough to give any indication of its probable life or success. The many changes which have been made in such ties with respect to weight and design show that weaknesses have been developing. I must confess, however, that I was not able to come in contact with those individuals who are responsible for promoting the use of the steel tie. The trackmen with whom I have talked in the vicinity of Berlin were strongly against steel ties, and the engineer at Zurich was strongly in favor of them.

THE SO-CALLED MILITARY TRACK AT ZOSSON.

The track is twenty miles long, constructed in 1903 for trials of electric locomotives, on which speeds of 120 miles per hour were attained. The track is laid on broken stone ballast 20 in. deep below the ties, which are 5 in. x 10 in. x 9 ft., creosoted pine, spaced 25 in. centers and 20 in. at the joints, protected with hook tie plates. Two screw spikes pass through the tie plate on the outside of the rail. The rail is held on the outside by the hook and on the inside by a clip, through which a screw spike passes. The pine ties are doweled with creosoted beech dowels. An examination of this track showed that tie plates had not cut into the tie and the thread in the dowels had not been spread by the action of the screw spikes. There are 18 or 20 trains a day passing over this track.

VISIT TO THE EXPERIMENTAL TRACK AT ORANIENBERG, ABOUT 25 MILES NORTH OF BERLIN.

This experimental track was constructed in 1906 by the central department of the Prussian State Railroads, to determine experimentally the best track construction to meet given conditions. It consists of an oval track two miles in circumference, over which runs a train consisting of electric locomotive and cars. At about every 50 ft., two vertical rail ends were sunk in the ground on each side of the track, and clips riveted onto them to serve as a reference line for measurement of track deformations. The service is considered as severe in one year as eight years on the main line. The cost of the roadbed and equipment is stated to have been $40,000.

About a year before my visit the first track had become worn out and the new track, consisting mainly of steel and beech ties, had been set under service.

Some of the elements which were being experimented with at Oranienberg may be listed as follows:

1. Prussian standard steel tie with side ribs have been down one year in different forms of ballast. The evidences of derailment of cars were visible, but the steel ties were not sprung. The modern double steel tie was used at the joints. It was said that the steel ties did not keep the track in line in gravel ballast, but did so in stone ballast. Wooden ties in gravel ballast were about as effective as steel in stone ballast.

2. Various forms of anchoring the rails to the ties were under experimentation. These anchors are found more necessary in steel ties than in the case of wood. The various forms of anchors seemed all to be effective, although the track as a whole had not been down long enough to give final results.

3. The scarf joint appeared to be unsuccessful inasmuch as the inner edge of the scarf sheared off at the edge, due to the wave motion in the rail.

The records of traffic passing over this experimental track show that in 369 working days the number of kilometer tons was about 8 million. In the months of January, February, March and April, in 1909, there were nearly 7 million kilometer tons. The locomotive weighed 59½ tons and would pull a train of from 240 to 375 tons. The speed of the train was 60 kilometers per hour.

INSPECTION OF THE TRACK OF THE PRUSSIAN STATE RAILWAY NEAR CHARLOTTENBURG.

This piece of track was on a curve 350 meters radius. Pine ties, treated with zinc chloride and creosote, and doweled with creosoted beech dowels, had been in service eight years. Tie plates had cut in the pine about ¼ in., the thread in the dowel still being perfect. On the same curve were creosoted white oak ties without dowels that had been worn down three-eighths of an inch on the inside rail toward the center of the curve. The shoulder tie plates were used in each case. There was no difference between the widening of the gage between the oak and the pine. It was stated that without the dowels the pine ties would not keep the gage in line. The rail weighed 41½ kilograms per meter, and 70 trains, on 2,100 axles, passed over the track in one day. The gage had not been changed since 1901. There was little if any wear on the outside of the rail, the wear taking place on the guard rail next to the inner rail of the curve. The action of the traffic did not seem to lift the rails and there was no noticeable motion of the joints. The wear of the rail had been equivalent to 1½ millimeters widening of the gage due to wear since 1901.

The special form of double tie plate was used for holding the guard rail and inner rail of curves below 400 meter radius.

Certain new forms of joints were also under test in this track. In one case the rail was scarfed and two keys were inserted to prevent the wave action of the track from raising one side of the scarf with reference to the other. These keys were 10 millimeters in diameter and 50 centimeters long. It cost 20 marks per rail to scarf the joint and three marks for channeling the opening for the key. There was no indication of a blow when the trains passed over this form of joint, which had been in for 4½ years. Ordinary scarf joints were bad in two years in this track.

Another form of joint was made by bridging over between the ties, but this was not successful in the opinion of the Geheimrat.

It was quite noticeable on this track that with the hook plate and clip there was a large amount of motion of the rail on the tie plate. Over this line passed 11,000 axles per day.

At the office of Hulsberg & Co., I saw a creosoted pine tie, preserved with zinc chloride and creosote that had been eight years in the line between Nurnberg and Lindau. The ties were doweled with beech dowels. The holes were sharp and round and little but ordinary compression visible.

There were also two creosoted pine ties which were put in the line of the P. L. & N. Ry. in 1887 and taken out in 1895, for doweling, eight dowels per tie, on account of the holes for the screw spikes having been somewhat enlarged. They were then put back in the track to the number of 250, and were taken out for examination in 1907, after eight years of original service and twelve years of doweled service, or twenty years in all. My observation of these ties showed that there was no evidence of wear or compression of the tie, and the holes in the dowels were sharp and perfect.

The dowels are made from young beech trees 3 to 4 in. in diameter, called white beech. The botanical species was stated by Mr. Kukuck of Hulsberg & Co. to be Carpinus Betulus, the ordinary beech being Fagus Silvatica.

VISIT TO ROTTING PIT AT STENDAL, NEAR BERLIN, GERMANY.

This rotting pit occupies a small brick building, the upper story of which is devoted to a museum for various kinds of wood and peculiarities of interest. Below is a three-chambered rotting pit. The first chamber is about 8 ft. x 8 ft. in floor area, kept at a temperature from 17 to 20 degrees Centigrade for the cultivation of fungus; the second chamber is about 6 ft. x 12 ft. by 10 ft. high for rotting experiments. The samples are exposed in galvanized iron boxes with covers.

The bottom of the box contains some garden mold with the pieces under test half buried and on top of this another piece of wood which has been infected with the fungus. The sides of the chamber are concrete, and on the upper part are corrugated forming channels for water to keep the air moist.

There is no ventilation in the chamber. The third chamber is also a rotting chamber, somewhat smaller than the second. Here specimens of wood are nailed to boards and exposed in comparison with one another to the action of infecting fungus.

The fungi being used are (1) merulius lacrymans (house fungus), (2) polyparus vaporarium (forest fungi). The investigations under way and the results obtained are, of course, in the interest of the company, and have not yet been made available for public distribution. One or two things, however, were shown to me.

It is evident that in this rotting pit the accelerated test may be made of the resistance of wood to the attack of fungus. For instance, the heart wood of the Baltic pine lasts but a little longer than six months in a rotting pit, while ordinary sapwood is entirely decayed in nearly two months. A piece of sapwood treated by the Rueping process was not at all attacked after 18 months' exposure.

In the third chamber endeavor was made to determine which constituent of creosote was effective in preserving wood and how much was necessary. To do this, pieces of pine were treated with a solution of (a) anthracene oil in ether, and (b) ordinary creosote in ether. Both solutions were forced in the specimens to refusal, which would amount to, perhaps, 40 lbs. per cubic foot. It appeared that pieces that were preserved with 1 per cent. of anthrecene were all good after two years, and with only ½ per cent. were all rotten. Pieces treated with less than 2 per cent. of a solution of ordinary creosote in ether were rotten. For instance, a piece treated with 1 per cent. solution was rotten when a piece with 2 per cent. was not. In the above it is understood that the 2 per cent. solution is a solution in ether, and as much of this solution as could be put in the wood was forced therein. A 2 per cent. solution of creosote would be .8 lb. per cubic foot. Little, if any, evaporation was involved here. The chemist in charge said to me that the strange figures which are often seen in birch, and especially in red gum, are deposits put there by the tree to fight the attacks of fungus, or to kill the fungus which is in operation. The deposit is a resinous coloring matter.

THE TREATING PLANT AT STENDAL.

The treating plant of the Rutgerswerke at Stendal has two cylinders, 2 meters by 17 meters, treating some 50,000 cubic meters of wood per year, working during the day only. Russian Pine is treated from nine months to one year and nine months after cutting. Beech from Germany and also from the Hartz Mountains is treated, the Rueping process being used.

While there a run was made of beech ties, weighing about 250 lbs. each when treated, as follows: The ties are adzed by a machine, but not bored. It is to be noticed that there is considerable drip after the ties leave the cylinder, which continues up to one day. About 10 to 15 per cent. of the beech ties must be bolted through after treatment; all of them are ironed with an "S" iron to prevent splitting. A core was cut from one tie showing complete penetration under the Rueping process. These beech ties are piled before treatment up to a time of nine months, but must not be held longer. They are piled solid after treatment.

It is to be noted that a new process, somewhat different from the old Rueping process, is used for beech ties, as shown by the cards, the creosote being put on in two stages. The theory is that first application heats the wood and lubricates the passageway for second application of creosote, and by preventing the cooling also prevents the solidification of any naphtaline. In this way a thorough penetration throughout the beech can be attained.

(C) A SERIES OF REFERENCES IN CONNECTION WITH DISPUTE AMONG PROFESSIONAL GERMAN RAILROAD MEN ON THE QUESTION OF SUBSTITUTE TIES.

A series of articles having their inception in an editorial, entitled "Iron Sleepers and Wooden Sleepers, Their Relative Economy," but are found not to be of sufficient definite scope or conclusion to warrant inclusion in this report. Most, if not all, of these articles were published originally in the Zeitung des Vereins deutscher Eisenbahnverwaltungen and are reprinted in the Bulletins of the International Railway Congress. Therefore, reference only as follows is made to these articles as a matter of convenience and interest to the Association.

1. January, 1909, page 48, "Iron Sleepers and Wooden Sleepers, Their Relative Economy." Editorial discussion in the Zeitung of an article appearing in No. 25 of the Zeitung. The conclusions, page 57, are of value.

This article consists chiefly of extracts from papers by Mr. Haarmann and Mr. Ernest Biedermann. Mr. Haarmann's paper is written from the standpoint of the iron manufacturer and presents comparative annual cost of pine sleeper vs. iron sleepers, which are exceedingly favorable to the latter. Mr. Biedermann, a maintenance of way inspector, questions the data and method of calculation and attempts to prove that Mr. Haarmann's conclusions are wrong.

2. October, 1909, page 1317, under Miscellaneous Information—No. 2, "Wooden Sleeper Superstructures." An article taken from the Zeitung, with editorial comment.

3. July, 1913, page 573, "Wooden Sleepers or Iron Sleepers," by Mr. Rectanus, State Councillor. An article taken from No. 11 of the Zeitung.

This article by Mr. Rectanus and the discussion on it in Bulletins for November, 1913, and April, 1914, are interesting. Apparently the author of the article and his critics in numbers 4, 5, 6 and 7 following do not agree on the relative life of iron and wooden sleepers. The economy of either depends on the length of life that is assumed.

4. November, 1913, page 906, "Wooden Sleepers or Iron Sleepers," by Mr. Waas, Railway Track Inspector of Stuttgart. An article taken from No. 26 of the Zeitung and being a discussion of Mr. Rectanus' article printed in the Bulletin of July, 1913, No. 3. immediately above.

5. November, 1913, page 909, "Wooden Sleepers or Iron Sleepers," by Mr. Biedermann. An article taken from No. 45 of the Zeitung, and being a discussion of article No. 11, by Mr. Rectanus, printed in July, 1913, No. 3, mentioned above, and also discussing article No. 26 by Mr. Waas, printed in November, 1913, No. 4, mentioned above.

6. April, 1914, page 337, "Wooden Sleepers or Iron Sleepers," by Ed. Lang, Member of the Board of Works, Baden. An article taken from the Zeitung and being a discussion of article No. 11 by Mr. Rectanus, printed in July, 1913, No. 3, mentioned above; article No. 26, by Mr. Waas, printed in November, 1913, No. 4, mentioned above; article No. 45, by Mr. Biedermann, printed in November, 1913, No. 5, mentioned above.

7. May, 1914, page 437, "The Question of the Life of Iron and Wooden Sleepers," by Mr. Biedermann. An article taken from the Zeitung and being a discussion of the article outlined in No. 6, immediately above.

8. May, 1914, page 445, "The Permanent Way of the Baden State Railway," by Ed. Lang, Member of the Board of Works, Baden. An article taken from the Zeitung and being a discussion of Mr. Biedermann's article, mentioned immediately above, i. e., No. 7, May, 1914, page 437. In a footnote the editor of the Zeitung states that with this article the discussion of the subject is considered closed.

(D) REFERENCE TO INTERESTING ARTICLES ON THE USE OF SUBSTITUTE TIES IN FOREIGN COUNTRIES—PREPARED BY A. C. KAESTNER.

1. I. R. C. Bulletin, September, 1898.—Metallic Sleepers on the Netherlands State Railway Company, by Ch. Benson. A report on the testing of (Post) type XI metallic sleepers laid for comparative purposes between 1881 and 1898 on the Liege-Limburg line. See item 14. Engineering News article, in which it is stated the Post ties have been removed.

2. I. R. C. Bulletin, March, 1899.—Metallic Sleepers on the Congo Railway by Leon Trouet.

3. I. R. C. Bulletin, May, 1899.—Latest Standard Permanent Way on the Gothard, Types IV and IVa.

4. I. R. C. Bulletin, December, 1899.—Steel Sleepers on the Sumatra State Railway, by L. K. Lindhout.

5. Railroad Gazette, page 600, 1901.—Metal Ties in Europe, by Foster Crowell. This subject is also treated in the Engineering News of June 26, 1913 (see No. 14).

6. Railroad Gazette, December 16, 1904.—Metal Cross Ties in Austria, by Hermann von Schrenk, Chief of the Forestry Bureau of the Agricultural Department.

7. "Handbuch fur Eisenbetonbau," Vol. III, Page 3.—Sarda Reinforced Concrete Tie."

8. "Handbuch fur Eisenbetonbau," Vol. III, Part 3.—Bavarian State Railroad Tie.

9. I. R. C. Bulletin, November, 1909.—Compound Sleepers on the Michel System, by Hector Michel, giving the results of seven years' experiment on the Paris-Lyon-Mediterranean and Paris-Metropolitan railroads. The compound sleeper consists of two shallow channel irons, back to back; between their ends are placed two blocks of parallelopipedon shape, compressed by means of metal clips.

10. "Beton u. Eisen," 1910, Page 69 of Vol. III.—Jensen & Schumacher Reinforced Concrete Tie, Denmark. (Fig. 13.)

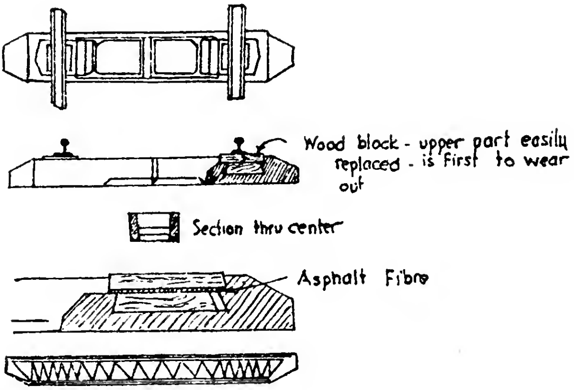


FIG. 13. JENSEN & SCHUMACHER REINFORCED CONCRETE TIE (DENMARK).

"These ties have proven successful after three years' service in private lines and two years' service in state lines. The theory of design of this tie is to have a block under each rail to take the load, and a tie between these blocks which does not take any load. Ordinary or screw spikes can be used."

11. Engineering News, August 17, 1912.—Standard Track Construction of the Great Indian Peninsular Railway (India), using Cast Iron Ties.

12. I. R. C. Bulletin, February, 1912.—The Life of Wooden and Iron Transverse Sleepers, by Mr. Cauer, Permanent Way and Traffic Inspector of Germany, based on Mr. Biedermann's paper in "Organ fur die Fortschritte des Eisenbahnwesens."

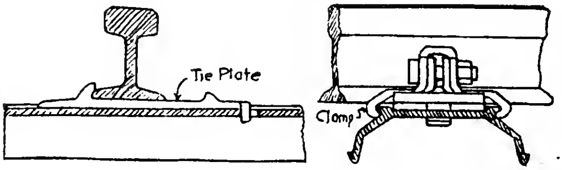


FIG. 14. STEEL TIE OF THE HAARMANN TYPE, 1911 DESIGN (PRUSSIAN STATE RAILWAYS).

13. I. R. C. Bulletin, September, 1912.—The Dyckerhoff-Widman and the Rudolf Wolle (German) reinforced concrete tie in Germany with comparisons with Maciachini's tie (Italian). There are three types of construction in this test:

(a) Dyckerhoff & Widman—plain reinforced concrete.

(b) Rudolf Wolle Reinforced Concrete Tie, in which concrete under rail seats is replaced by asbestos concrete. (Fig. 17.)

(c) The Italian Maciachini Reinforced Concrete Tie. For further report on this, see item No. 15. (Fig. 16.)

14. Engineering News, June 26, 1913.—Steel Ties on Foreign Railways. Results of tests with steel ties in Germany, Switzerland, Netherlands and Belgium. See illustrations of Haarmann and Swiss Government types of ties. (Figs. 14 and 15.)

A good summary to date.

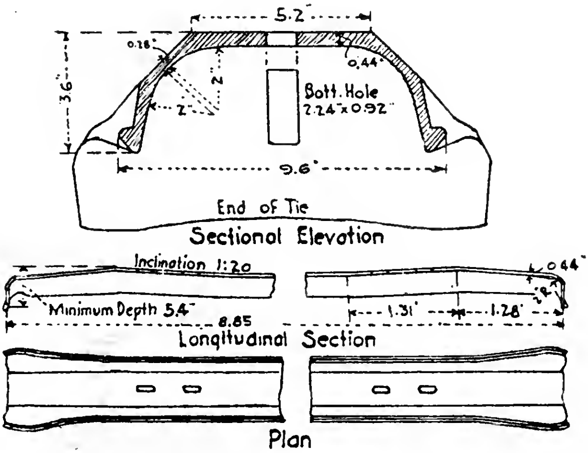


FIG. 15. STEEL TIE OF THE SWISS GOVERNMENT RAILWAYS (STANDARD DESIGN).

15. I. R. C. Bulletin, September, 1913.—Recent results with Reinforced Concrete Sleepers, by R. Bastian, Chief Engineer, Stuttgart.

"The Italian Railway has had some hundred thousand reinforced concrete sleepers made and laid. As yet not much reliable information is available about the behavior of these sleepers in actual practice, but we may draw sundry conclusions from the different types which have been tried in succession in Italy.

Type I—1900: This sleeper is 8 ft. 6¾ in. long, 7⅞ in. wide and 5⅛ in. deep. The reinforcement consists of numerous round iron rods, which are distributed through the cross-section in T shape. The rails are secured by means of screw spikes and Collet dowels (screwed bushes). The rails are placed on the concrete direct and are given a suitable inclination by giving the concrete surface a corresponding slope immediately under the rail.

Type II—1906: The sleeper is given an extra width, namely, 9 7-16 in., immediately under the rails. The iron reinforcement is placed near the boundary of the cross-section, instead of the middle, and is hence more effective in resisting tensile forces. The Collet dowels are replaced by four-sided wooden dowels of pyramid shape. The expansive action of the wood is counteracted by coils of wire and iron stirrups.

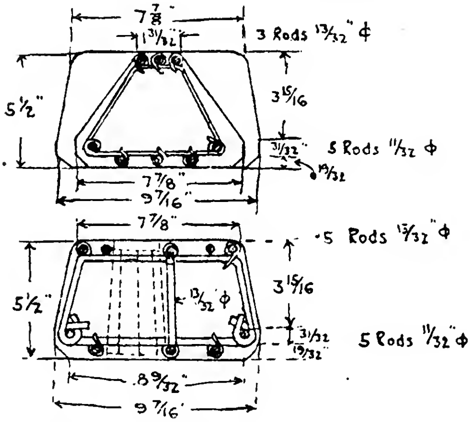


FIG. 16. MACIACHINI REINFORCED CONCRETE TIE (TYPE V).

Type III (Maciachini)—See 13c: The external dimensions are unchanged. The iron reinforcement is simpler and consists of a smaller number of thicker iron rods, having approximately the same total cross-

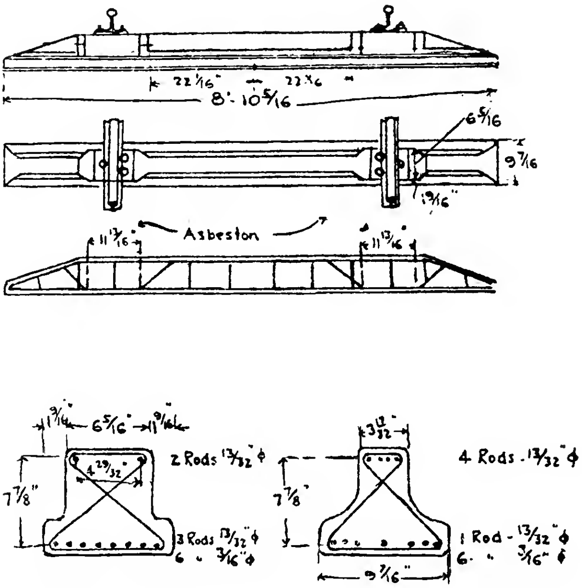


FIG. 17. "ASBESTON" REINFORCED CONCRETE TIE (RUD. WOLLE, LEIPZIG, GERMANY).

section. The center of gravity of the reinforcement is again nearer the boundary of the cross-section. In order to distribute the rail pressure and in order to give the rails the necessary inclination, iron sole plates are used, which also strengthen the rail fastenings. (Fig. 16.)

Ties of the Italian State Railways, by Rete Adriatica.

"Experiments since 1900 have been made by the Italian Railway on ties made under a patent by Ansano Caio.

"The cross-section of the tie is triangular except underneath the rail, where it is rectangular. The reinforcing consists of twenty-eight .20-in. to .24-in. round iron.

"Rails are fastened by means of screw spikes, which are held in place by hardwood dowels set in concrete.

The weight of the tie is 286 lbs.; costs $2.25 to $2.50.

Experiments were made on a large scale between Anconia and Foggia, a two-track road. As a result of many experiments, a modified tie was made in 1906. The position of the reinforcing rods was radically changed; where formerly it was located throughout the section, in the new type it is placed only at the top and at the bottom, and is all firmly tied together with wire."

16. I. R. C. Bulletin, June, 1914, Page 580—"The Sleeper Question in Russia," being a reprint from the Zeitung. This article is of considerable interest, not so much for the technical information as for the insight into conditions in Russia.

REPORT OF COMMITTEE XIX—ON CONSERVATION OF NATURAL RESOURCES.

C. H. Fisk, *Chairman;*	R. C. Young, *Vice-Chairman;*
R. H. Aishton,	William McNab,
Moses Burpee,	A. L. Moorshead,
F. F. Busteed,	Francis Lee Stuart,
A. L. Davis,	S. N. Williams,
W. A. Hammel,	*Committee.*

To the Members of the American Railway Engineering Association:

FORESTRY ABROAD.

Your Committee refers to the last two reports, particularly the 1915 report, showing success of the Illinois Central and other railways in practical forestry. On account of the limited time elapsed since previous data were secured, it has not been thought necessary to attempt similar railway data for the present year. However, the success of France in forestry deserves notice as showing what has been done under unfavorable conditions and that the work should be managed by the government, as it deals with long-time periods and requires much capital. Dr. B. Fernow's Canadian report deserves credit for information furnished. During the first half of the nineteenth century up to 1865 the French Forestry Department planted 200,000 acres of sand dunes and placed them under management at a total expense of $2,700,000, or $13.50 per acre. About half was ceded to municipalities and private owners for $2,745,000, repaying the outlay, and the remaining 125,000 acres are valued at $10,000,000. In 1901 the first cutting was made, yielding $92 per acre from a property that cost nothing. Improvement by ditching and planting of nearly 2,000,000 acres adjoining was begun in 1837 by private interests, who by 1857 had reclaimed 50,000 acres. The government then began building roads, railways and drainage systems, furnishing plans free and assisting municipalities in reclaiming land. It bought 390,000 acres of land to enable them to accomplish the improvements. This once poverty-stricken district, which a century ago was hardly inhabited, in 1907 was traversed by the densest net of railways in France at an expenditure of $10,500,000 or $6.50 per acre. One million six hundred thousand acres were reclaimed, 85 per cent. in forest, of which the state owns somewhat over 100,000 acres, municipalities 185,000 acres and private owners the bulk of 1,500,000 acres. In 1898 the value of these holdings, made from nothing, was estimated at over $96,000,000. In 1892 the average net yield was $2.40 per acre and has since been rising, so that now an annual income of $8,000,000 is the result from an expenditure of $10,000,000. Another region of extensive waste-land planting is that of the Sologne near Orleans, a sandy, poorly-drained plain on an impermeable, calcareous sub-soil, which causes swamps. This was once densely wooded, but by the end of the eighteenth century about 1,250,000 acres had been devastated and abandoned. Private interests began its reclamation and 200,000 acres were planted at an expense of $5 an acre. An estimate of the value of these plantations places it at $18,000,000, so the lands which 50 years ago could hardly be sold at $4 per acre, now bring over $3 an acre as their annual revenue. The fourth district lies on the arid wastes in the Province of Champagne. Here since 1830 over 200,000 acres were planted and prepared at a cost of less than $10 per acre. The present stumpage value is placed at from $50 to $100 per acre, and yields $2 per acre revenue. This property is estimated at $10,000,000. France has therefore 2,000,000 acres recuperated at an expenditure of less than $15,000,000, now representing a capital of $135,000,000, or nine times the outlay, and an income of about $10,000,000 annually, or seven per cent. on the valuation.

RESULTS SECURED IN THE UNITED STATES.

Similar success has followed forest planting on the sand hills of Nebraska. Jack pines planted by the United States Government Forest Service ten years since now have a height of 15 feet and a diameter of over 4 inches. Forbach, Germany, is said to have the most profitable town forest known, as it yields an annual net gain of $12.14 per acre. The U. S. Forest Service shows that on third-quality soil, 50,000 feet B. M. per acre of white pine can be grown in 80 years, and one-half more on best quality soil, while stumpage values actually obtained for inferior second growth average $280 per acre for 70-year-old wood, while raising the crop including all items of expense averages $140 per acre, leaving a net return of $140 from land valued at $5 per acre. Even 35 to 40-year-old wood can be profitably marketed.

PROGRESS IN CANADA.

H. R. MacMillan, Chief Forester in British Columbia, reports that about 69 per cent. of the area of Canada south of the sixtieth parallel is unsuited for agriculture, but a large proportion is suitable for the production of merchantable timber, and forest products will always be an important industry, as they furnish 12 per cent. of the foreign trade, 16 per cent. of the railway traffic and equals in value the annual wheat crop.

The future forest industries, which are almost the only ones possible in three-fifths of eastern Canada, must be supported by the timber grown on the logged- and burned-over non-agricultural land. Care of the young forest on these is not only a duty to posterity, but an insurance of timber industries affecting Canada's prosperity.

The one great obstacle in the way of proper preservation of young forest growth, as well as of mature timber, is the annual recurrence of forest fires. Unfortunately, efforts at fire protection are confined largely to merchantable timber, throughout a large percentage of the area of Canada, leaving great bodies of yiung forest growth to be destroyed each year. However, distinct progress can be reported in some directions. Under the regulations of the Railway Commission, the railways of Canada appear now to be only a minor source of damage from forest fires. Settlers, sportsmen and tramps are reported as being responsible for much damage, due largely to carelessness. In some of the provinces, progress has been made toward regulating the setting out of settlers' fires, by the issuance of permits at safe times. The extension of this plan is to be anticipated. The merit system of appointments in fire-ranging services has been agitated for years, but has not yet been made effective. In Quebec, the St. Maurice and Lower Ottawa Forest Protective Associations have demonstrated conclusively the value of co-operative effort in forest-fire protection. These two associations protect an area of sixteen million acres of land, more or less timbered. The fire-rangers employed by the associations are selected on the basis of merit and their work is closely supervised by competent inspectors. The necessary funds are contributed by timber owners in proportion to the acreage owned or controlled by each. The further extension of the co-operative idea in forest fire protection is being agitated by some of the more progressive limit-holders.

REFORESTATION IN THE UNITED STATES

The U. S. Forest Service reports there are 250,000,000 acres of forest area on which there is sufficient natural reproduction to insure a fair second crop. No reforestation on a large scale will be undertaken by private capital, but the government will take steps to insure a continuous supply of timber sufficient for the country's need. The estimated annual production of wood in the United States is only 12 cubic feet an acre, while in Saxony, where forestry has been practiced for years, it is 93 cubic feet per acre, hence the necessity for practice of scientific methods which would yield enough wood for the per capita consumption of 150 cubic feet by 150,000,000 people.

LOSSES BY FIRE.

The U. S. Forest Service reports that an average of 10,000,000 acres is annually burned over, causing a loss of $25,000,000. These fires destroy the soil covering in a forest, causing rapid runoff on steep slopes and the erosion and irregularity of stream flow with loss of navigability, hence the necessity of continued state and national co-operation to secure protection from forest fires, which destroy annually 12,000,000 board feet of timber. It is stated that Nature has taken 10,000 years to form a foot of soil, hence waste should be avoided by proper drainage.

DEPLETION OF NATURAL RESOURCES.

Leonard Lundgren, of the U. S. Forest Service, estimates that the forests have been reduced from 800,000,000 acres to 550,000,000 acres and 5,200 billion board feet of lumber to 2,900 billion feet. The annual cut of saw timber is estimated at 43 billion board feet, and the present timber supply would last about 65 years without renewal, but as the annual consumption is three times as great as the annual growth, the forests are being harvested three times as fast as they grow, and this compels economy in the use of wood. Forty cubic feet of wood per acre are used, and only twelve cubic feet is produced by the natural growth. We use 260 feet per capita, while Germany uses only 37 feet, France 25, Great Britain 14. Dr. Swain estimates the total waste of mineral products at one million dollars daily, or more than one-sixth of the production, besides the waste of lives. Dr. Douglas estimates that only 60 per cent. of the hundreds of millions of dollars yielded by the Comstock lode were recovered at the time, and at first the enormously rich tailings were not even collected. The deplorable feature of this waste is its permanent loss to national resources. At present rate of consumption the known supply of high-grade iron ores will be practically exhausted by the middle of the present century and phosphate rock supplies in twenty-five years. Natural gas has been known to waste at one time sufficient to light all the cities in the United States having a population over 100,000. At present rate of use, all known supplies will soon be exhausted. The oil supply will be exhausted before 1950. By uneconomical mining and extracting only high-grade material, or allowing mines to cave in, a large per cent. of coal is wasted, hence the easily accessible and available supply will be exhausted by the middle of the next century. In any period of ten years the production of coal and its consumption equals the total production up to the beginning of that period.*

ANTIQUATED COKING METHODS.

Millions of dollars' worth of by-products from coke production are literally thrown away annually in the United States through the continued use of the obsolete beehive-oven process, according to reports of the United States Geological Survey. The loss by that method last year is estimated at $40,000,000. In 1914 the total output of coke was 34,555,914 short tons, valued at $88.334,217. Of this output, 23,335,971 tons were made in beehive ovens with an almost total loss of the by-products—tar, ammonia, gas, benzol—and 11,219,943 short tons were produced in modern type ovens with a recovery of over $17,500,000 worth of by-products.

HYDRO-ELECTRIC POWER.

Conserve fuel as we will, fuel supplies are absolutely limited in quantity, which makes a serious problem if we depend entirely upon steam for power. Any power development, not dependent on a decreasing natural resource, must become increasingly valuable. The electric age requires cheap power to maintain its growth, so as water will always be raised by the sun, precipitated on the land and descend into the ocean; this gives the needed source of energy, 70,000,000,000,000 cubic feet of water run off to the sea annually, enough to generate 250.000 H.P. for every foot of fall between the place of precipitation and the ocean. By various estimates the commercial developable power is about 37,000,000 H.P., of which 30,-

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*Dr. G. F. Swain's Yale University Lectures on the Conservation of Water, 1914; page 10. Also Henry Gannett, U. S. Geol. Sur. and Conservation of Resources, 1909.

000,000 H.P. are wasting, and the ultimate capacity of streams 230,000,000 H.P. The first requisite of power is continuity of service, which means constant supply of water. Of 70,000.000,000,000 cubic feet of water available, only about one-seventh of one per cent. is used for all water supply, two per cent. for irrigation, five per cent. for navigation; 1,500,000 H.P. at the government dams are wasted in navigation, while 90 per cent. of the water flows away unused and does flood damage. Water power not utilized is constantly wasting with no good results to anyone, and its utilization means a saving of a corresponding amount of non- or slowly-renewable resources. The use of water power saves an equivalent amount of coal in motive power for railways or lighting. The development of water power also aids in rendering streams navigable. In 1912 the Secretary of Commerce and Labor estimated the total stationary power developed by water as 6,000,000 H.P. and 19.000,000 undeveloped. The present annual coal consumption is over 500.000.000 tons, and at the present rate of increase the anthracite coal deposits will be exhausted by the end of the present century (Gannett). The bituminous supply will last indefinitely. If we could utilize the available 19,000,000 H.P. instead of coal, we would save 95,000,000 tons of coal, which at three dollars per ton equals $285,000,000. Every H.P. developed by water and used to replace steam saves fifteen dollars' worth of coal yearly. One H.P. a year requires five tons of coal. If 5,000,000 H.P. could be developed by water, it would mean an annual saving of $75,000,000 in cost of coal alone. In an ordinary steam power plant less than ten per cent. of the theoretical energy of the coal is utilized and in lighting plants less than one per cent. of the energy of the coal is utilized in light.

The value of the wasted water powers in New York State has been estimated at $15,000,000 annually. The development and use of less than 25 per cent. of California's available water powers would stop all wood. oil and coal-burning for power purposes in that State. The same is true for nearly all of the Western States, also many of the Eastern and Southern States. If all the water powers could be developed and their output substituted for steam, the available coal supply could be husbanded and used for other purposes, for which there is no other equal substitute.

Water power developments have been enormous, but have not kept pace with the demand for electric current. During all this time millions of H.P. have been going to waste in the streams of the United States. Seventy-two million tons of coal are annually consumed in steam power. The undeveloped water powers are estimated from 30,000,000 to 50.000,000 H.P., which are now lost in the industrial effort of steam. This emphasizes the necessity for water power development in making provision for future power demand.

Use of water power to furnish motive power for railways saves an equivalent amount of coal. Its conservation is then a double conservation as it involves a non-renewable resource of a strictly limited supply, and this is of greater importance than that of any other of our material resources; if not used, water power is continually wasting with no good results, and as the power is perpetual, a free gift from the Creator to man, its use saves a similar amount of one of the non-renewable or slowly renewable resources. Other resources, if not utilized, are in general stored and preserved for the use of future generations.

In Canada, in 1914, the total water-power developed was approximately 1,500,000 H.P. Assuming that under average conditions 1 horsepower hour can be produced in a steam plant from three pounds of coal, this amount, calculated on a 12-hour basis and taking a load factor of 50 per cent., which is a conservative allowance, represents a saving of 4,050,000* tons of coal per year. As the total output of coal in Canada for the same year amounted to 13,637,529† tons, the amount saved by water-power represents less than one-third of this, while the greater portion of it could be replaced by the unutilized water-power which is now running to waste.

RESULTS OF ELECTRICAL OPERATION IN THE NORTHWEST.

The Butte, Anaconda & Pacific Railway is an illustration of the value of hydro-electric power in economy of operation, the total saving from steam locomotive performance being estimated at $237,581 annually, and of trainmen's wages at $31,146, or a total of $268,727. The electric locomotives are much easier on track on curves, but not on tangents, and are better adapted to the heavy mountain divisions. It operates 114 miles of single track, including main-line sidings and yards, uses 2,400-volt, direct-current locomotives, the largest installation in the world using such locomotives. Fifteen are used, weighing 75 tons, hauling ore trains and run in groups of two hauling trains against a ruling grade of three per cent. in the prevailing direction of traffic. These replace 28 steam and two passenger specials for the regular passenger trains. The freight locomotives have a free running speed of 35 miles per hour, the two passenger locomotives haul three loaded coaches at 45 miles per hour. The freight locomotives have a tractive effort of 25,000 pounds at 15 miles per hour against the ruling grade and 21 miles per hour on level track. Power is furnished from several power plants of the Great Falls Power Company, 125 miles distant. The traffic is five million tons of freight per year, trains consisting of fifty loaded steel ore cars of 3,400 tons on a grade of three per cent. Locomotives of two-unit capacity are used in rougher country, where the current is stepped up from 2,400 volts to 102,000 volts. The transmission is to Butte, 130 miles, on two separate parallel lines.

Electric locomotives can successfully replace the heaviest type of steam engine on mountain grade divisions of main steam roads if the daily tonnage is sufficiently heavy to justify the first cost of electrification. They are better adapted to the rigorous requirements of heavy mountain grade divisions.

The locomotives of 2,200 H.P., weight 150 tons, in continuous operation, move up the ruling grades at twice the speed of steam and

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*Short tons and assuming 300 working days in the year.

†Short tons.

control on the down grades by the electric brake. In the far Western mountain districts, where fuel of low grade and water power is near at hand, as in the Denver and Rio Grande District, and in rapid transit commuter service near densely populated districts, and in sparsely settled mountain districts, the electric power service gives increased track capacity, which is very important, and electric power is the cheapest means of getting it.

The Chicago, Milwaukee & St. Paul Railway has recently made elaborate tests on its Edmont grade of 1.66 per cent. over the Rocky Mountains east of Butte, to show the tonnage its electric locomotives would haul and the application of regenerative braking. Two electric locomotives pulled a trailing load of 48 cars, 3,000 tons, over the range at a speed of 16 miles per hour. A steam train of 37 cars, 2.100 tons, followed, drawn by two of the heaviest road engines and a Mallet pusher at a speed of 9 miles per hour. The greater ease with which the electric locomotives pulled the heavier load stopping on the grade then gathering speed gave great satisfaction to the officials. The new locomotives pull a load thirty-eight per cent. heavier than those now pulled between Butte and Anaconda, freight engines being geared to a maximum of 35 M. P. H., while passenger engines will be expected to make 65 M. P. H.; 113 miles of the proposed 440.5 miles of main track and 141 miles of side and yard tracks to be electrified have been completed, and work will continue at rate of 100 miles per year until finished. Power is furnished from the Montana power companies' hydro-electric plants at Great Falls and Thomson Falls, Mont., the power plants having a capacity of 244,000 H.P.. while large storage reservoirs insure an ample continuous supply of power, which is brought as 100,000 volts, three-phase, 60-cycle, alternating current, at a cost .536 cents per K. W. hour, based on a 60 per cent. load factor. The cost of operation is reduced 40 per cent. on four entire engine districts, giving opportunity for full development of economies in yard as well as line operation and for working out methods of electrical operation. Surplus energy not needed on trains on descending grades is returned to the line for further use, giving safety on heavy grades and preventing excessive wear on brakes and shoes. The passenger locomotives will haul 800 tons on grades up to 2 per cent., and maintain the present schedule with 650 tons from 30 miles to 60 miles per hour, and freight locomotives 2,500 tons on one per cent. grade, at 16.8 miles per hour, using two locomotives where necessary.

On account of the war in Europe, the Conservation Association of the United States has done no active work for two years, while both Federal and State Conservation work has been suspended, so that no progress report of work done by other Conservation Associations can be given.

CONCLUSION.

The Committee offers the above as a progress report and requests that it be received as information.

NEXT YEAR'S WORK.

Your Committee recommends continuing the study of the relation of railways to the different conservation projects, reviewing work done by each up to the present time, and to recommend such policies as may appear desirable for railways to follow.

Respectfully submitted,

COMMITTEE ON CONSERVATION OF NATURAL RESOURCES.

REPORT OF COMMITTEE XIV—ON YARDS AND TERMINALS.

E. B. Temple, *Chairman;*
W. G. Arn,
H. Baldwin,
G. H. Burgess,
A. E. Clift,
L. G. Curtis,
H. T. Douglas, Jr.,
A. C. Everham,
R. Ferriday,
G. H. Herrold,
D. B. Johnston,
B. H. Mann, *Vice-Chairman;*
H. A. Lane,
A. Montzheimer,
H. J. Pfeifer,
S. S. Roberts,
C. H. Spencer,
E. E. R. Tratman,
E. P. Weatherly,
W. L. Webb,
C. C. Wentworth (deceased),
J. G. Wishart,
Committee.

To the Members of the American Railway Engineering Association:

The Committee on Yards and Terminals begs to submit the following as its seventeenth annual report:

The Board of Direction outlined the work of your Committee for 1915, as follows:

(*1*) *Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.*

(*2*) *Report on handling of freight in double-deck freight houses and cost of operation.*

(*3*) *Continue study of typical situation plans of passenger stations and approaches and methods of operating same.*

(*4*) *Continue the study of classification yards.*

(*5*) *Continue study and, if possible, make report on track scales.*

A general meeting of the Committee was held in Philadelphia on October 27th and 28th, and the reports of the Sub-Committees appointed to consider and collect information pertaining to the respective subjects were carefully considered.

REVISION OF MANUAL.

The section of the Manual applicable to Yards and Terminals was discussed very fully in our work for 1914, and the recommendations involving a new definition or a change in principle of an old definition appear in the Bulletin for February, 1915, Vol. 16, No. 174, pp. 958 and 959. These suggestions were reviewed this year, and, except to add the following definition of a "Holding Yard," no further modifications are deemed necessary for the present.

"Holding Yard."—A convenient relief yard for holding cars or trains for immediate use.

HANDLING OF FREIGHT IN DOUBLE-DECK FREIGHT HOUSES AND COST OF OPERATION.

The Sub-Committee having this subject in charge is collecting information and making studies, but will not be ready to submit its report until some time in 1916.

It has been suggested that consideration be also given to a kindred subject, which has recently been brought to the attention of some of the members of your Committee, i. e., the Advisability of Constructing and Operating Storage Warehouses in Large Cities in Connection with Inbound Houses. A number of railroad companies have built and are now building some structures of this kind, and the subject is an interesting one. We are somewhat in doubt as to whether it comes under the jurisdiction of this Committee or of the Committee on Buildings, but either one or the other, as the Board of Direction may specify, might consider it with advantage to the Association.

TYPICAL SITUATION PLANS OF PASSENGER STATIONS AND APPROACHES AND METHODS OF OPERATING SAME.

Three methods for studying the working capacity of station and approach tracks were referred to in our report for 1912, which has been published in the Bulletin for February, 1913, Vol. 14, No. 154, and our work during the current year pertaining to passenger stations has been devoted principally to an observation of the results obtained by the use of two of the methods then discussed, viz., that used by the Pennsylvania Railroad Company in analyzing the capacity of Broad Street Station in Philadelphia, and the Co-ordinate Train Diagram and Track-Occupancy Diagram.

In 1910 and 1911 the track layout of the station and approaches at Broad Street Station, Philadelphia, of the Pennsylvania Railroad Company, were seriously congested by the movement of traffic, particularly during certain hours of the morning and evening, and a Board of Engineers and a Transportation Committee appointed to study the situation devised a method of showing graphically the actual occupation of the tracks during the peak-load periods, also the measure of relief that would be afforded by the adoption of the multiple-unit system of electrification. One of the lines within the suburban zone has since been electrified, namely, Broad Street Station to Paoli, on the Main Line, a distance of twenty (20) route miles, and electrically-operated trains were put in service on September 4th. The results so far have come up to expectations and the practicability of the charts that were used in the preliminary studies has been satisfactorily demonstrated. The Committee, after the adjournment of the meeting on October 28th, were taken over the electrified line in an electric train to inspect the new construction.

The Committee's Co-ordinate Train Diagram and Track-Occupancy Diagram were used at Kansas City just subsequent to the opening of the new Union Station last year for the purpose of scheduling trains on the proper tracks. The complete change all at once in the handling of the traffic of twelve tenants in an entirely new layout made it practicable to use any memory method for planning the train and switching movements in the congested periods, and these diagrams permitted a reasonably accurate forecast to be made of the best schedule of accomplishing the loading and unloading of trains and the transfer to and from trains, also for obtaining the most efficient use of the throat tracks during the rush hours.

CLASSIFICATION YARDS.

Three classification yards were selected for study—two hump yards and one flat yard.

Report is attached, giving details of the cost and results of operation for the month of August, 1915, for the hump yards, and September, 1915, for the flat yard. In case members of the Association desire to make further study of these costs the names of the railways operating the yards will be supplied by the Secretary. Where possible, the reports covering the three yards are shown in parallel columns for comparative purposes and additional information covering each yard is also shown.

The Committee has conferred with a Committee of the American Railway Electrical Engineers in reference to the question of yard lighting and track spacing, and we are endeavoring to make typical layout plans which will permit of proper yard lighting without dangerous side or overhead obstructions.

A Sub-Committee has also been working on the proper grade over track scales on the hump, including the grade on each side of the scale, but no definite conclusions have as yet been reached.

Unit costs on the operation of three hump yards and three flat yards are published in this report and that of last year. Your Committee desires to get some further data in regard to the unit costs of operation on the car basis in some small flat and hump yards, and we will be in position to draw some valuable conclusions next year from the information obtained.

ADDITIONAL INFORMATION COVERING OPERATION OF YARD "A" FOR THE MONTH OF AUGUST, 1915.

(Plan of yard is not published.)

	Capacity cars.
(1) Capacity of Yard:	
Yard No. 6:	
Tracks 4, 5, 6 and 7 are running tracks, No. 7 siding is used as an overflow track. Total capacity..................	80
Yard No. 5:	
This yard, east and west of the hump, is used as an east and west overflow yard. Total capacity....................	1200

STATEMENT SHOWING COMPARISON OF OPERATING COSTS AND CONDITIONS OF TWO HUMP YARDS AND ONE FLAT YARD.

Questions Asked.	Yard "A" (Hump) August, 1915.	Yard "B" (Hump) August, 1915.	Yard "C" (Flat) September, 1915.
			Loads Empties Total
(1) Percentage of south or eastbound traffic........	92% loads 8% empties	92% loads 8% empties	East 82.9% 17.1% 100%
(2) Percentage of north or westbound traffic.......	75% empties 25% loads	75% empties 25% loads	North 68.1% 31.9% 100% West 54.2% 45.8% 100%
(3) Character of south or eastbound loads............	55% mineral freight balance various	55% mineral freight balance various	19.6% grain—13% sand and gravel—12% merchandise—9.6% fruit—6.6% lumber—4.4% coal—balance miscellaneous.
(4) Character of north or westbound loads........	Mixed—various	Mixed—various	North—45.9% coal—29.6% grain—4.4% lumber—4.4% fruit—4.2% cement—balance miscellaneous. West—36% merchandise—21.8% coal—5.4% company material—3.9% lumber—balance miscellaneous.
(5) Number of loaded cars handled during month..	(Both Yards Combined) 250,686 loads	....	78,576 loads
(6) Number of empty cars handled during month.. Note—In making up figures covering questions 5 and 6 each car was counted when received in yard and counted again when leaving yard.	170,790 empties Delivery crews operating between yards, industries and other foreign roads handled to and from various points, a total of 218,730 mixed loads and empties.	....	33,722 empties
(7) Number of cars weighed during month...........	1700	450	1717
(8) Maximum number of cars handled during 24 hours	Eastbound (Poling Yard) 3146 Westbound 5478	Eastbound 5382 Westbound 5188	4509
(9) Maximum number of cars handled during any one hour....................	Eastbound (Poling Yard) 150 Westbound 270	Eastbound 264 Westbound 278	209
(10) Number and cost per car thru the yards considering only cars that are switched in the yard, including cost of preparing cars for departure from the Yard (Costs do not include general office or administration expense).	Eastbound 125,002 cars Cost 18.533c per car Westbound 114,262 cars Cost 17.981c per car	Eastbound 91,888 cars Cost 12.639c per car Westbound 90,324 cars Cost 13.193c per car	112,298 cars 14.99c per car
(11) Number and cost per car thru the yards, considering only cars in trains that are not broken in the yard (this question is intended to cover cars received in solid trains which are not broken up. The total cars given in answers to questions 5 and 6 should be the same as to the total cars given in answer to questions 10 and 11.	We handle all of these trains as we classify them, cut out "shop" cars and "re-consign" cars: and find it cheaper to handle them in this way than to try to pass them around the yard.		No cars handled thru the yard in solid trains.

STATEMENT SHOWING COMPARISON OF OPERATING COSTS AND CONDITIONS OF TWO HUMP YARDS AND ONE FLAT YARD.

Questions Asked.	Yard "A" (Hump) August, 1915.	Yard "B" (Hump) August, 1915.	Yard "C" (Flat) September, 1915.
(12) Average number of cars per cut in making and breaking up trains in classification yard (In case of hump yards give average number of cars per cut passing over the hump). To get this information divide total number of cars classified by the number of cuts.	Eastbound 2.157 cars per cut Westbound 1.89 cars per cut	Eastbound 2.298 cars per cut Westbound 1.89 cars per cut	2.23 cars per cut
(13) Number of engine hours expended during month.	7608 engine hours	4143 engine hours	3686½ engine hours
(14) Cost per engine hour.....			
Cost per 100 Locomotive Miles Run—			
Repairs to locomotives including replaced locomotives........	$13.80	$14.79	$ 2.61
Fuel yard locomotives	5.05	4.60	17.54
Lubricants yard locomotives...........	.29	.29	.26
Other supplies yard locomotives..........	.29	.29	.33
Engine house expenses	2.72	2.72	4.05
Total.................	22.15	22.69	24.79
Average cost per mile	.2215	.2269	.2479
Average cost per hour (based on 6 miles per hour)..............	1.329	1.3614	1.4862
(15) Wages of all men engaged in operation of Yard—used in giving answers to questions 10 and 11 including the following: Yardmasters and Assistant, Foremen, Switchmen, Engineers, Firemen, Switch Tenders, Clerks, Car Inspectors, Weighmasters, etc.	$32,963.78	$17,058.97	$11,332.96
(16) Cost of Supplies—			
Air..................	141.83	56.58	
Light (Offices).......	9.81	24.66	4.80
Heat.................	8.80	21.03	1.10
Furniture............	6.40	7.73	
Ice (Yard Office).....	41.71	62.54	
Water...............	21.60	2.50	
Bumper lamps........	17.42		
Janitor..............		39.84	
Miscellaneous.........	111.45	72.57	11.80
Light for Yards......	278.19	543.20	
Total..............	637.21	830.65	17.70
(17) State if company purchases or generates current for light and power.	Company purchases current for lights.		Current for lights generated at roundhouse.
(18) Give estimated cost of duplicating yard exclusive of grading, bridges and buildings.	$3,000,000.00	$3,000,000.00	$600,000.00

STATEMENT SHOWING COMPARISON OF OPERATING COSTS AND CONDITIONS OF TWO HUMP YARDS AND ONE FLAT YARD.

Questions Asked.	Yard "A" (Hump) August, 1915.	Yard "B" (Hump) August, 1915.	Yard "C" (Flat) September, 1915.
(19) Number of cars damaged in yard—Total cost of repairing same.	In order to closely analyze the damage Yardmaster keeps a record in two different classes, first, cars damaged by classification on humps and while shifting; second, cars damaged by delivery crews working between yards and individual plants, or between yards and foreign roads.		60 cars damaged, Repairs $1,554.75
	Eastbound 11 cars Damage $186.53 Westbound 15 cars Damage $480.60 In industrial switching eastbound yards handled 20,434 cars, damaging 3 at a cost of $179.48. Westbound delivery crews handled 19,557 cars, damaging 1 car at a cost of $54.44.	Eastbound 11 cars Damage $331.69 Westbound 9 cars Damage $18.16 In industrial switching eastbound delivery crews handled 19,124 cars and westbound delivery crews handled 17,916 cars, damaging none. The delivery crews operating between Rockville, Enola and Marysville handled 9,882 cars, damaging 1 car at a cost of $13.24.	
20) Are trains departing from yard made up in station order?	Trains departing from yards are made up in station order for the abutting divisions, Middle and Central division, but not for our own division at all times.		Yes

Yard No. 4: Capacity cars.

None of the tracks in this yard is assigned regularly to a particular classification. They are changed continually, more especially since the yards are so crowded with coal cars. Total capacity....................................1450

Yard No. 3:

This yard is used exclusively for loaded cars, both slow and preference. No. 1 track is used as a pull-up. No. 2 to 11, inclusive, are used for the various classifications in the loaded cars, and one changed every six hours by a different make-up of the various trains. No. 12 track is used as an inlet and outlet to the transfer. No. 14 to 22, inclusive, are used as receiving tracks to No. 4 Yard. No. 23 track is used as a return track for Philadelphia Division engines. No. 13 and A to H, inclusive, are transfer tracks. Capacity, 295 cars. Total capacity.....2754

Yard No. 2:

From tracks 3 to 8, inclusive, are receiving tracks to No. 1 Yard. Tracks 9 to 18, inclusive, are used for the shifting of slow freight. Total capacity......................1025

Yard No. 1:	Capacity cars.
Tracks 1 to 24, inclusive, are used for eastbound slow-freight classification. There is also being made a light and heavy equipment classification for cars for Morrisville and beyond. Total capacity	1400
Grand total	8709

(2) If we were to rearrange and rebuild our yards we would seriously consider making the classification tracks in all yards of sufficient length to hold 150 cars, which would enable us to take care of our maximum trains, with a little room for expansion. This condition would be governed entirely by the trainload hauled on the division that yard is intended to serve; the receiving tracks to hold 130 cars. This would also be governed by the trainload of the division taking the cars from the yard. In the receiving yard the grade between the receiving end and dispatching end, toward the hump, to be .50 to .75; this would enable one engine to shove the trains out of the receiving yard with considerably less damage, as at present we use two pushing engines, and even then it is necessary to take slack, making several attempts to move the draft, which results in damage to equipment and lading.

Above also applied to Yard "B."

(3) Tractive power and hours of service of engine:

Hours of Service.	Tractive Power.	Class of Engine.
214	24,313 lbs.	A4
2268	28,116 lbs.	B8
32	23,040 lbs.	H3A
4480	39,688 lbs.	H6
614	39,688 lbs.	H6N
7608		

ADDITIONAL INFORMATION COVERING OPERATION OF YARD "B" FOR MONTH OF AUGUST, 1915.

(Plan of yard is not published.)

(1) Capacity of Yard:	No. of Tracks.	Car Capacity.
A—Eastbound classification yard	18	1100
B—Westbound classification yard	20	2082
C—Eastbound receiving yard	10	950
D—Westbound receiving yard	11	880
E—Eastbound car repair yard	4	264
F—Westbound car repair yard	8	421
G—Eastbound solid train yard	7	455
H—Eastbound advance yard	4	292
Total tracks and capacity	82	6444

(2) Tractive power and hours of service of each engine:

Hours of Service.	Tractive Power.	Class of Engine.
374	23,040 lbs.	H3A
3672	39,688 lbs.	H6
97	39,688 lbs.	H6N
4143		

ADDITIONAL INFORMATION COVERING OPERATION OF YARD "C" FOR THE MONTH OF SEPTEMBER, 1915.

(Plan of yard is not published.)

(1) Capacity of Yard:

Capacity of each division of yard, including car repair tracks, caboose tracks, hold tracks, transfer tracks, icing facilities, etc.

Repair tracks. 280 cars
Yard No. 1...1280 cars
Yard No. 2...1120 cars (30-car transfer track included)
Yard No. 3...1250 cars (30-car caboose track included)
Yard No. 4... 800 cars (160-car hold track included)

Total.....4730 cars

(2) West end of yard has about .12 descending grade toward yard. East end of yard has 800 ft. of flat grade and then .16 ascending grade toward yard.

(3) No changes to suggest in the rearrangement of yard.

(4) Character of loads handled:

Commodity.	East.	North.	West.
Grain	19.6%	29.6%	
Lumber	6.6%	4.4%	3.9%
Flour	2.6%		
Butter and eggs	1.0%		
Merchandise	12.0%		36.0%
Fruit	9.6%	4.4%	1.0%
Meat	3.6%		
Coal	4.4%	45.9%	21.8%
Stock	3.0%	1.2%	
Iron and steel	1.3%		2.7%
Automobiles	1.1%		3.7%
Sand and gravel	13.0%		
Cement	3.5%	4.2%	
Potatoes	1.0%		
Paper	1.1%		1.2%
Company material	2.6%		5.4%
Machinery	1.0%		1.2%
Brick	1.0%		1.6%

Commodity.	East.	North.	West.
Oil	1.1%		1.2%
Pipe		1.2%	
Syrup		1.6%	
Implements			1.3%
Beer			1.4%
Furniture			1.9%
Miscellaneous	10.9%	7.5%	15.7%
	100.0%	100.0%	100.0%

(5) Tractive power and hours of service of each engine:

Engine	Class.	Travtive Power.	Hours Service.	Duty.
446	R-1	30900	77 hrs. 45 min.	Making and breaking up trains in classification yards.
1335	R-1	30900	11 “	
2047	M-1	23300	421 “ 36 “	
2049	M-1	23300	6 “	
2051	M-1	23300	35 “ 45 “	“
2053	M-1	23300	394 “ 50 “	“
2055	M-1	23300	664 “ 55 ”	“
2056	M-1	23300	417 “ 07 “	“
2057	M-1	23300	253 “	“
2059	M-1	23300	561 “	“
2060	M-1	23300	358 “ 30 “	“
2061	M-1	23300	485 “ 01 “	“

TRACK SCALES.

The Committee has been working on specifications for track scales for two or three years. A report was prepared by the Sub-Committee more than a year ago, but was not published with our report for 1914 on account of track scale developments then under way.

Several meetings have been held with members of the Committee on Weighing of the American Railway Association, and the "Recommendations for the Design, Construction, Maintenance and Operation of Railroad Track Scales" which follow have been submitted to them and conform in general to their "Track Scale Specifications and Rules," dated November 19, 1913, with such modifications as have been discussed by the two Committees.

We submit these recommendations to show progress and for the consideration of the Association, and do not ask that they be adopted as a standard of the Association to be printed in the Manual this year.

We understand that the American Railway Association is contemplating a revision of its "Track Scale Specifications and Rules," dated November 19, 1913, and we hope by another year that our Association will be in position to publish approved specifications on Track Scales.

The Railway Age Gazette in issue No. 25 of Volume No. 59 has printed an article on the Plate Fulcrum Track Scale, which has been installed by the Pennsylvania Railroad Company at East Tyrone. Our Sub-Committee inspected this scale and were very much pleased with its action and think it has good possibilities for the future. As it is still in the experimental stage, however, we are making no further reference to it in this report.

Mr. C. C. Wentworth, Principal Assistant Engineer of the Norfolk & Western Railway Company, who was an expert on track scales and a member of our Committee, died very suddenly on November 11th in Roanoke, Va. Mr. Wentworth attended the Committee meeting in Philadelphia in the latter part of October and appeared to be in good health and to enjoy immensely the trip that was taken over the Main Line of the Pennsylvania Railroad in the Philadelphia suburban zone and the trip to Valley Forge to visit the site of the encampment of the Continental Army under Washington during the Revolutionary War, all of which territory was familiar to him in earlier years. His death came as a great shock to his friends, and his valuable services will be greatly missed by the Yards and Terminals Committee.

RECOMMENDATIONS FOR THE DESIGN, CONSTRUCTION, MAINTENANCE AND OPERATION OF RAILROAD TRACK SCALES.

The following recommendations are made with the view of setting an ultimate standard to which railroads generally may work, but are not intended to condemn scales, methods of installation or reinstallations, etc., now in service which come within the sensibility and tolerance prescribed in Section 4 and respond to tests as prescribed in Section 12, and are not intended to cover installations for special weighing, such as twin loads, etc.:

SELECTION, LOCATION AND INSTALLATION OF NEW SCALES.

General.

1. The most essential features of a good track scale are the design, capacity and length, and in the selection and installation of such a scale the following must be given careful consideration:

(a) Maximum loads to be moved over scale for weighing or otherwise, considering the spacing of and concentration of weight on axles.

(b) Length of wheel base of cars or other equipment to be weighed.

(c) Whether cars are to be weighed spotted or in motion.

(d) Location with respect to yard work and grade.

(e) Character of foundations.

(f) Method of installation.

(g) Drainage, lighting, heating and ventilation.

Design.

2. (a) Scales should be so designed that when the load is applied to the main supporting levers, the oscillation of the platform will not displace the bearings at points of contact on the knife edges.

(b) They should be constructed preferably in not more than four sections. The vital parts should be as accessible as practicable for cleaning, inspection and adjustment.

(c) In scales of more than two sections, one of two methods of designing bridge girders may be employed:

First, girders of continuous type.

Second, non-continuous girders tied together to prevent longitudinal displacement.

(d) Practical means of adjustment should be provided to secure uniform distribution of load on scale at points of support.

(e) Like parts of a given type, length and capacity of scale should be interchangeable as far as practicable. The position of each nose iron should be clearly indicated by a well-defined mark showing its position when the lever is sealed. (Some roads specify that the scale, as a whole, made by one maker, should be interchangeable on foundations with that made by another.)

(f) Check devices should be used transversely and longitudinally. If rods are used they should be placed as near the top of the weigh bridge as practicable and should be level under full load, with adjustment to keep them so, and set up with little or no initial strain.

(g) Beams should be so designed as to weigh all loads on main and fractional bars without use of hanger weights. The main bar of the beam should have not more than six notches to the inch, assuming each notch to represent 1,000 lbs. The fractional bar should be graduated to 50-lb. subdivisions, with not more than four subdivisions to the inch, which would correspond to 200 lbs. per inch. A shoulder stop must be provided on all beams to prevent the poise traveling back of the zero graduation. Where the scale is not equipped with a beam of full capacity, the maximum capacity must be clearly and permanently shown on the scale where it can be easily seen.

(h) Multiplication at butt of beam should not exceed 800 to 1. High multiplication in levers is undesirable.

(i) Recording beams should be used where spot weighing is performed.

(j) The sensibility reciprocal is the weight required to move the beam a definite amount from pointer or other indicating device of a scale. In scales provided with a beam and trig loop the sensibility reciprocal is the added weight required to be placed upon the platform to break and turn the beam from a horizontal position in the middle of the loop to a position of equilibrium at the top of the loop. This may be determined by subtracting the weight instead of adding it, or by using the sliding poise on the beam, if this is done without jarring the beam. For railroad track scales the angular movement or play should be 2 per cent. and the sensibility should correspond to 1 per cent. angular movement of the beam.

The sensibility reciprocal of a track scale should never be greater than 100 lbs. When the scale is new this should not be greater than 50 lbs.; that is, a load of 50 lbs. when applied to the scale platform should cause the beam to move from a position in the middle of the trig loop to the top of the loop. For verification purposes when new, a scale should be capable of adjustment to within 1-2000 (½-lb. to the 1000 lbs.) of the capacity and should be maintained in adjustment to within 4 lbs. to the 1000 lbs. in excess or recess. Track scales should be kept in the closest possible adjustment.

(k) Bearings should be compensating, wherever practicable, to insure full length contact of pivots or knife edges with bearings.

(l) Friction in all parts of the suspension should be reduced to a minimum by providing hardened steel contacts. The design of scales should contemplate this important factor.

(m) All bearing surfaces of the scale on the masonry should be planed to true surface and the bearing surface of the weigh bridge on the scale should be in true surface.

Capacity.

3. (a) When locomotives are not weighed the capacity of the scale should be determined by the maximum weight of the cars it will have to weigh. Each pair of main levers should be proportioned to carry half of this load, whether there be four pairs or two. The other levers should be proportioned to carry what comes to them from this loading. In addition to this live load, the dead weight of the track, track girders, etc., should be included, the loads being, of course, altered by the reduction employed.

(b) The design of levers should be governed by the use of such sections that, under the load or weight determined from the capacity, the stresses and deflections are within the limits specified:

Stress:	Cast-iron, tension	2500 lbs. per sq. in.
	Compression	5000 lbs. per sq. in.
	Cast-steel, tension	8000 lbs. per sq. in.
	Compression	8000 lbs. per sq. in.

Maximum deflection at any point of lever resulting from the load applied at the intermediate pivot with lever supported at end pivots as a simple beam and measured from a straight line joining the end pivots:

Cast-iron	.04 in.
Cast-steel	.08 in.

(c) All loops should be so designed that the respective strengths are equal to those of the pivots, the latter being the basis for calculation. The combined stress in tension due to flexure plus direct tension should not exceed 8000 lbs. per sq. in.

(d) Knife edges and, when practicable, pivots should be subjected to no bending stress, and should be supported their full length by projections cast on the levers.

(e) All knife-edges, pivots and bearing surfaces for same should be made from a steel which possesses such properties as will insure a maximum toughness combined with the necessary degree of hardness to insure minimum wear under maximum loads. The following physical properties, based on steel with the internal strains relieved by drawing after hardening, should be as follows:

Ultimate tensile strength	200,000 lbs. per sq. in.
Elastic limit	165,000 lbs. per sq. in.
Elongation in 2 inches	5%
Reduction in area	25%
Maximum working stress	20,000 lbs. per sq. in.

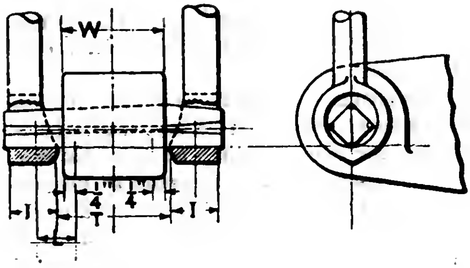
(f) Application of load and methods to be followed in determining the cross-section, based on the stress specified:

In determining the bending moment, the lever arm "L" should be defined as half the length of the bearing surface in the loop or connection, plus ¼-inch plus one-half of the difference between the dimensions of the friction faces in the loop and the friction faces on the lever, as expressed in the following formula:

Let L = Lever arm required.
I = Bearing surface in loop.
T = Distance between friction faces of loop.
W = Width of boss or sustaining member enveloping pivot.

Then:

$$L = \tfrac{1}{2} I + \tfrac{1}{2} (T - W) + \tfrac{1}{4}''.$$



(g) The bearing per linear inch of knife-edge should not exceed 7000 lbs. when the hereinbefore-mentioned loading is considered.

(h) Structural steel used for the track girders of the live rail and for the cross girders supporting the dead rail should conform to the specifications for steel structures as adopted by the American Railway Engineering Association. To avoid skew or wind each pair of girders should be put in place without the sway and lateral bracing being riveted to them and then the bracing be added and secured by bolts, unless the necessity for this can be obviated by proper shop inspection.

(i) The scalemakers should be required to submit stress sheets and plans showing dimensions of levers and of the various parts of the scale sufficiently in detail for making a satisfactory check.

Length.

4. (a) The length of the scale is the distance between the ends of the available live or weighing rail.

(b) When cars are to be weighed spotted, the scale should be of sufficient length to place the entire car on the scale, and preferably longer to facilitate spotting. A length of 50 ft. is recommended.

(c) When cars are to be weighed in motion, the length of scale shall be such that, at a maximum speed of four (4) miles per hour, each car will be entirely and alone on the scale a minimum of four (4) seconds.

(d) The length of pit inside of end walls should be not less than 2 ft. longer than the extreme length of scale parts.

(e) The ends of scale rails should not project beyond the knife edges of the end main levers.

Location.

5. The proper location of a track scale depends principally on the following conditions:

(a) The volume of traffic to be weighed in comparison with that switched over the scales and not to be weighed.

(b) Whether scale is to be equipped with dead rail or relieving gear.

(c) Whether a run-around track will be installed for switching and a separate track for weighing.

(d) Whether cars are to be weighed spotted or in motion.

(e) The cost of extra switching when the scales are not located on a lead to classification track.

(f) Cost of maintenance when scale is located on lead to classification track and only a small proportion of cars are to be weighed.

(g) The necessity for quick dispatch of cars that are weighed. So much depends on local conditions that it would be difficult to give exact rules in connection with the above suggestions. It is recommended, however, that there be not less than 50 ft. of tangent track at both ends of scale rail. When only a small proportion of the cars handled are to be weighed, the rails leaving the scale in the direction of weighing may be curved and the dead rails straight or the curvature may be equalized between them.

Grade.

6. (a) When scales are located on a lead to classification tracks in hump yards, they should be at such an elevation that cars will run by gravity as far as desired into the classification yard, considering a maximum speed of four miles per hour over the scale.

(b) When scales are not located on the hump, they should be at sufficient elevation to provide the necessary grade on the track leaving the scale in the direction of weighing, and such that the usual cut of cars to be weighed will run away from the scale by gravity in order to prevent impacts on the scale and also for protection against surface water.

(c) Scales in all cases must be built level, and supports used to fix weighing rails at the desired incline.

(d) The distance and grade from top of hump to scale should be such that free running cars will pass over the scales at a speed not to exceed four (4) miles per hour without brake application, and cars be so spaced that the minimum weighing period of four (4) seconds shall not be reduced.

(e) Scales to be used for motion weighing should be constructed with scale rails on a grade not greater than 1 per cent.

(f) Where it is the practice for one car rider to take several cars into the classification track, the grade over the scale should be maintained for at least 100 ft. (and preferably 200 ft.) beyond the scale in the direction of weighing. This provides that cars may be stopped easily by the car rider, and that succeeding cars will not cause excessive impact when striking the car ahead, which should occur not less than one car length from the scale.

Foundations.

7. (a) Scale foundations should be constructed preferably of concrete or cut stone laid with cement mortar, and should be designed and constructed with especial care to prevent settlement.

(b) Foundations should be constructed in accordance with the best engineering practice.

(c) Piers or parts of foundations supporting scale stands or dead-rail system should be of sufficient area that the pressure per square inch, in accordance with the best engineering practice, will not be exceeded, and must be constructed as nearly as possible to exact elevations. Grouting is undesirable. The tops of piers or supporting walls should be of cement mortar in the proportion of one to one to the depth of approximately one and one-half (1½) inches and after setting dressed to exact elevations. (On four-section scales the four pedestals forming half of the eight supports—they being divided into groups of four by the fifth lever—may be bolted together with cast-iron struts, if necessary, for the purpose of keeping the pedestals precisely plumb and at the proper distance apart.)

(d) Where necessary to prevent seepage of water through foundations into the scale pit, they should be waterproofed and drained into a waterproof cistern located outside of scale pit, and equipped with either handpump, air siphon or steam siphon.

(e) The masonry should extend at least ten and preferably 25 ft. from the pit face of the end walls back under the track in both directions to provide proper support.

(f) The foundation pit should be of ample size to allow freedom in making inspection.

(g) Access to the pit should be from the side if practicable; otherwise by means of stairway from scale house.

(h) The pit masonry should provide for supports of dead rails when used and fixed floor system.

(i) The minimum period of ten days should elapse between the placing of the last concrete and the putting of the scale in service so as to permit proper setting of the concrete. This setting will be influenced by the prevailing temperature and weather conditions, which should be given due consideration.

Installation.

8. (a) Scale should be installed with dead rail or relieving apparatus.

(b) The deck or platform should be of the rigid type so that the balance of the beam is not affected by weather conditions, etc. It should be made as nearly dirt- and waterproof as possible.

(c) Wedge or other means of adjustment, if used between bridge and scale supports to secure uniform distribution of loading, should be set as low as possible when scales are installed. The future lining usually requires raising the bridge rather than lowering it.

(d) Material such as wooden ties, placed between the bridge and the scale rail, will absorb the shock and protect the vital parts in case of derailment. This material should not be framed until the bridge is installed, in order to secure proper elevation of the scale rails, and it should be fastened securely to the bridge to prevent shifting.

(e) Scale should be set directly on foundations or on metal bed plates resting on foundation.

(f) Scale parts should be securely anchored to the foundations. Unless pedestals are strutted, it is desirable that means of slight adjustment longitudinally and transversely be provided for properly setting the scale, interchanging scales in the same pit, etc. This is in order to secure perfect freedom of action for all parts in suspension.

(g) Scale beam and shelf supports should rest directly on steel or masonry foundation.

(h) The use of extension levers between the fifth lever and scale beam is undesirable.

(i) Scales and structural steel should be cleaned and painted with one coat of red lead paint before being installed and one coat after installation.

(j) Clearances between the movable parts and the fixed parts adjacent shall not be less than 1 in., except that when scale and approach rails are securely anchored, a clearance of not more than ½-in. will be permitted for them.

(k) Open-Hearth rails of full length and sufficient capacity for supporting the load are desirable.

(l) An efficient transfer rail or other connection may be used to prevent impact of cars moving over the joint between approach and scale rails. Such connection must not interfere with the action of the scale.

(m) Approach and scale rails should be anchored to prevent creeping and should be maintained in proper line and surface.

(n) Scale pits should be heated, where necessary, to prevent freezing and rust.

(o) Scale pits should be properly lighted for purpose of cleaning, inspection and testing.

(p) A scale house should be constructed for proper housing and protection of the scale beam and protection of weighmaster.

(q) The interior and exterior of scale houses should be well lighted.

Maintenance, Operation and Testing of Track Scales.

9. (a) All track scales should be numbered and referred to by number and location.

(b) Extensive repairs to scales, such as renewal or of sharpening of pivots, should be made in a properly appointed shop.

(c) When scales are in service regularly, the scale parts, substructures and foundations should be cleaned at stated intervals and at such other times as may be necessary.

(d) The application of rust preventatives to bearings is desirable, but they should be so applied as not to interfere with the proper working of the scale.

(e) If ice obstructs the levers, salt should not be used to melt it, but artificial heat should be used.

(f) Equipment should not be allowed to stand on the scales except when being weighed.

(g) Engines or other equipment not to be weighed should not be passed over the live rail, except on authority of the weighing department.

(h) Cars should not be bumped off scales by an engine or another car on a dead rail, nor be pulled across the scales coupled to another car moving over the dead rail.

(i) Enginemen should not apply sand on scale or dead rail, nor should the injector on the engine be applied when the engine is standing on or passing over the scale.

(j) The weighing beam should be balanced before the scale is used, and, when not in use, it should be locked with the beam catch.

(k) Cars should not be violently stopped on the scale by impact, by the sudden application of brakes or by throwing obstructions under the wheels. When pushing off scale cars which have been stopped for weighing or otherwise, impact must not occur at a greater speed than two miles per hour. When necessary for any reason to run cars over the scale rails, the speed must not exceed four miles per hour.

(l) The weighmaster should familiarize himself with the construction of the scale and make such inspection at such intervals as are necessary to determine if the scale is in proper working condition.

(m) Parties appointed to inspect and maintain scales should be properly instructed and duly authorized. It is desirable that they be present with the scale inspector when scales are tested.

(n) The metal work in the scale and the structural steel must be maintained in a well-painted condition.

Testing.

10. (a) The standards of mass for testing scales should be derived from primary weights, verified by the National Bureau of Standards, Washington, D. C., to within what is known as their "Class B Tolerance." Such weights can be obtained either direct or through scale manufacturers. The 50-lb. secondary or working cast-iron weights, which are transported from place to place and used directly in testing scales, should be rectangular and of such design as to facilitate stacking; they should be free from pockets, blowholes, etc., which are liable to catch and hold foreign matter. No adjusting cavity or cavities in the bottom of the weights should be permitted. These weights should be tested and adjusted in comparison with the master weight, which has been verified to within "Class C Tolerance." The working weights shall be adjusted to within 25 gr. and maintained to within 100 gr. of their true values.

Note.—There is a wide variation of practice in regard to the design of scale test cars. It is thought, however, that the majority of cars weigh from 30,000 to 60,000 lbs. and have a wheel base of from 6 ft. to 8 ft. Some have a body made up of solid castings with space provided for a small super-cargo; others have a body of plate steel with space for super-cargo or test weights, weighing about as much as the car. Local requirements principally determine the type of construction to be followed. It is not thought desirable, however, to have the test car weigh less than 30,000 lbs. nor more than 60,000 lbs. for general testing. Heavier cars on two axles up to 80,000 lbs. are desirable for use in making graduated tests up to the capacity of the scale of the capacity of loads to be weighed.

Note.—The standards for testing scales in the Republic of Mexico must be in accordance with the Metric System Standards and will be verified by a Federal scale inspector in accordance with the Federal Law.

(b) Scales in regular service should be tested at least every three months with a test car or test weights up to at least ten per cent. of their rated capacity.

(c) Scales should be given a graduated test up to their working capacity when installed and periodically thereafter. The necessity for the frequency of such tests depends on the design, capacity and method of installation of the scale, the wear of scale pivots, and the amount of weighing performed.

(d) A test should be made each week by weighing a heavily loaded freight car with as short a wheel base as is obtainable, on each end and the center of scale. When scale is equipped with an automatic weighing attachment, the cars should, in addition to the above, be weighed spotted on the trip end of the scale and in motion with the automatic attachment connected. A report of these tests should be sent to officer in charge of scales and weighing.

(e) In addition to the above, a daily test should be made on each scale equipped with an automatic attachment, by weighing a car spotted on the trip end of the scale with beam, also in motion with the automatic attachment connected. A book record of this and other tests is to be kept by weighmaster.

Equipment for Testing.

11. For verifying or sealing test weights and test cars, it is desirable to have the following in addition to standards of mass prescribed above:

(a) An accurate even-arm balance of 100 lbs. capacity in each pan, sensitive when loaded to 2 grains.

(b) A master scale of sufficient length and capacity for scaling test cars, sensitive to within 5 lbs. in 50,000, should be installed under cover and properly maintained and tested to insure accuracy.

For the proper design of test cars, consideration should be given to the following:

(c) All metal construction.

(d) Length of wheel base.

(e) Uniform distribution of load on axles.

(f) The elimination, as far as practicable, of ledges or projections likely to catch and hold dirt.

(g) The elimination of all unnecessary parts.

(i) Strength and durability so that frequent repairs will not be necessary.

(j) Surface area to be reduced as much as possible to limit wind pressure.

(k) The accessibility of all parts for inspection.

(l) The ease with which it may be barred or moved by scale inspector.

(m) Weight of car and weight of super-cargo if used.

Automatic Weighing and Recording Devices.

12. Efficient automatic weighing and recording devices may be used where desired. There has been in the past, however (and may be at present), an impression that the automatic weigher and recorder will overcome all outside influence and give correct results regardless of scale and track conditions and the speed at which the cars are handled over the scale. This is an erroneous impression and it is absolutely necessary that the scale and the automatic device be in first-class condition with properly maintained approach tracks, and cars must be run at a slow rate of speed (with particular attention to steadiness of motion) if best results are to be obtained.

SUGGESTIONS FOR NEXT YEAR'S WORK.

1. Report on handling of freight in double-deck freight houses, and cost of operation.
2. Continue study of typical situation plans of passenger stations and approaches, and methods of operating same.
3. Continue study of classification yards.
4. Make final report, if possible, on track scale specifications.

Respectfully submitted,

COMMITTEE ON YARDS AND TERMINALS.

REPORT OF SPECIAL COMMITTEE ON UNIFORM GENERAL CONTRACT FORMS.

E. H. Lee, *Chairman;*
C. Frank Allen,
W. G. Atwood,
John P. Congdon,
Thos. Earle,
C. A. Wilson, *Vice-Chairman;*
J. C. Irwin,
R. G. Kenly,
C. A. Paquette,
J. H. Roach,
Committee.

To the Members of the American Railway Engineering Association:

Your Special Committee on Uniform General Contract Forms begs to submit the following report:

The Committee as its work for the current year was instructed as follows:

(1) *Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.*

(2) *Report on Siding Agreements.*

(3) *Report on Forms for Interlocking and Railway Crossings, conferring with Committee on Signals and Interlocking.*

In order to facilitate the work of the Committee in dealing with the subjects assigned to it, three Sub-Committees were appointed as follows:

(1) Critical Review:
  C. Frank Allen, Chairman; J. C. Irwin and E. H. Lee.
(2) Industry Track Agreements:
  E. H. Lee, Chairman; C. Frank Allen, J. P. Congdon, Thos. Earle and J. C. Irwin.
(3) Interlocking Agreement and Railway Crossing Agreement:
  C. A. Paquette, Chairman; W. G. Atwood, R. G. Kenly, J. H. Roach, C. A. Wilson and E. H. Lee.

(1) CRITICAL REVIEW.

The Sub-Committee received a number of suggestions from members of the Association relative to changes in the adopted Agreement Form.

Your Committee recommends the following changes in this Form, as included in the Manual, for the consideration of the Association:

Bond.

1. The Contractor shall, at the time of the execution and delivery of this contract and before the taking effect of the same in other respects, furnish and deliver to the Company, a written bond of indemnity to the amount of..dollars, in form and substance and with surety thereon satisfactory and accept-

able to the Company, to insure the faithful performance by the Contractor of all the covenants and agreements on the part of the Contractor contained in this contract.

This bond shall remain in force and effect for the full amount or such smaller sum as may at any time be specified by the Chief Engineer.

AGREEMENT FORM.

Timely Demand for Points and Instructions.

9. The Contractor shall provide reasonable and necessary opportunities and facilities for settling points and making measurements. He shall not proceed until he has made timely demand upon the Engineer for, and has received from him, such points and instructions as may be necessary as the work progresses. The work shall be done in strict conformity with such points and instructions.

Inspection.

12. All work and material shall be at all times open to the inspection, acceptance, or rejection of the Engineer or his authorized representative. The Contractor shall give the Engineer reasonable notice of starting any new work and shall provide reasonable and necessary facilities for inspection, even to the extent of taking out portions of finished work; in case the work is found satisfactory, the cost of taking out and replacement shall be paid by the Company. No work shall be done at night without the previous approval of the Engineer.

Insurance.

14. The Contractor shall secure in the name of the Company, policies of fire insurance in amount, form and companies, satisfactory to the Chief Engineer, upon such structures and material as shall be specified by the latter, payable to the Company for the benefit of the Contractor or the Company as the Chief Engineer shall find their interests to appear.

Intoxicating Liquors Prohibited.

22. The Contractor, in so far as his authority extends, shall not permit the sale, distribution or use of any intoxicating liquors upon or adjacent to the work, or allow any such to be brought upon, to or near the property of the Company.

Annulment.

33. (b) In such case the Company may give the Contractor ten (10) days' written notice, and at the end of that time if the Contractor continues to neglect the work, the Company may provide labor and materials and deduct the cost from any money due the Contractor under this agreement; and may terminate the employment of the Contractor under this agreement, and take possession of the premises and of all materials, tools and appliances thereon, and employ such forces as may be necessary to finish the work. In such case the Contractor shall receive no further payment until the work shall be finished, when, if the unpaid balance that would be due under this contract exceeds the cost to the Company of finishing the work, such excess shall be paid to the Contractor; but if such cost exceeds such unpaid balance, the Contractor shall pay the difference to the Company.

33. (b) Add, "In case of train haul of material, unless otherwise provided in this contract, the price for haul shall be computed at ....cents per cubic yard per mile. (This shall also apply to 33. (c).)"

Note:—The attention of the Committee has been called to a case where complications between a railroad company and its contractor resulted on account of overhaul, where the work was taken from the contractor, and train haul substituted by the railroad company for the team haul provided for in the contract. The proposed addition to paragraphs 33 (b) and 33 (c) is suggested to cover such a contingency, although your Committee is inclined to the opinion that it might be better to cover this point in the specification for roadway.

(2) FORM OF AGREEMENT FOR INDUSTRY TRACK.

The Sub-Committee requested members of the Association to furnish copies of agreements for industry tracks used by their companies. This request met with a gratifying response, 58 forms of agreement used by 44 railroads having a mileage of 108,000, or 40 per cent. of the total mileage of the United States, being submitted.

These forms point clearly to the widely differing conditions that exist. Railroads located entirely in an agricultural region are required to meet conditions unlike those encountered by railroads serving a mineral region.

Track elevation or depression and the presence of streets, buildings and other improvements greatly complicate matters in large city terminals, as compared with conditions in territory outside. Some of the larger systems are required to meet all of these varying conditions.

The attitude of the Courts and of various Federal and State legislative and regulating bodies further complicates conditions.

Moreover, competitive conditions between railroads in the same territory vitally affect the provisions which might otherwise be incorporated in an Agreement for Industry Track, and any one company can hardly be considered an entirely free agent in the matter.

In the preparation of the form of Agreement for Industry Track herewith submitted, your Committee has been guided largely by the majority practice of railroads, as shown in the forms submitted by the members of the Association. While the form of Agreement as prepared does not include all the special provisions covered in the forms submitted by the members, it does include many provisions which, although of considerable importance, are omitted from some of these agreements.

Your Committee feels that while the Standard Form of Agreement for Industry Tracks may not be widely adopted as a whole, even when approved by the Association, yet it will be of value as a compilation and adaptation of what are regarded as the more important provisions, which should be incorporated in such a document as circumstances may require.

AGREEMENT FOR INDUSTRY TRACK.

Preamble.

THIS AGREEMENT, made this............day of......................, in the year..........., by and between.................................. ...., party of the first part, hereinafter called the Shipper, and.., party of the second part, hereinafter called the Company, WITNESSETH:

THAT, WHEREAS, the Shipper for the more economical and convenient conduct of his business, desires the construction of an industry track substantially in accordance with the plans hereto attached and hereby made a part hereof, and the Company is willing that said track shall be so constructed, upon the terms and conditions hereinafter set forth:

NOW, THEREFORE, in consideration of the covenants and agreements hereinafter mentioned to be performed by the parties hereto and of the payments hereinafter agreed to be made, it is mutually agreed as follows:

Right-of-Way.

1. The Shipper shall provide at his own expense all necessary right-of-way, outside of the right-of-way of the Company, required for the proper construction of said track, said additional right-of-way to be satisfactory to the Chief Engineer of the Company. In case the lands of third parties are required, the Shipper shall secure good and sufficient titles or easements thereto and shall submit documentary evidence thereof satisfactory to the Company.

During the continuance of this agreement the Company shall have the right at all times to enter upon said lands for the purpose of constructing, maintaining and operating said track or any extension or addition thereto. If at any time this agreement is terminated as hereinafter provided, and the said track removed, the Company shall no longer have any right upon or interest in said additional right-of-way.

Permits, Ordinances, Consents, Etc.

2. If for the construction and operation of said track it be necessary to cross any public street, highway, or alley, or any public property whatsoever, and if the consent of any municipality, county, state, or of other lawful public body shall at any time be required for the construction or operation of said track, the Shipper shall at his own expense obtain and secure for the Company all necessary permits, consents, acts or ordinances of any nature whatsoever. In case any such body shall pass any rule, ordinance, order or other act which in any way affects said track, the Shipper shall furnish all facilities necessary on his part to secure compliance therewith, and shall pay all expenses incurred thereby.

Construction.

3. The Shipper, at his own expense and subject to the approval of the Chief Engineer of the Company, shall furnish and do everything required to grade and prepare the roadbed for said track, including the construction of any culverts, drains, bridges, trestles, fences or other structures that may be necessary, except that by mutual agreement this work may be

performed by the Company, in which case the Shipper shall reimburse the Company for the actual expense, including...........per cent. on the cost of labor and...........per cent. on the cost of material.

The Company shall furnish and do everything required to lay and complete the track above subgrade, including the turnout switch, at the expense of the Shipper, except as follows:

....

....

....

....

Advance Payment.

4. Within.................(......) days after the execution of this agreement the Shipper shall deposit with the Company the sum of ....Dollars ($...........), being the estimated cost of the material to be furnished and the work to be performed by the Company in the construction of said track. Until said sum of ....Dollars shall have been so deposited, this agreement shall not become binding upon the Company.

Adjustment of Cost.

5. If the actual cost exceeds the estimated cost, then upon receipt of a statement from the Company of the actual cost, the Shipper shall pay to the Company the difference between said actual cost and said estimated cost, and if said actual cost is less than said estimated cost, the Company shall refund the difference to the Shipper.

Rental.

6. For the use of land, structures and material owned by the Company for said track, the Shipper shall pay to the Company an annual rental of...............Dollars ($...........), payable in equal quarterly installments, in advance.

Maintenance and Operation.

7. The said track, together with switch lamps, signals and interlocking devices required in connection with its operation, shall be maintained by the Company at the expense of the Shipper. The operation of said switch lamps, signals and interlocking devices shall be under the direction of the Company, at the expense of the Shipper.

Ownership.

8. That part of said track located on the right-of-way of the Company shall be and forever remain the property of the Company.

Control.

9. The Company shall have the right to enter upon said track for the purpose of construction, maintenance and operation, or if this agreement shall be terminated as hereinafter provided, for the purpose of removing the part of said track beyond its right-of-way.

Use and Extension.

10. The Company shall have the right to use said track for general railroad purposes, and to extend said track, or to connect other tracks thereto, for the use of other shippers, providing such use, extension or connection does not unreasonably interfere with the business of the Shipper.

The Shipper shall not permit others to use said track, nor permit any other railroad company to connect its tracks thereto without the written consent of the Company, nor assign. transfer, lease or convey any of the rights, privileges or obligations of this agreement to any person or persons without the written consent of the Company.

Division of Rental.

11. If the use of said track be granted to other shippers, or if said track be extended to serve other shippers, as provided in Section 10 hereof, the Company shall credit the shipper an amount which is in the same proportion to the charges for rental, maintenance and operation as referred to in Sections 6 and 7, that the number of cars handled on said track for parties other than the Shipper bears to the total number of cars handled on said track during the period for which said total was computed.

Changes and Enlargement.

12. If any rearrangement, extension or enlargement of said industry track or structures shall at any time be required by reason of any change in the Company's track, or tracks, or because of any changes in the operating practice of the Company, or for any other cause, or, if in the opinion of the Chief Engineer of the Company the introduction of signals or any other protective appliances shall be necessary in connection with said industry track, such parts of the work shall be done by the Shipper and the Company, respectively, as the Chief Engineer shall determine, and the cost, rental and charges for maintenance and operation shall be borne on the basis provided in the foregoing sections for the original construction, rental, maintenance and operation of said industry track.

If said change in the Company's track, or tracks, is of such a nature as to render advisable, in the opinion of the Chief Engineer of the Company, the temporary discontinuance of said industry track, the Shipper agrees that the Company may so discontinue said industry track, and hereby waives all claims therefor.

Freight Routing.

13. In consideration of the benefits to be derived herefrom the Shipper agrees that so far as lies within his control, all freight shipped to or from said track shall be so routed as to travel the greatest practicable distance over the lines owned or controlled by the Company unless, in the opinion of the Shipper, rates are lower or service better over another route, in which case the matter shall be brought to the attention of the Company, and if the Company shows that its rates or

service are as advantageous to the Shipper as those of its competitors, then the business of the Shipper shall be routed as hereinbefore.

Freight Guaranteed.

14. The Shipper further agrees to ship not less than.............. carloads of freight annually from said track.

Liability and Indemnity.

15. The Shipper hereby assumes all risk and responsibility for destruction of or damage to his property or that of the Company or of any person or persons, whether by fire or otherwise, or of death or injury to any person or persons, arising out of the construction, maintenance or operation of said industry track, and will defend and save harmless the Company from all claims, demands, payments, suits, actions, recoveries and judgments of every description brought or recovered against it arising out of the construction, maintenance or operation of said track, together with all costs and expenses connected therewith. The Company, however, reserves the right to join in the defense of any such suit or action.

Prevention of Accidents.

16. The Shipper shall promulgate and enforce upon its agents and employés the necessary precautions and regulations for their conduct, guidance and protection, while engaged in and about his business, against injuries from engines, trains or cars moving or standing upon said industry track or the main or lead tracks of the Company. The Shipper shall take every precaution to prevent and avoid accidents of any nature whatsoever in connection with said track.

Clearances.

17. The Shipper shall not erect nor permit to be erected any building or structure, nor permit any material to be placed above top of rail within................ (........) feet of the nearest rail of said track on straight track, or within................ (........) feet on curves; nor permit anything to be placed above said track lower than a height of................ (........) feet above the top of rail, unless permission so to do is granted in writing by the Chief Engineer of the Company.

Obstructions and Inflammables.

18. The Shipper shall at all times keep said track free from obstructions of any nature whatsoever, and shall guard against cars running from said track to the main track of the Company, and shall keep the said track and adjacent property free and clear of inflammable or combustible materials.

Load and Unload.

19. The Shipper shall promptly load and unload his freight at his own expense and shall fully comply with the car service and demurrage rules of the Company.

Taxes.

20. All taxes or assessments levied against said track by any municipality, county, state or other lawful authority shall be paid by the Shipper.

Forfeiture.

21. If the Shipper shall at any time fail to perform any of the covenants herein contained, the Company may terminate this agreement by giving the Shipper................days' written notice thereof. If at the end of the said................days' time the Shipper still fails to perform his covenants to the satisfaction of the Company, this agreement shall become null and void, at the option of the Company.

If the number of loaded cars handled on said track for the Shipper is less than the number specified in Section......and if in the opinion of ....of the Company the amount of freight received from the Shipper is not sufficient to justify the continuance of this agreement, it may be terminated by the Company by giving the Shipper................days' written notice of its intention so to do. The fact that the Company has not terminated this agreement on previous occasions when it had the right so to do shall not be construed as a waiver of its rights to so terminate it and shall not prevent the termination of said agreement by the Company on any subsequent occasion as herein provided.

Cancellation.

22. This agreement may be canceled at any time by either party hereto, by giving.................. (........) days' written notice thereof to the other. Notice shall be deemed given to the Shipper if mailed to him at................(Address)................................, or if posted in a conspicuous place on..............premises. Notice shall be deemed given to the Company if mailed to its..............................at his office in................................

Removal of Track.

23. Upon termination of this agreement as herein provided, the Company may disconnect said industry track and may enter upon the premises of the Shipper and may remove therefrom anything which is owned by said Company, and the Shipper agrees to permit the Company to disconnect said track, and to remove its property, and to prevent any person or persons from hindering, molesting or interfering therewith.

24. This agreement shall inure to the benefit of and be binding upon the parties hereto, their heirs, executors, administrators, successors and assigns for a period of................years from the date hereof and thereafter until canceled by either party giving to the other........... days' written notice of its intention so to do, as hereinbefore provided.

In Witness Whereof, the parties hereto have executed this agreement in..the day and year first above written.

WITNESS:

....
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....
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....

(3) FORMS FOR INTERLOCKING AND RAILWAY CROSSING AGREEMENT.

At the request of the Sub-Committee many members of the Association submitted forms of agreement for Interlocking, and for Railroad Crossings used by their companies. The Sub-Committee has been unable to entirely complete the work of tabulating and comparing these agreements, and the preparation of uniform contract forms to cover.

Your Committee therefore reports progress as to these forms.

Respectfully submitted,

COMMITTEE ON UNIFORM GENERAL CONTRACT FORMS.

REPORT OF SPECIAL COMMITTEE ON STRESSES IN RAILROAD TRACK.

A. N. TALBOT, *Chairman;*	W. M. DAWLEY, *Vice-Chairman;*
A. S. BALDWIN,	J. B. JENKINS,
J. B. BERRY,	GEO. W. KITTREDGE,
G. H. BREMNER,	P. M. LABACH,
JOHN BRUNNER,	C. G. E. LARSSON,
W. J. BURTON,	WILLIAM MCNAB,
CHAS. S. CHURCHILL,	G. J. RAY,
W. C. CUSHING,	A. REICHMANN,
DR. P. H. DUDLEY,	E. STIMSON,
H. E. HALE,	F. E. TURNEAURE,
ROBT. W. HUNT,	J. E. WILLOUGHBY,

Committee.

To the Members of the American Railway Engineering Association:

The Special Committee on Stresses in Track presents the following report of progress:

It will be recalled that the Committee of the Association and the Committee of the American Society of Civil Engineers are co-operating in the work on stresses in track.

The Joint Committee has held three meetings during the year. At the meeting in Chicago, March 16, 1915, eighteen members being present, the results of the preliminary tests made on track were considered, the conduct of experimental work for the season was discussed, and a general outline of tests was agreed upon as the plan of work for the season. At the meeting held in Champaign-Urbana, June 8, 1915. seventeen members being present, field tests on the track of the Illinois Central Railroad north of Champaign were inspected, including static tests and speed tests with locomotive and load dynamometer test. The program considered at the last meeting was discussed and the points upon which it was thought emphasis should be placed were considered and a general program approved. It was decided to confine the tests of the season to one location. At the meeting in New York, January 18, 1916, eight members being present, there was a general discussion of the results of the tests made.

The experimental work has made satisfactory progress during the year. A considerable amount of effort has been expended on the development of instruments and methods of conducting the tests. It was apparent in advance that the problem was so complicated and the conditions so variable and the difficulties so great that satisfactory instruments for determining stresses could be obtained only after long and patient trials. Especially in the case of the instrument for measuring strains in the rail under moving loads were difficulties found and it was only late in the season, after repeated trials and changes, that the instruments for measuring strains in the rail under rapidly moving loads were put into acceptable form. It was believed to be important that these instruments should make a continuous record of the action of the rail under and between the wheel loads of the moving load. It was found essential that the stresses on both sides of the rail be measured simultaneously. A method of finding the depression of the track under moving load by photographic methods has been developed. The measurement of stresses under static loads was not found to be difficult, although the time consumed in this test is considerable.

The field tests have been conducted on the main line of the Illinois Central Railroad north of Champaign. Only the general character of these tests can be outlined in this progress report. Data were taken to determine (1) the distribution of stresses and moments along the rails for a given loading, (2) the division of vertical load among adjacent ties for a given loading, (3) the distribution of vertical pressures among the ties, through the ballast, and over the roadbed, (4) the depression, compressibility or stiffness of the track, (5) the effect of wheel spacing of some types of locomotives and also the effect of single and double concentrated loads, (6) the effect of speed upon most of the foregoing items. Tests have been conducted at speeds as high as 65 miles per hour. Among the variables of the track were three weights of rail, two sizes of ties, and three depths of ballast. In addition to tests on standard track, minor tests have been made at spots where uneven tie spacing or worn or decayed ties may affect the stresses developed. The Illinois Central Railroad Company has provided the locomotives and crew. The calculation and compilation of the results has proved to require a great deal of time. The data are now being put into shape and it is expected the results will be ready soon for the consideration of the Committee. The results appear to give fairly definite quantitative values for stresses in the rails and for the general distribution of loads and pressure under the various conditions of the test. The Committee believes that it will be able to determine the general action of the track under moving loads. It is the purpose of the Committee to report to the Association at an early day the results of the tests already carried out.

The Committee plans to continue the tests during the coming season, to complete the matters already partly covered, and to extend the experiments to include other features, like action on curves and on track of different kinds.

Respectfully submitted,

SPECIAL COMMITTEE ON STRESSES IN TRACK.

REPORT OF COMMITTEE I—ON ROADWAY.

W. M. Dawley, *Chairman;*
J. R. W. Ambrose,
A. F. Blaess,
S. P. Brown,
B. M. Cheney,
W. C. Curd,
Paul Didier,
S. B. Fisher,
Frank Merritt,

J. A. Spielmann, *Vice-Chairman;*
L. G. Morphy,
F. M. Patterson,
W. D. Pence,
W. H. Petersen,
A. C. Prime,
H. J. Slifer,
W. P. Wiltsee,

Committee.

To the Members of the American Railway Engineering Association:

The Board of Direction assigned the following subjects to your Committee:

1. *Make critical examination of the subject-matter in the Manual, particularly the subjects relating to steam-shovel work and roadbed sections, and submit definite recommendations for changes.*

2. *Continue the study of unit pressures allowable on roadbed of different materials, co-operating with Special Committee on Stresses in Railroad Track.*

3. *Report on the prevention and cure of water pockets in roadbed.*

Two general meetings of the Roadway Committee were held during the year—both in Chicago.

In apportioning the work of the Committee among the members it was deemed advisable to assign subject No. 1 to two Sub-Committees. No. 1-a, on Revision of Manual, including increased width of Roadbed Sections to provide for increased depth of ballast; the other, No. 1-b, on steam, electric and air shovels, dragline excavating machinery and locomotive cranes, general specifications for, method of handling and blank forms used.

REVISION OF MANUAL.

Sub-Committee No. 1-a: W. P. Wiltsee, S. B. Fisher, W. D. Pence.

A circular letter requesting standard roadbed cross-sections was sent out and thirty-eight replies thereto have been received.

From an inspection of the sections so far received it does not seem that it is necessary to increase our present recommended widths of roadbed to cover current practice, and that is also the opinion of most of those who expressed themselves.

Mr. H. E. Hale, Chairman of the Ballast Committee, reports that the Ballast Committee will stand by their recommendation of 24 inches of ballast for Class A track to secure an approximately uniform distribution of load over the subgrade, and in case this depth is adopted by the Association, a width of subgrade of approximately 26 feet will be necessary to accommodate the increased spread of the ballast.

It is also possible that the investigation of the distribution of pressures on the roadbed to be conducted by the Joint Committee on Stresses in Railroad Track (provided their funds hold out) may develop that an increase in width of roadbed is desirable from the standpoint of stability.

Your Committee is unable from information at hand to make recommendations of different widths of roadbed required for different depths of ballast and recommends that the question be held open for further consideration next year.

In further explanation of the subject of Haul and Overhaul discussed in last year's report of the Committee, and to incorporate in our Proceedings an illustrated method of determining the proper distribution of excavated material in the construction of the roadbed, the following monographs, entitled "The Profile of Quantities," by S. B. Fisher, and "The Overhaul and Distribution Diagram," by J. R. W. Ambrose, are submitted.

Sub-Committee No. 1-b: S. P. Brown, A. C. Prime, H. J. Slifer, Paul Didier.

The following circular letter and list of questions has been sent to sixty-four representative members of the Association:

Dear Sir:

As you doubtless know, we are revising and enlarging the Manual of the American Railway Engineering Association relating to steam shovels and mechanical excavators. In order to make our work representative of present practice and of the greatest value to the Association and various railways that are to benefit by it, we require the co-operation of all the more important roads, to the extent of answering the accompanying questions.

Will you kindly turn the following list of questions over to one of your assistants with instructions to collect the desired information and transmit it to me? As this reply will be treated confidentially by the Committee, he may speak freely and discuss the various subjects referred to without restraint.

An early and satisfactory reply to this communication will be deeply appreciated by your Committee and will add greatly to the value of its report to the Association.

Please answer the following questions as fully and concisely as possible and return to S. P. Brown, 411 Dorchester street, W., Montreal, Canada, at your earliest convenience. Your answers will be treated confidentially by the Committee, so a free and unrestrained discussion and criticism may be given without hesitation.

SHOVEL QUESTIONS.

1. What makes of steam shovels do you use, and which do you find the most satisfactory?

2. Why? Please criticize unsatisfactory shovels without hesitation or restraint.

3. Do you use any air or electric shovels; if so, what make, and what is your opinion and criticism? Please answer fully.

4. What sizes of shovels do you find best adapted for your different types of work?

5. What accidents, breakdowns and causes of delay do you find most common in connection with your shovel work?

6. What parts most liable to breakage?

7. What parts most liable to wear?

8. What parts do you stock for urgent repairs and replacements?

9. What parts do you have especially designed or made of special material, and why?

10. How is all the above affected by the character of the material excavated?

11. Please send copies of your specifications, if you do not buy standard shovels under the common manufacturers' specifications.

12. Please send copies of all blank forms (daily, weekly, monthly, etc.) used in connection with steam shovel work, especially records and reports.

13. Please volunteer any information of interest about steam shovels or kindred *machinery, work* or *methods.* It will help the Committee.

LOCOMOTIVE CRANES.

Please apply the foregoing shovel questions also to your locomotive cranes with the three following questions in addition:

14. What types and makes of grab buckets do you find best adapted to your various purposes?

15. Have you ever used a drag bucket on a regular locomotive crane, and if so, with what success and under what conditions?

16. What make, type and size of drag bucket was it?

DRAG-LINE EXCAVATORS.

Please apply the foregoing shovel questions also to your drag-line excavators with the five following questions in addition:

14. What size, type and make of bucket do you use?

15. If you have discarded other makes of bucket, why?

16. If bucket used is not standard, state why and send plans and specifications.

17. How does the character of the ground affect your wheels and propelling mechanism, and will it dig hard clay and boulders; if so, how large?

18. Please discuss cables.

19. How does the drag-line excavator compare with the steam shovel, economically and in capacity?

SPECIAL EQUIPMENT.

A. Hydraulic Excavators:

A-1. What hydraulic excavators have you used, and with what success?

A-2. If suction, was it for purposes of making a fill, and how did its results compare, economically, with the more usual methods, and why?

A-3. Send specifications and plans if possible.

A-4. Give criticism and suggestions.

A-5. If hydraulic monitor, was it for cutting or filling?

A-6. How did it compare, economically, with the more usual methods, and why?

A-7. What makes of monitor and what special parts did you specify?

A-8. Give criticism and suggestions.

B. If you have used special ditching or excavating machines, as for instance, the Harris Excavator, please send plans and specifications and description with criticism.

C. Steam Shovel Work and Train Filling:

C-1. What types, kinds and sizes of cars do you use with your steam shovels, etc., for different classes of work and lengths of haul?

C-2. Please send specifications and plans, if available, of the different cars found most successful, if not standard manufacturers' product, for the different classes of work.

C-3. What unloading plow have you found most satisfactory?

C-4. Please send plans and specifications for unloading plows and accessories, including winding engine, etc.

C-5. Please send specifications and plans, if available, of spreaders which you have found most successful.

C-6. At what height of fill do you normally stop lifting and commence trestling? (First, on new location; and, second, under traffic.)

C-7. How is the above affected by the length of haul, class of equipment and kind of material?

C-8. What allowance for shrinkage, both in width and height, have you found satisfactory for different heights of fill and different materials? (First, on new location; second, under traffic.)

C-9. Besides the blank forms already requested, please send any regular instructions issued to resident engineers or superintendents, regarding steam-shovel work or train filling.

Note.—Please make any suggestions or volunteer any information relating to this class of work that are not already covered by the above questions. It will be appreciated by the Committee and of value to the Association.

Letters of similar import were sent to twenty-four members of the General Contractors' Association, and to forty manufacturers of excavating machinery.

A comparatively limited number of replies have been received, but the number is growing daily, and they are usually intelligent and valuable.

In view of the importance of this subject, it is deemed advisable to delay its completion until we have sufficient information to make it thoroughly comprehensive.

All members are urged to give the list of questions careful consideration and to send their answers thereto to Mr. S. P. Brown, Chairman of the Sub-Committee, 411 Dorchester St., W., Montreal, Canada, as requested.

(2) UNIT PRESSURES ALLOWABLE ON ROADBED OF DIFFERENT MATERIALS.

Sub-Committee: J. R. W. Ambrose, Frank Merritt, L. G. Morphy, F. M. Patterson.

Some further work has been done by the Sub-Committee looking toward a classification of soils, but the information so far obtained is not in sufficient harmony to justify the adoption of any one classification to the exclusion of others.

A classification designed for identification of soils subject to pressure of engineering structures must necessarily deal with soils as found in their natural state, in situ, or, as in the case of the roadbed, as modified by the excavation, transportation and deposition. A classification of soils, either natural or artificially prepared for use in mortars, concrete work, cement, brick, tile, porcelain or terra cotta manufacture or as molding sand, etc., may have considerable interest and value from an engineering point of view as having a bearing on the strength or quality of the product produced, but might be of no practical value for the subsequent identification of a particular kind of soil which had been found by test to have a certain unit-bearing power.

The object of the Committee is to determine and adopt a classification which by the application of a simple field or laboratory test, preferably the former, will enable the locating or maintenance engineer to identify the soils of which it is proposed to define and limit the bearing power.

An effort has been made by the Committee to co-operate with similar committees of other societies and to take into consideration the results of research work carried on by municipal, State and National authorities, having a bearing on the subject-matter in hand.

Mr. Robert A. Cummings, Chairman of the Soils Committee of the American Society of Civil Engineers, advises that the forthcoming report of that committee contains a proposed classification for all kinds of soil and an appendix of the scientific work which is being done by the Bureau of Standards.

Some work has been done by the Joint Committee on Stresses in Railroad Track toward the determination of the distribution and amount of stress communicated to the roadbed through ballast of different depths, but it has not progressed far enough to enable this Committee to base any conclusion as to units pressures allowable.

Until further work has been done along this line your Committee can only report progress.

(3) REPORT ON THE PREVENTION AND CURE OF WATER POCKETS IN ROADBED.

Sub-Committee: J. A. Spielmann, W. C. Curd, A. F. Blaess, W. H. Petersen, B. M. Cheney.

The Sub-Committee has on hand a large amount of correspondence which has not as yet been thoroughly digested; some requiring still further correspondence to bring out the result of experiments which have given promise of success, after passing through another winter and spring.

It has been deemed advisable to delay drawing conclusions until the efficacy of the remedies adopted have been clearly demonstrated.

Your Committee hopes to be able to conclude this subject during the coming year.

RECOMMENDATIONS FOR NEXT YEAR'S WORK.

1. Make critical examination of the subject-matter in the Manual, particularly the subjects relating to steam shovel work and roadbed cross-sections.

2. Continue the study of unit pressures allowable on roadbed of different materials, co-operating with Special Committee on Stresses in Railroad Track.

3. Report on the prevention and cure of water pockets in roadbed.

OBITUARY.

During the year your Committee has lost one of its valued members, Mr. Ward Crosby, Chief Engineer of the Carolina, Clinchfield & Ohio Railway, at Johnson City, Tenn. He was born in Canada in 1859, and entered the railway service in 1880. He was transitman for three years on the location of the Mexican Central Railroad, and later Assistant Engineer of the Boston & Lowell Railroad, and its successor, the Boston & Maine Railroad. He went to the Carolina, Clinchfield & Ohio Railroad as Assistant Engineer in 1891, and was successively promoted to be Division Engineer, Principal Assistant Engineer and in 1911 Chief Engineer.

Respectfully submitted,

COMMITTEE ON ROADWAY.

Appendix A.

THE PROFILE OF QUANTITIES.

By Samuel B. Fisher, Chairman, Valuation Committee, Missouri, Kansas & Texas Railway.

As no reference to Brückner's Profile of Quantities has yet appeared in the Proceedings of this Association, it is inferred that it is not so widely known as its merits deserve.

To the few Engineers who have used it, it seems the most complete, accurate and satisfactory method, not only of computing overhaul, but for the preliminary and final distribution of quantities or volumes in earthwork.

It is due to Brückner, a Bavarian Engineer, and was first published in Cuhlman's Graphic Statics, 1868. It was used 1871-73 in the Pennsylvania Company's engineering office in Pittsburgh, and afterward in the South Pennsylvania Railroad work, 1882-85. The present writer wrote a short article on it which appeared in Engineering News, January 31 and February 7, 1891.

I. The first step in making the profile of quantities is the compilation of the data.

To give a complete record of the work, the data is arranged in eight vertical columns:

Column No. 1 contains the station numbers.

Column No. 2 contains the total excavation in the station.

Column No. 3 contains the total embankment in the station.

Column No. 4 contains the quantity deposited within the station limits, which is not hauled beyond the station, and is the lesser of the volumes in columns 2 and 3.

Columns 2, 3 and 4 may be omitted if a record of the quantities deposited within the station is not desired.

Columns 5 to 8 are all that are used in making the profile.

Column 5 contains the net volume of excavation on the station, or the difference between the excavation and embankment.

Column No. 6 contains the net volume of embankment.

The quantities in columns 5 and 6 are increments. Excavation is considered plus or positive and embankment is taken as minus or negative. A picturesque appearance is given to both tabular data and lines of profile, by using blue ink for excavation and red ink for embankment.

The ordinates in columns 7 and 8 are now obtained by the algebraic addition of the increments in columns 5 and 6. The ordinate at any point is equal to the algebraic sum of the excavation and embankment or of the increments, and should be verified at convenient points as the summation proceeds.

II. The next step is the plotting of the profile.

Ordinary profile paper is used for the plotting. Horizontally the stations are plotted as for the profile of the ground. Vertically, instead of referring elevations to a datum plane, below the limits of the drawing. we take an initial horizontal line or axis of abscissas at a convenient location on the profile, from which the ordinates are laid off, above for plus and below for minus. Connecting the ends of these ordinates we have a broken line, which, in geometrical terms, may be called a curve. This curve may have a superficial resemblance to the ordinary profile, but carries an entirely different meaning.

If the increment, by the addition of which the ordinate is formed from the previous one is positive, this element will incline upward, will indicate excavation, and be shown by a blue or dotted line. If the increment is negative, the element will incline downward, will indicate embankment, and be shown by a red or full line. Excavation on the profile of quantities is therefore always shown by an ascending line and embankment by a descending line. The greater the inclination of these lines, the greater the quantities or volumes indicated, and vice versa.

We come now to the *Balancing Line,* which is the most important line of the profile. The initial point of this line is the point "A," the beginning of the work on the section. The terminal point, B, is the end of the work. Often one or more intermediate points on this line are fixed by the patent conditions of the work. For the section under consideration, the balancing line is drawn A, C and B.

From A to C, station 26759 to 26785+50, which shows embankment on the profile of ground surface, the material deposited was obtained from shallow borrow pits and moved by teams. From C to B, station 26785+50 to 26014, it was steam shovel work.

The limit of free haul on this work was 500 feet.

The contractors who undertook this work got into financial difficulties and failed to complete it. The overhaul was computed for their final estimate.

III. The final step is to take off from the diagram the overhaul and each item of haul if wanted.

The first limit of free haul lies between stations 62+50 and 67+50. and is shown by the broken horizontal line on the diagram. Drawing other horizontal lines parallel to the balancing line and the free haul line from each point of flexure of the ascending curve representing the excavation, we have successive lengths of haul and overhaul. If minute accuracy is desired, these lines of haul may also be drawn to points of flexure on the descending curve or line representing embankment. For preliminary work, the volumes for overhaul may be read off the diagram, but for final estimates it is best to compute them with the data, from the table of ordinates, as is shown on the diagram.

The cut between stations 74 and 75 is hauled back to make the fill between 73 and 74 without overhaul.

The cuts between 78 and 79 and between 80 and 82 make the fills between 75 and 78, also between 79 and 80, without overhaul.

The quantities between 80 and 85 are hauled forward to fill from 85 to 85+50, just reaching the limit of free haul.

No expansion or shrinking of material is considered between A and C, material to replace shrinkage being assumed to be drawn from the borrow pits. From C to B there is an expansion of 9 per cent., owing to the cut from G to H being largely rock. Graphically, this is represented by prolonging the line C—B to an intersection with the horizontal from G, giving a point or pole P, from which point lines are drawn to points of flexure on the curves of quantities. The sections of these polar lines lying between the plus and minus curves are the lengths of haul. The overhaul and the volumes are thus plainly shown, and can be written down from inspection of the diagram or computed from the table of ordinates.

The method above outlined assumes the expansion is uniform for the entire cut. If the material is of different kinds, an auxiliary pole can be established.

The excavation between 97 and 3+70 is hauled back to make the fill from 85+50 to 97.

In a similar way the excavation between 03+70 and 10 is hauled forward to make the embankment from stations 10 to 14, all with overhaul as shown on diagram.

GENERAL REMARKS.

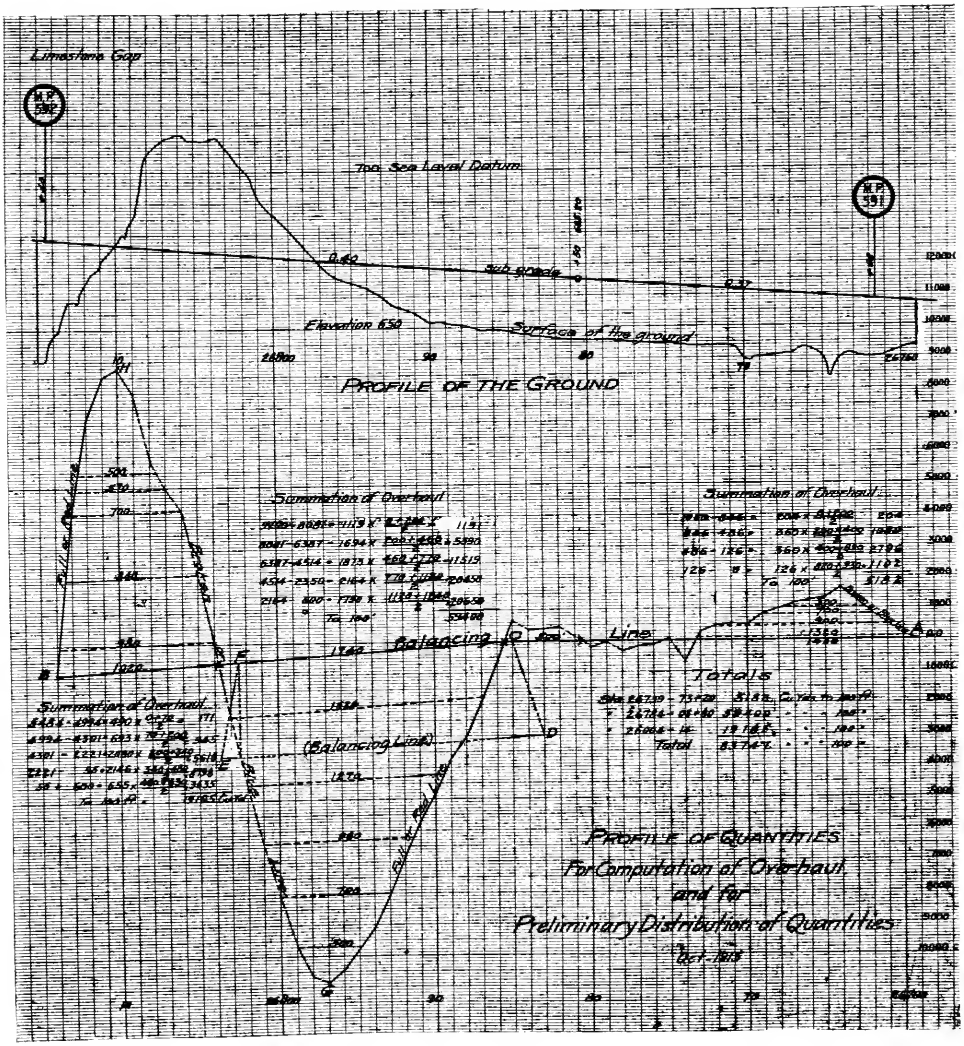
If instead of making the fill between 85+50 and 88 by hauling backward from 26002—4, it was put in from a borrow pit stations 83—85, it would be so shown by the portion of the balancing line C—D. In that case there would be a corresponding waste, EF, between 2+40 and 4.

The system is, in fact, perfectly flexible, and anything that is done on the ground can be indicated on the diagram.

The profile of quantities is as convenient and useful for the preliminary distribution of quantities before commencing work as it is for determining the overhaul after the work is done. For this latter purpose it shows in advance the most economical way to dispose of the quantities, where to get the excavation, and where to put it in on the embankment. In the example in diagram it shows as follows:

Cut, Sta. 59—64, haul south, deposit Sta. 64—73+35.
Cut, Sta. 74—75. haul north to Sta. 73—74.
Cut, Sta. 78—79 and 80—80+50, haul north to Sta. 75—80.
Cut, Sta. 80+50—85. haul south to Sta. 85—85+50.
Cut, Sta. 97—03+70. haul north to Sta. 85+50—97.
Cut, Sta. 03+70—10, haul south to Sta. 10—14.

With above information, work can be started at any or all points at any convenient time, with the assurance that the quantities will be properly placed.


Limestone Gap
M.P. 592
M.P. 591
Top Sea Level Datum
0.40
Sub grade
0.37
Elevation 650
Surface of the ground
26800
90
80
70
26760
PROFILE OF THE GROUND
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0.0
H
500
570
700
340
380
1020
B
Fill or Mass Line
Excavation
E
F
Summation of Overhaul
9204-8081=1113 X 0+230/2 X 1131
8081-6387=1694 X 200+460/2 = 5390
6387-4514=1873 X 460+770/2 = 11519
4514-2350=2164 X 770+1130/2 = 20450
2164- 800=1738 X 1130+1840/2 = 20650
To 100' 59480
1740
Balancing Line
C
D
(Balancing Line)
1826
1874
880
300
500
G
Fill or Mass Line
Summation of Overhaul
5484-4994=490 X 0+70/2 = 171
4994-4301=693 X 70+500/2 = 345
4301-2221=2080 X 500+340/2 = 5616
2221- 55=2166 X 340+480/2 = 4998
55+600=655 X 480+620/2 = 3635
To 100 ft = 19185 Cu.Yds.
Summation of Overhaul
1126-846= 280 X 0+1200/2 204
846-486= 360 X 1200+400/2 1080
486-126= 360 X 400+1150/2 2796
126- 0= 126 X 1150+350/2 1102
To 100' 5182
100
700
300
1350
1438
Fill or Mass Line
A
Totals
Sta. 26739 - 73+20 5182 Cu.Yds. to 100 ft
" 26784 - 88+40 59480 " " " 100 "
" 26804 + 14 19185 " " " 100 "
Total 83747 " " " 100 "
PROFILE OF QUANTITIES
For Computation of Overhaul
and for
Preliminary Distribution of Quantities
Oct. 1913
26800
90
80
70
26760

DATA FOR PROFILE OF QUANTITIES.

1	2	3	4	5	6	7	8
Station	Excavated on Station	Embank. on Station	Deposited within Station	Hauled off Station	Hauled on Station	Ordinates	
				Increments		+	—
				+	—		
26759							
760	152	26	26	126	....	126	....
1	534	174	174	360	....	486	....
2	823	463	463	360	....	846	....
3	1026	623	623	403	....	1249	....
4	1150	717	717	433	1682	1682	....
5	743	1115	743	....	372	1310	....
6	820	832	820	....	12	1298	....
7	843	966	843	....	123	1175	....
8	932	1120	932	188	188	987	....
9	1094	1245	1094	....	151	836	....
770	1004	1378	1004	....	374	462	....
1	1511	1458	1458	53	....	515	....
2	1594	1617	1594	....	23	492	....
3	1465	1689	1465	....	224	268	....
4	1439	2408	1439	....	969	....	701
5	1266	482	482	784	....	83	....
6	1504	1709	1504	....	205	....	122
7	1101	1163	1101	....	62	....	184
8	341	474	341	....	133	....	317
9	276	....	....	276	....	....	47
780	....	164	....	....	164	....	211
1	439	41	41	398	....	187	....
2	285	40	40	245	....	432	....
3	....	41	....	....	41	391	....
4	35	80	35	....	45	346	....
5	1000	660	660	340	....	686	....
6	1070	2405	1070	....	1335	....	649
7	1764	3015	1764	....	1251	....	1900
8	1806	2906	1806	....	1100	....	3000
9	1955	2692	1955	....	737	....	3737
790	1176	2284	1176	....	1108	....	4845
1	1131	1989	1131	....	858	....	5703
2	697	1824	697	....	1127	....	6830
3	153	1377	153	....	1224	....	8054
4	....	957	....	....	957	....	9011
5	....	781	....	....	781	....	9792
6	49	718	49	....	669	....	10461
7	55	460	55	....	405	....	10866
8	262	29	29	233	....	....	10633
9	952	....	....	952	....	....	9681
26800	1600	....	....	1600	....	....	8081
801	1694	....	....	1691	....	....	6387
2	1873	....	....	1873	....	....	4514
3	2164	....	....	2164	....	....	2350
4	2405	....	....	2405	....	55	....
5	2166	....	....	2166	....	2221	....
6	2080	....	....	2080	....	4301	....
7	693	....	....	693	....	4994	....
8	854	....	....	854	....	5848	....
9	2104	....	....	2104	....	7952	....
810	829	....	....	829	....	8781	....
1	13	302	....	....	289	8492	....
2	....	1363	....	....	1363	7129	....
3	....	2990	....	....	2990	4137	....
4	....	5120	....	....	5120	....	983

Appendix B.

THE OVERHAUL AND DISTRIBUTION DIAGRAM.

By J. R. W. Ambrose, Chief Engineer, Toronto Terminals Railway.

This is a very simple and efficient method of distributing material and obtaining the resulting overhaul.

Method: The quantities are taken from the profile in the case of preliminary work and from the cross-section notes for finished work.

For platting the distribution profile, we first select a point in the fill outside of the haul area such as station 140 on the accompanying diagram, then assuming that all embankment quantities have the plus sign and all excavation quantities the minus sign, we plat the algebraic sum beginning at the point selected and working through the haul district.

The line of distribution may be laid to suit the conditions on the ground or it may be adjusted to its most economical position (EE.). After this line has been located, the free haul distance is then laid off and the yardage determined, as shown hatched on the diagram. The remaining yardage between the free haul line and the line of distribution is then subdivided to conform to any irregularities much the same as any area is determined.

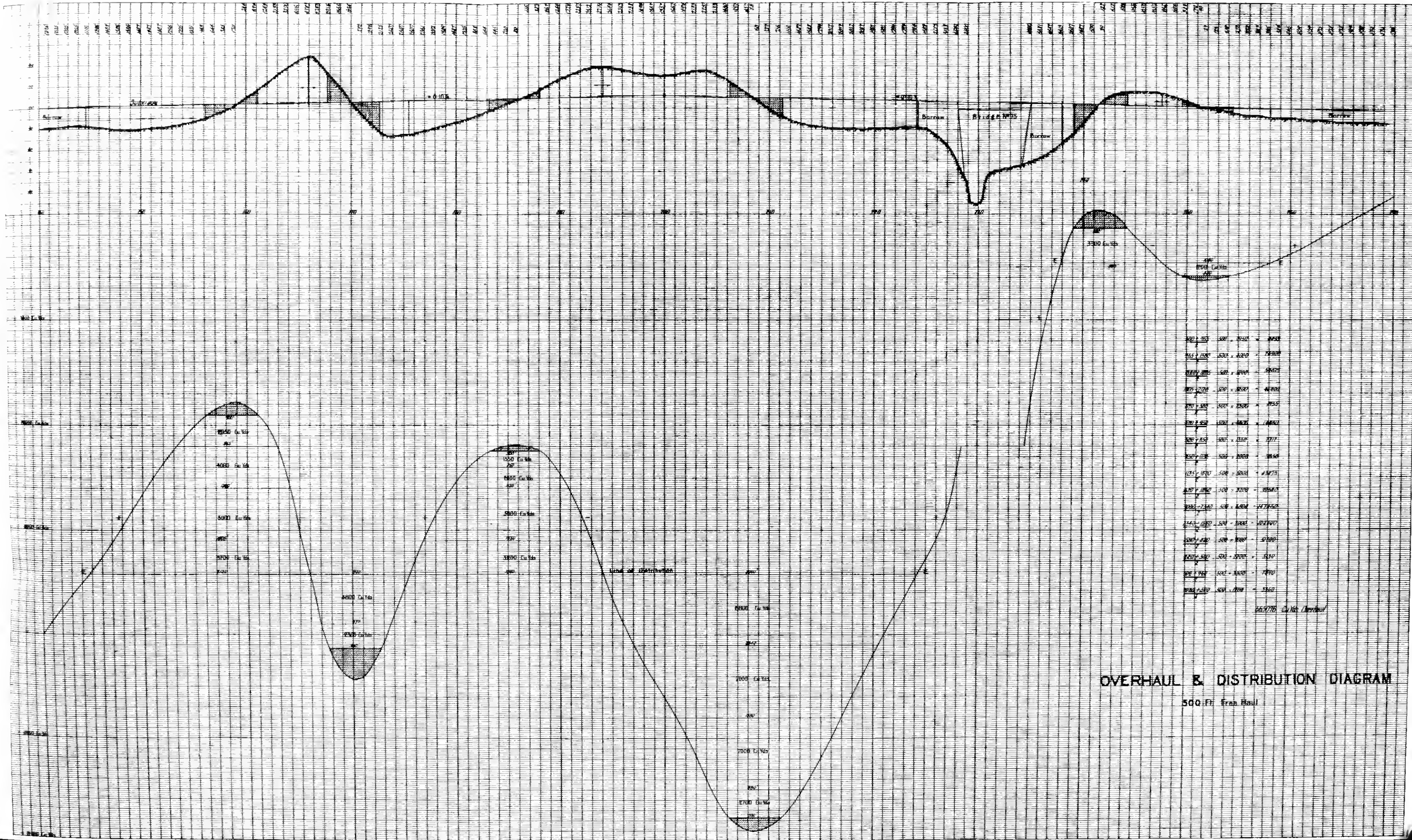
To obtain the overhaul the included yardage between the subdivisions is multiplied by the average length of the subdivision lines, less the free-haul distance.

The points where the line of distribution and free haul cut the mass diagram, if projected up to the track profile, will show the limits of distribution.

In case of a rock cut, the probable expansion of material is added before the distribution profile is platted.

In case a certain amount of borrow is desired in the base of an embankment before finishing by haul, the amount of borrow is deducted from the total embankment before the distribution profile is platted.

OVERHAUL AND DISTRIBUT
DIAGRAM.



OVERHAUL & DISTRIBUTION DIAGRAM

500 Ft Free Haul

REPORT OF COMMITTEE II—ON BALLAST.

H. E. Hale, *Chairman;*
L. W. Baldwin,
D. P. Beach,
W. J. Bergen,
Carl Bucholtz,
T. C. Burpee,
O. H. Crittenden,
J. M. Egan,
T. W. Fatherson,
H. L. Gordon,
Geo. H. Harris,
J. M. Meade, *Vice-Chairman;*
C. C. Hill,
S. A. Jordan,
William McNab,
S. B. Rice,
E. V. Smith,
D. L. Sommerville,
F. J. Stimson,
D. W. Thrower,
R. C. White,
Committee.

To the Members of the American Railway Engineering Association:

The Committee on Ballast submits herewith its annual report for 1916.

Two meetings of the General Committee on Ballast were held during the year, the first in Chicago, on July 3, 1915, with seven members present, the second in Chicago on November 19, 1915, with eleven members present.

The following subjects were assigned your Committee by the Board of Direction:

(1) *Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.*
(2) *Report on the economical and efficient depth of ballast, co-operating with Special Committee on Stresses in Railroad Track.*
(3) *Methods and cost of applying ballast—*
  (a) *Ballasting by contract.*
  (b) *Mechanical tamping and shoulder formings.*
(4) *Efficiency of various stone and gravel ballasts.*

(1) EFFICIENCY OF VARIOUS STONE AND GRAVEL BALLASTS.

SUB-COMMITTEE A.

J. M. Meade, Chairman;
D. P. Beach,
T. W. Fatherson.
C. C. Hill,
D. W. Thrower,
R. C. White.

EFFICIENCY OF STONE BALLAST.

The question of efficiency of stone ballast is largely covered and determined by the "physical tests of stone for ballast," which was thoroughly investigated by your Committee several years ago and the tests which were approved by the Association are specified in the Manual. The Committee has no changes in these tests to recommend.

Your Committee feels that the above physical tests of stone for ballast are the best tests which have come to the attention of the Committee to date, and while no absolute formula based on these tests has been proposed, yet the tests give a very full idea of the character of the stone.

EFFICIENCY OF GRAVEL BALLAST.

Your Committee in its discussions for several years has felt that the old specifications for gravel ballast, "30 to 35 per cent. sand," was not sufficient and that some further specifications as to the proportion of various sizes of gravel should be made.

Stretches of track have been selected where the results from the use of the ballast were known, and samples of the ballast have been tested to determine the per cent. of various sizes of gravel used in the ballast as follows:

Per cent. of material passing through screen with 1/10-inch mesh.

Per cent. of material passing through screen with ¼-inch mesh and retained on screen with 1/10-inch mesh.

Per cent. of material passing through screen with ½-inch mesh and retained on screen with ¼-inch mesh.

Per cent. of material passing through screen with 1-inch mesh and retained on screen with ½-inch mesh.

Per cent. of material retained on screen with 1-inch mesh.

The results of five such tests with photographs showing actual size of ballast are given in Appendix B.

The number of tests made are too few to arrive at a definite conclusion and it is the recommendation of the Ballast Committee that a large number of similar tests, possibly fifty or more, should be made, as it is felt the result will indicate what per cent. of each size of gravel will produce the best results.

An effort has been made to classify different kinds of ballast in the order of their desirability. This has been found very difficult on account of certain ballast being considered best for certain conditions, whereas other kinds of ballast are considered most satisfactory for other conditions.

CONCLUSIONS.

Your Committee recommends the following:

It is generally conceded that stone ballast, as defined by the Manual, is the most efficient ballast, and experience has demonstrated that the other ballast materials (using the definition for each as appearing in the Manual) should fall in the following order of efficiency:

(1) Stone.
(2) Broken Slag (not granulated).
(3) Gravel.
(4) Chatts.
(5) Burnt Clay or Gumbo.
(6) Cinders.

The efficiency of gravel for ballast in the opinion of your Committee is much improved by washing, for the following reasons:

(a) Washing removes clay, dust and other undesirable materials.

(b) If the washing plant is properly arranged the desired per cent. of each size of gravel can be placed in the ballast during the process of washing.

Your Committee obtained a very complete report made in 1913 of the Brookhaven Ballast Washing Plant, which is a very efficient plant, and the Committee was fortunate to have this report checked and revised in 1915. A copy of this report, including sketches of the general layout and detailed sketches of the method of washing, is printed in Appendix C.

One part of particular interest in this washing plant is the method of separating the clay (appearing in considerable quantities in certain strata) from the sand and gravel without the loss of sand or gravel and permitting considerable profit from the sale of clean sand and gravel of various sizes.

This report printed in Appendix C is called to the particular attention of the Association.

METHODS AND COST OF APPLYING BALLAST.

SUB-COMMITTEE B.

H. L. Gordon, Chairman;
Carl Bucholtz,
J. M. Egan,
S. A. Jordan,
S. B. Rice.
E. V. Smith,
D. L. Sommerville.

The mechanical tie tamper has been in experimental use on the following railroads:

Bessemer & Lake Erie.
Boston & Albany.
Boston Elevated.
Delaware, Lackawanna & Western.
Erie.
Hudson & Manhattan.
Lehigh Valley.
Long Island.
Michigan Central.
New York Central.
New York, New Haven & Hartford.
Pennsylvania.
Pittsburgh & Lake Erie.
Queen & Crescent.
St. Louis Merchants Bridge Terminal
Union Pacific.
Washington Terminal.

The results of tests of the use of the mechanical tie tamper reported to your Committee are as follows:

Delaware, Lackawanna & Western Railroad.

"The Pneumatic, or Mechanical Tamping Machine, as made by the Ingersoll-Rand Company and purchased by this company having a compressor and gasoline engine, same being equipped with two tampers driven by compressed air furnished by this machine, requiring a man to operate said machine, using about one gallon of gasoline per hour for its operation, requiring a man for each tamper. This machine having been carefully tested out on our line during the summer, we cannot see that same has any advantage from a cost standpoint over hand tamping. In fact, our figures indicate an increased cost with this machine over hand tamping, as the cost indicates 2c per tie for mechanical tamping and 1.8c per tie for hand tamping. Therefore we do not favor the use of a two-tamper outfit account of the smallness of the unit. We do, however, favor a mechanical tamping outfit equipped with four tampers that will represent the equivalent of eight men. Such a machine will reduce the cost below the cost of hand tamping and meet every requirement now met by the two-unit machine. We do believe that such a machine will some day be universally used for the tamping of track."

TEST OF MECHANICAL TIE TAMPER.

Daily Record of Tie Tamping Machine for the Month of September, 1914.

Date	Hours Machine Worked	Gasoline Used	Value	Oil Used Qts.	Value	Foreman Exp.	Laborers		Machine Operating Expense	No. Ties Tamped	Total Cost Op. Machine
							Hrs.	Exp.			
1	9	10	$1.00	3	.15	$1.20	36	$5.76	$2.50	565	$10.61
2	9	10	1.00	3	.15	1.20	36	5.76	2.50	536	10.61
3											
4											
5	9	12	1.20	3	.15	1.20	36	5.76	2.50	513	10.81
6	8	9	.90	2	.10	1.20	32	5.12	2.50	517	9.82
7	9½	13	1.30	3	.15	1.20	38	6.08	2.50	468	11.23
8	9	11	1.10	3	.15	1.20	36	5.76	2.50	492	10.71
9	9½	12	1.20	3	.15	1.20	38	6.08	2.50	550	11.13
10	Overhauling Machine										
11											
12	9½	11	1.10	2	.10	1.20	38	6.08	2.50	556	10.98
13	9½	13	1.30	3	.15	1.20	38	6.08	2.50	602	11.23
14	9	11	1.10	2	.10	1.20	36	5.76	2.50	552	10.66
15	8	9	.90	2	.10	1.20	32	5.12	2.50	527	9.82
16	9	12	1.20	3	.15	1.20	36	5.76	2.50	530	10.81
17											
18											
19	9½	12	1.20	2	.10	1.20	38	6.08	2.50	549	11.08
20	9	12	1.20	3	.15	1.20	36	5.76	2.50	596	10.81
21	9	12	1.20	3	.15	1.20	36	5.76	2.50	530	10.81
22	9½	13	1.30	3	.15	1.20	38	6.08	2.50	570	11.23
23	9½	13	1.30	2	.10	1.20	38	6.08	2.50	582	11.18
24											
25											
26	9	11	1.10	2	.10	1.20	36	5.76	2.50	535	10.66
27	9	11	1.10	2	.10	1.20	36	5.76	2.50	540	10.66
28	9½	13	1.30	2	.10	1.20	38	6.08	2.50	565	11.18
29	9	12	1.20	2	.10	1.20	36	5.76	2.50	575	10.76
30	9½	13	1.30	2	.10	1.20	38	6.08	2.50	592	11.18
Cost per tie, $.02								Total-----		12042	$240.53

New York, New Haven & Hartford Railroad.

"We have made a comparative test of one of these Pneumatic Tie Tamping machines compared with hand labor. The total expense for tamping with machine and with hand labor was taken for a period from July 26th to August 18th, this year. The average cost of tamping a tie with the machine for that period was $0.0517 per tie, the cost varying from day to day, from $0.0392 to $0.0930 per tie. The cost of hand tamping for the same period was $0.0651 per tie, the cost varying from day to day, from $0.0444 to $0.1009 per tie. Traffic conditions caused the difference in price from day to day.

"These figures are based upon the use of five men and a foreman with each machine and I consider that further economies can be made; in fact, we have reduced our gang to four men and a foreman.

"We are planning to purchase three more of these machines and then it is proposed to work them together and have at least two machines under the supervision of one foreman with one man to look after the four compressors and three men with each tamping machine. With this arrangement I believe that we can reduce the cost of tamping to below $0.04 per tie. As the work that we are doing with these machines is in a more or less undeveloped stage, these figures merely show what can be done under favorable conditions, and I believe that later in the season we will be able to give you figures that are of considerably more value. I will be glad to keep this matter in mind and let you know what results are secured."

Erie Railroad.

"Replying to your letter of September 30, and supplementing my letter of August 27, and referring to other correspondence with reference to thirty days' test of the Ingersoll-Rand Pneumatic tie tamping outfit inaugurated on the Susquehanna Division, August 11, 1915, which is now complete.

"This test was conducted by the local officials of the Susquehanna Division assisted by representatives from this office and such test reported on by such parties; also by the Superintendents or Division Engineers of other divisions on lines east of Salamanca. The device furnished is what is known as a 'two-tamper' machine, i. e., it was equipped with two tamping arrangements. In its operation the following men were employed:

Two men operating the tampers;
One man for picking away from the ties or filling in;
One man with jack;
Foreman supervising;
Total, five men.

"The two men doing work other than operating the tampers about the machine in its operation are necessary to get the utmost from the machine and to change off with the two men operating the tampers who must be relieved from time to time as the vibration received from holding the tampers is so heavy that one set of men cannot make continuous operation.

"With the organization we found that the cost to tamp ties with the device in stone ballast was $0.036 per tie, comparing with a similar cost tamping by hand with pick of $0.034 per tie, and that corresponding prices prevailed in the handling of the work with each of the systems in slag, gravel or cinder ballast. Therefore, the results from our experiment so far with this 'two-tamper' machine indicate that the cost of tamping with this device is about the same as manually with picks, but the results obtained are very much better in that there is more uniformity obtained and the track stays up better after the tamping is done. In developing this test consideration has been given to lengthening the sectional divisions of our territory as a result of the use of these machines, but as the work of surfacing constitutes only a moderate proportion of the season's work on each section, it is not felt advisable to take such action, which would result in less supervision, and supervision is greatly needed in our track work now.

"The machine furnished does not appear to be as well designed for the best results, as it easily could be, and the following defects which, it is believed could be readily modified as indicated later on, were noted by our men:

"Due to the fact that the main shaft is connected throughout with both the air compressor and engine together with the sprocket or driving wheel, fan, etc., it was oftentimes difficult to start the apparatus, especially on cold mornings, of which we had a number which were relatively cold during the months of August and September, 1915, on the Susquehanna Division, but which conditions would, of course, be greatly augmented later on in the season. This would delay the operation of the machine getting started in the morning sometimes an hour. It is believed this fault could be overcome by supplying a clutch to throw in after the engine had warmed up thoroughly and was capable of carrying the load necessary to operate the machine.

"The instructions received for the operation of the machine provided for the use of a heavy grade of oil in the compressor parts, etc. This, we found, during the colder weather tended to stiffen and retard the operation of the machine. By an experiment made substituting lighter oil this was overcome and no ill results noted.

"Another trouble experienced was in the operation of the hose connections, which were of rubber equipped with wire clamps. Incidental to the vibration of the machine and passage of the warm air through the hose the latter would quickly deteriorate on the connections, enlarging the inside diameter, loosening the clamps and destroying the connections. Our suggestion is that metal clamps with bolts be furnished instead.

"Another suggestion made was that instead of having a hose leading from the machine to each of the pneumatic tampers that but one main hose be used from the machine to within about 25 ft. of the tampers with 'Y' connections furnished therefrom as may be necessary. This would save time and labor in starting the operation of the machine; also reduce the cost account less hose required.

"Another suggestion made is that the various connections subject to air pressure and vibration be all equipped with bolts supplied with nut locks to prevent the ill effects of the vibration in loosening connections.

"Another suggestion is that some device be developed to go with the machine so that it may be easily removed from the track. The present compressor, engine, etc., weighs about 2,000 lbs. and makes it necessary to have at least four men to lift the machine from the tracks and afford a man to flag as may be necessary, whereas it is thought that this number could be lessened after men were familiar with its operation based on using only the minimum number necessary to operate the machine and not work with the idea of having men available to move the machine quickly from the tracks at all times as is now necessary.

"It is understood that the Ingersoll-Rand Company, which developed this device, is now getting out an improved apparatus embodying more or less of the above suggestions and designed with four tie tampers instead of two, with which the machine we had was equipped.

"Such a machine would result in greater economy and we would recommend that sufficient of these improved machines be purchased to the extent of one for each Supervisor's territory on the New York Division main line, Susquehanna Division and the eastern sub-division of the Buffalo Division, or seven in all for use next season. We would further recommend that the present machine, which was tested on the Susquehanna Division, be returned to the manufacturer and not retained in view of the recommendation made as to the purchase of the machines of the new type."

The difference in cost of tamping by the mechanical tamper as reported in the second above test is probably due to different methods of accounting, but the comparative figures taken for each test separately are of much interest.

In the August, 1915, Bulletin (Vol. 17, No. 178, page 195) of the American Railway Engineering Association, Mr. George W. Vaughan, Engineer Maintenance of Way, New York Central Railroad East of Buffalo, reported results of the mechanical tie tamper used on the New York Central.

FIG. 1. ELECTRIC TIE TAMPER.

The following photographs show various views of the mechanical tampers illustrating the size of the tamper and the method of using it. Some of these photographs are a reproduction of cuts previously issued in various reports, but all are reprinted here in an effort to show more completely the operation of this machine.

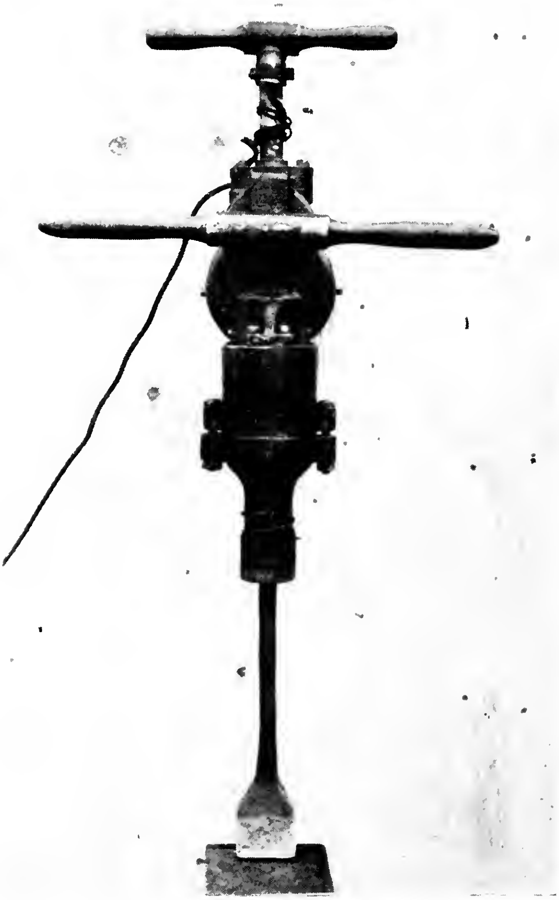


FIG. 2. ELECTRIC TIE TAMPER.

FIG. 3. PNEUMATIC TIE TAMPER.

Fig. 4. The Pneumatic Tie Tamper at Work.

Fig. 5. Resurfacing with Pneumatic Tampers.

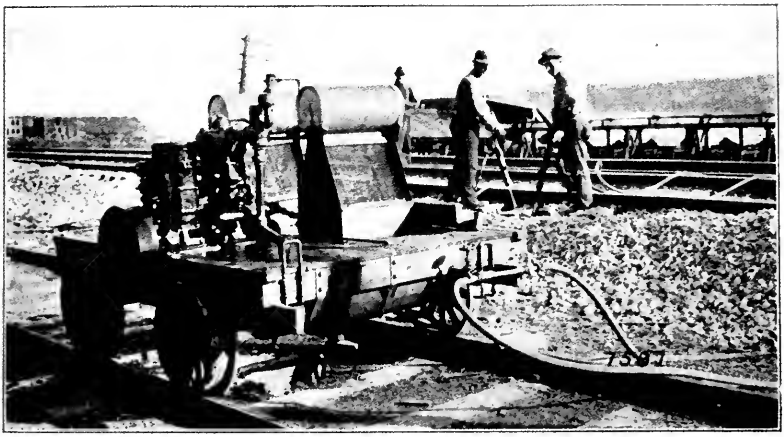


Fig. 6. This Shows the Pneumatic Tamper in Operation on Track Where New Rails Were Laid. Ties Were Being Spaced and the Track Ballasted and Lifted from Two to Four Inches.

Fig. 7. The Pneumatic Tamper Permits Tamping in Places More or Less Inaccessible by Other Methods.

Fig. 8. Track Gang Riding on Motor Car That Produces Power to Operate Mechanical Tamper.

FIG. 9. MOTOR CAR BEING "SET OFF" THE TRACK.

FIG. 10. MOTOR CAR REMOVED FROM MAIN TRACK.

FIG. 11. PNEUMATIC TAMPERS IN OPERATION.

FIG. 12. PNEUMATIC TAMPERS IN OPERATION.

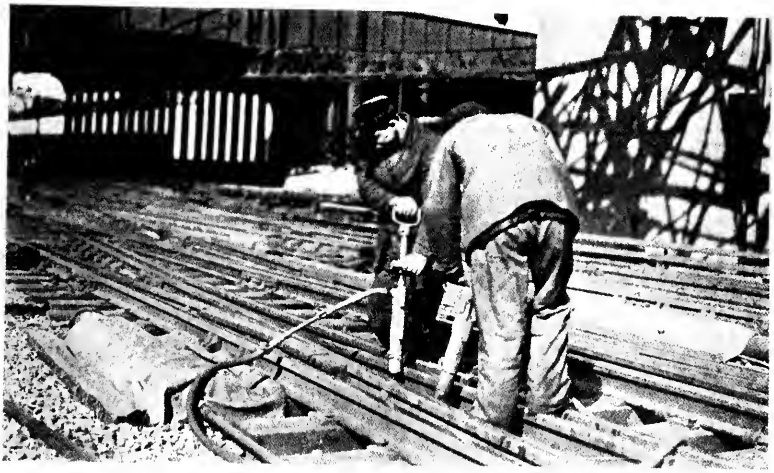


FIG. 13. TAMPING A CROSSOVER IN YARDS.

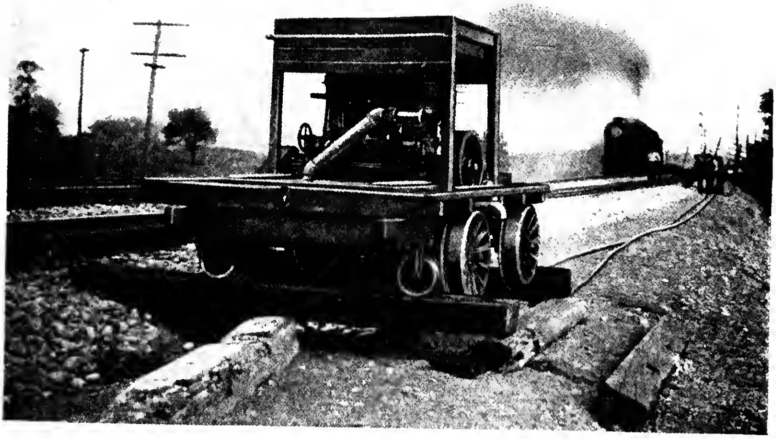


FIG. 15. TAMPING OUTFIT.

FIG. 14. A NIGHT GANG TAMPING TIES IN THE RIVER TUBES.

CONCLUSIONS.

With the data now available in the tests herein referred to, your Committee feels unwilling to make any definite recommendations in regard to the mechanical tie tamper, but trusts that further development and tests of the mechanical tamper will place the Committee in a position to make a more detailed report and more definite recommendations.

BALLAST FORMERS.

The following is a report of the Ballast Formers used on the Santa Fe, together with photographs illustrating method of operating same:

"Attached are five photographs of the Cafferty-Markle device on Car No. 199707 which has been in use on the Eastern Division. Fig. 16 shows the devices fastened up for handling on the road. It will be noted this arrangement consists of a regular ballast plow ahead of a shaping board, there being on the front end of the car a four-thousand-gallon capacity tank. We carry about 2000 gallons of water in this tank for weighting the car down. You will notice just behind the shaping board there is a sprinkler pipe which we used to sprinkle the ballast.

FIG. 16. CAFFERTY-MARKLE BALLAST SPREADER AND FORMER WITH PLOW AND WINGS RAISED FOR HANDLING ON ROAD.

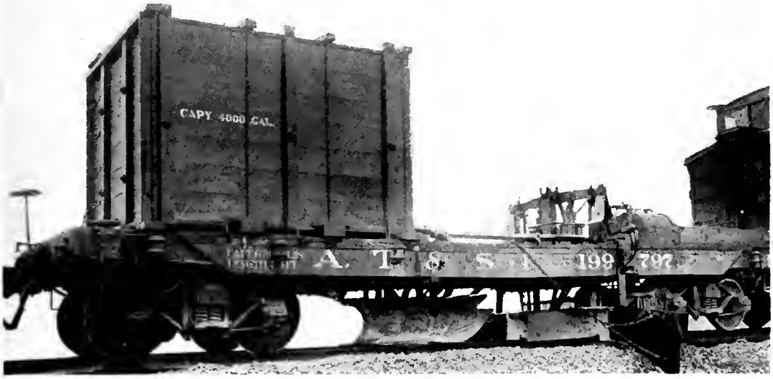


FIG. 17. BALLAST SPREADER AND FORMER WITH PLOW AND WINGS LOWERED FOR OPERATION.

"Fig. 17 shows the devices let down on ballasted track. They are ready for operation, except that there is no ballast in the track.

"Fig. 18 is looking at the car from the rear end, devices all in position for traveling on the road. Fig. 19 is looking at the car from side after ballast has been dropped in the track, both plow and shaper in operation.

FIG. 18. END VIEW OF BALLAST SPREADER AND FORMER.

Fig. 20 is looking from side, plow shaper and sprinkler in operation. Fig. 21 shows track skeletonized ready for dropping ballast. Fig. 22 shows track after ballast has been dropped and Cafferty-Markle device has passed over it. Fig. 23 shows the ballast after having been dressed.

Fig. 19. Ballast Spreader and Former in Operation.

"The appliances are handled by air. The shaping wings are raised and folded back for transporting.

"As to the cost of the machine, we can only make a close estimate. There have been so many changes in developing it up to the present stage that it is difficult to say just what it would cost, but as nearly as our mechanical people can figure it, the Cafferty device constructed of new material will cost approximately $290.00.

"It requires no more labor for operating it than we use in operating the ballast plow. On a test in unloading a train of ballast it was dropped in the track and spread in 48 minutes. The same amount of rock was then dressed from the condition shown on photograph No. 6 to that shown on Fig. 22 by 17 men in the same time it would have taken 50 men to handle it had they followed up an ordinary ballast plow.

Fig. 20. Ballast Spreader and Former in Operation, Showing Jet of Water Used to Sprinkle Ballast After Passing Over It.

Fig. 21. Track Skeletonized Ready for Dropping Ballast.

Fig. 22. Track After Ballast Has Been Dropped and Ballast Spreader and Former Has Gone Over It.

Fig. 23. Track Showing Ballast After It Has Been Dressed.

The following cuts illustrate the development of the spreader on cars with steel frames and the development of the ballast formers.

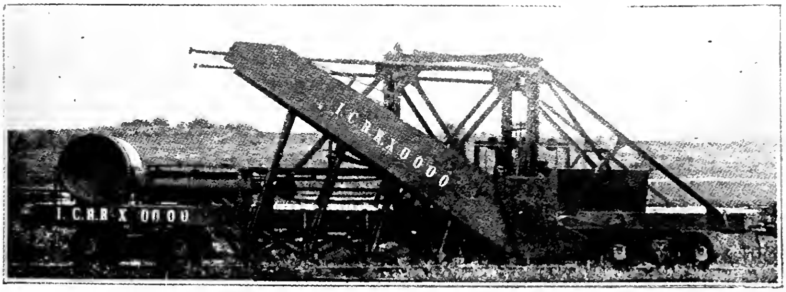


Fig. 24.

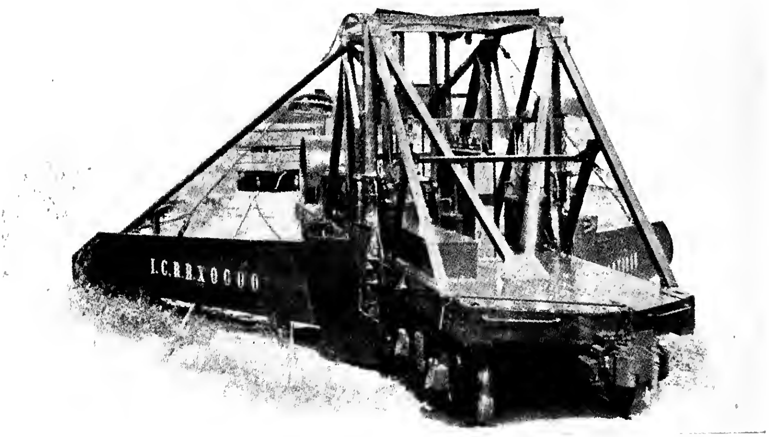


FIG. 25.

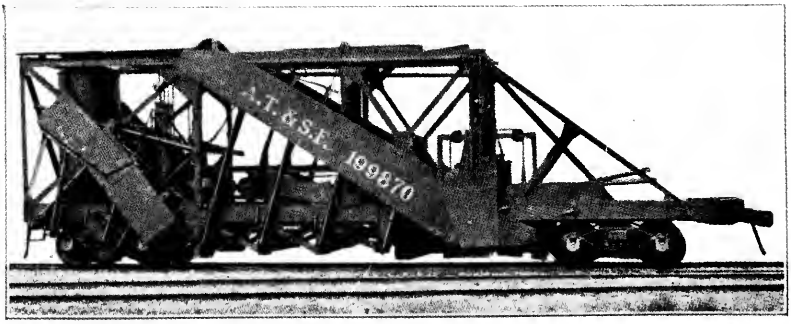


FIG. 26.

CONCLUSIONS.

Your Committee is of the opinion that the use of "formers" to shape the shoulder of the ballast, and also to a large extent, the path adjoining the ballast, results in considerable economy. Up to the present time sufficient data has not been obtained as to the saving resulting from the use of these formers to make a complete report. Further improvements on spreaders and formers are now being developed, such as the operation of the wings and formers by air from a reservoir supplied from the train line, etc.

BALLASTING BY CONTRACT.

Ballast has been applied by contract on several roads. The Michigan Central Railroad has applied ballast by contract as per article which was published in the Railway Age Gazette, issue of June 18, 1915, page 1436, by John Evans, Division Engineer, Michigan Central Railroad, Detroit, Mich., and reprinted in this report as Appendix A.

The Missouri Pacific Railway in 1909 to 1911 applied quite a large amount of ballast by contract, conditions being as follows:

(a) Certain ballast pits were specified in the contract as well as the location of the track to be ballasted and the work of "loading, hauling and unloading of ballast per cubic yard measured in the cars at the ballast pit," was paid for at a special price per cubic yard—the railroad furnished the ballast cars and spreaders and the contractor furnished the locomotives, steam shovels and all labor, including pay of train crew and supervision.

(b) After the ballast was applied on the track the "ballasting of track per cubic yard of ballast unloaded" was paid for per cubic yard at a specified price, the contractor furnishing all labor, tools and supervision.

(c) The ties which had to be renewed in the track that was being ballasted were renewed by the contractor, "including the necessary respacing," at a specified price per tie, "the ties to be furnished by the railroad," the contractor to furnish all labor, tools and supervision.

(d) The ballast section diagram was made a part of the contract and specified the dimensions of the ballast section, the railroad provided inspectors to report the amount of ballast loaded and the character of work done in ballasting. The number of ties to be renewed was determined also by the railroad inspector.

(e) The contract required that the track should be maintained by the contractor for a period after the ballasting was completed. This clause was inserted to insure good work being done in ballasting and particularly to insure proper tamping of ties.

(f) The contract provided that in case ballast was unloaded in excess of the ballast section specified by a diagram that the contractor should reload the excess ballast and distribute it where needed; this was done to prevent excess ballast being unloaded, as the work was paid for per cubic yard.

CONCLUSIONS.

Your Committee has had considerable difficulty in obtaining good comparative figures on the cost of ballasting by railroad company forces, and by contract, due to the different track and other conditions existing where ballasting has been done. They feel, however, that ballasting by contract under certain conditions has given very satisfactory results, and under certain conditions is more economical than ballasting by railroad company forces.

THE ECONOMICAL AND EFFICIENT DEPTH OF BALLAST.

SUB-COMMITTEE C.

Geo. H. Harris, Chairman;	O. H. Crittenden,
L. W. Baldwin,	William McNab,
W. J. Bergen,	F. J. Stimson.

The Chairman of the Committee on Ballast conferred with Prof. A. N. Talbot, Chairman of the Joint Committee on Stresses in Railroad Track, and Mr. W. M. Dawley, Chairman of the Roadway Committee, advising them of the progress of the work of the Ballast Committee. Mr. Dawley was advised that no action had been taken by the Ballast Committee to change its recommendations made in its last report of 1915 that the roadbed for single track should be 26 feet wide for Class "A" track, stone ballast, with a depth of ballast of 24 inches. It was suggested to the Committee on Stresses in Railroad Track that the test recommended by the Ballast Committee to determine the depth of ballast which would produce uniform pressure on subgrade should be made. This, in the opinion of the Ballast Committee, is the only test so far suggested that would determine this fact under actual operating conditions and without artificial devices. The artificial devices which have been used in most of the previous tests do not exist in normal conditions of track under operation, although they are very ingenious and give much valuable data in the study of the subject, therefore the Ballast Committee's tests would add valuable additional data.

Taking into account the three classes of roads as defined by the Manual, and their experience as regards efficiency with the depths now standard with them, the Chairman of the Sub-Committee took up with various roads, widely distributed as to geographical location, the question as to their present practice relative to ballast depths.

The valuation engineers of several roads now in process of valuation were also requested to furnish information relative to the actual depths of ballast found, while tests were being made for that specific purpose, in connection with such valuation.

The number of replies to both requests was not large or distributed enough to warrant a tabulation, undoubtedly due to the fact that only a comparatively few roads have as yet made any actual tests to determine the depths of the various kinds of ballast under each class of track.

The replies, however, from the several valuation engineers, while not giving a large amount of data, gave promise of some very valuable data for next year's report. In some cases tests had not yet been made, in others the data had not been sufficiently tabulated. All from whom information was requested have agreed to furnish data as soon as it is available, although it will not be received in time for incorporation in this year's report.

While the number of replies giving information as to depth of ballast found has not been large, it is surprising to note that in nearly every case the depth of ballasting materials given for Class "A" roads is at least equal to the 24 inches recommended by the Committee. In several cases a much greater depth has been found.

Taking into account the tests made in the past; the mathematical deductions as to proper depth, and the actual depths recently found in work of valuation, or in preparation therefor, the Committee feels that it cannot do otherwise than reaffirm the conclusion that a combination of ballasting materials, approximately 24 inches in depth in the aggregate, is necessary to insure uniform distribution of the load on the roadbed.

It is recognized that roadbed materials differ widely; some not requiring uniform distribution of the pressure; others requiring an almost absolutely uniform distribution in order to avoid excessive distortion. First may be cited the roadbed through a rock cut, where only sufficient ballast is necessary to provide drainage and allow of track maintenance work; second is the extremely soft clay or muck roadbed requiring the most uniform distribution possible.

The following reports are given as to the amount of ballast found by the Field Survey Parties of the Division of Valuation:

Missouri, Kansas & Texas Railway.

On certain lines it was supposed that the depth of ballast under the ties was approximately 3 inches, whereas it was found that the actual depth was 9 to 10 inches.

Kansas City Southern Railway.

Portions of the line were supposed to have six inches of ballast under ties, whereas 18 inches were found to exist. Instead of applying additional ballast as was previously intended with a view of obtaining 12 inches of ballast, the dirt shoulder on the outside of the ballast was plowed off and additional clean ballast added for dressing purposes. In most cases the ballast was found to be in good condition and to provide good drainage as soon as the bank of dirt on the side was removed.

Pennsylvania Railroad.

On the main line of the Philadelphia, Baltimore & Washington Railroad, between Philadelphia and Washington, there is a division which is subjected to a very heavy passenger and freight traffic. Originally this line was ballasted on gravel and as traffic conditions warranted the gravel ballast was replaced by crushed stone and there is at the present time an average of 24 inches of stone and 12 inches of gravel ballast measured from the top of tie. There are points on this railroad where there is not quite this amount of stone ballast. and there are other points where it is greatly exceeded. In the territory around Washington, D. C., we find as high as 42 inches of stone on top of 12 inches of gravel. This additional depth of ballast seems called for from the fact that the soil between Baltimore and Washington is very unstable, being principally a yielding clay formation and the depth of ballast has been increased from time to time.

On the Elmira Division, running from Williamsport to Lake Ontario, there is a single-track railroad handling a fair traffic, on which division there is principally cinder ballast. The average depth below top of tie is 18 inches. There are places, however, where the depth of ballast runs as high as 36 inches.

On the Delaware Railroad where there is a double-track system, handling a fair passenger traffic, and in some seasons of the year very heavy freight traffic, there is an average of 12 to 15 inches of stone ballast measured from the top of tie.

On the Pope's Creek Branch of the Philadelphia, Baltimore & Washington Railroad, a branch of very light traffic, there is a mean depth ballast below top of tie of 18 inches. In some instances the ballast is entirely gravel, and in other instances it is cinder, or cinder and gravel mixed. There are points on this branch where the depth of ballast greatly exceeds 18 inches, some places measuring 30 to 36 inches of gravel ballast.

There are many conditions entering into the amount of ballast on the different divisions of the railroad, but the depths given in the above locations are sufficient to properly support the track at the present time, provided there are not any unusual conditions of soil beneath the ballast, which prevents it from giving proper support to the track structure.

In such circumstances it is necessary to either drain the subsoil by an elaborate system of drainage, or greatly increase the depth of ballast, going so far on some divisions as to make the ballast five to six feet below top of tie.

Chicago & Eastern Illinois Railroad.

Referring to your letter requesting information as to depths of ballast found by the Government field parties in their valuation of our property, wish to advise as follows:

On one Class "A" line, they found an average depth of about 17 inches below bottom of tie. The greater part of this line is ballasted with gravel and probably 25 per cent. of the line has from 9 inches to 12 inches of stone on top of the gravel. The average included depth of both stone and gravel where both occur.

On another Class "A" line the Government found an average depth of about 15 inches below bottom of tie. All of this line is gravel ballast.

On another Class "A" line they found an average depth of about 13 inches below bottom of tie. Practically all of this line is gravel ballast. with a few miles of stone ballast on top of the original gravel.

On one line of Class "B" road they found 14 inches of ballast below bottom of tie. About 25 per cent. of this line is ballasted with 7 inches or 8 inches of stone on top of the original gravel, balance of the line being ballasted with gravel and some parts with burnt clay under the gravel.

On another Class "B" line the Government notes showed an average depth of about 13.5 inches below bottom of tie, all of which is gravel ballast.

On Class "C" road the Government notes showed an average depth below bottom of tie, various lines, from 10 inches to 13 inches, all of which is gravel.

In some cases, especially along the line which originally had burnt clay ballast, the Government did not go entirely through the burnt clay and, of course, we have taken exception to their notes at these points and it will still be necessary to obtain this information to arrive at the full depth. The information given in the foregoing is an average of that actually shown by the Government notes.

On some parts of our line we had information on the ballast charts as to the actual depth of the ballast, which checked very closely with the information obtained by the Government. On the parts of the road where we did not have this information, the Government, as a general rule, found more gravel than we thought we had.

Bangor & Aroostook Railroad.

The ballast has been inventoried on this road as follows:

Val. Sub-Section.	Mileage.	Depth of Ballast.
1-A	55.71	1.84 feet
1-B	2.15	1.4
2-A	14.65	1.57
2-B	13.00	2.00
2-C	48.48	1.72
2-D	7.31	1.85
2-E	12.53	1.3

From this consideration of the matter it appears:

(a) Depth of ballast thought to be under the track, 1 foot as a maximum and 0.6 foot as a minimum.

(b) The approximate depth actually found, the maximum of 2 feet and a minimum of 1.3 feet with a general average of 1.8 feet.

Richmond, Fredericksburg & Potomac Railroad.

There is probably not a heavy fill on this line to-day that does not have as much as 24 inches of gravel ballast.

I consider our line Class "A" track under as heavy traffic as any of the lines included in these reports. I think our test shows as good, if not better, gravel than some of the other reports. As a proof that we have a Class "A" line handled on washed gravel, have 7,537 freight trains per mile per annum, 223,631 freight cars per mile per annum, 9,365 passenger trains per mile per annum or 63,357 passenger cars per mile per annum.

Yours September 20; I have had some tests made of our ballast as we now use it from the washer and find the percentages of this material to be as follows:

¾ in. to 2½ in.....37.46 per cent.—Screen, 1 mesh to inch
½ in. to ¾ in.....35.42 per cent.—Screen, 2 mesh to inch
¼ in. to ½ in.....19.90 per cent.—Screen, 6 mesh to inch
Less than ¼ in.... 7.22 per cent.

I had photographs taken of these different sizes of material and am enclosing prints of same. The two larger sizes show up very small, but the smaller sizes do not show up so well. The percentages shown by this test were very accurately made and reflect the general average of material we have been using as we are using the same size screens now that we did when we started the plant. Cost, 32 cents per cu. yd., f. o. b. cars pit.

Report of ballast operations at Massaponax gravel pit for the year 1914, repairs not included:

Class of Work and Charges	Total	Steam Shovel	Spotting Engine	Washing	General
Supplies—					
Coal for steam shovel..$	224.38	$ 224.38			
Coal for washer	557.95			$ 557.95	
Coal for spotting engine	919.66		$ 919.66		
Supplies for spotting engine	115.77		115.77		
Supplies for shovel....	56.33	56.33			
Supplies for plant	187.17			187.17	
Wages—					
Superintendence	55.00				$ 55.00
Wages of shovel crew, pit hands and others	4,425.27	1,867.47	11.70	2.546.10	

Class of Work and Charges	Total	Steam Shovel	Spotting Engine	Washing	General
Wages—					
Wages of spotting engine crew	$ 1,354.05		$1,354.05		
Rentals—					
Hire of spotting engine	658.30		658.30		
Buildings and tracks	681.53				$ 681.53
Steam shovel	338.42	$ 338.42			
Washing plant	1,079.20			$1,079.20	
Miscellaneous Rent Income Acct. No. 510	1,125.86	84.61		359.72	681.53
Insurance on M. C. P. property	32.89				32.89
Total costs	$11,811.78	$2,571.21	$3,059.48	$4,730.14	$1,450.95
Produce 40,644 cu. yds. rough gravel:					
Cost of steam shovel	$ 2,571.21				
Cost of material	406.44				
One-half cost of general expenses	725.47				
One-half cost of spotting engine	1,529.74				
40,644 cu. yds. rough gravel @ 12.875c	$ 5,232.86				
2,264 cu. yds. rough gravel shipped @ 12.875c	291.49				
Cost carried forward into washing expenses			$4,941.37		
Washing expenses			4,730.14		
One-half cost of general expenses			725.48		
One-half cost of spotting engine			1,529.74		
36.179 cu. yds. washed gravel and sand @ 32.966c			$11,926.73		
6,822 cu. yds. sand sold C. W. Tiller @ 10c		$682.20			
1,481 cu. yds. sand used and given away @ 32.966c		488.23	1,170.43		
27,876 cu. yds. washed gravel @ 38.586c			$10,756.30		

Summary—

40,644	cu. yds. rough gravel loaded.
38,380	cu. yds. rough gravel dumped.
2,264	cu. yds. rough gravel shipped.
27.876	cu. yds. washed gravel shipped.
8,303	cu. yds. sand shipped.
2,201	cu. yds. wasted material.
40,644	cu. yds.

Cubic yards rough gravel loaded	40,644
Cubic yards washed gravel shipped	27,876
Cubic yards sand shipped	8,303
Cost rough gravel	.12875c
Cost washed gravel	.38586c
Cost sand	.32966c

Statement of cost of material excavated from Massaponax Gravel Pit, December, 1908 to December, 1910, inclusive:

Cubic yards rough gravel loaded	418,485
Average cost per cubic yard rough gravel	8.573c
Cubic yards washed gravel shipped	318.189
Average cost per cubic yard washed gravel at pit	21.544c
Cubic yards washed gravel placed in track	304,489
Average cost per cubic yard hauling	10.300c
Average cost per cubic yard placing in track	25.177c
Total average cost per cubic yard in track	57.021c

Note:—The average cost per cubic yard for washed gravel at pit, includes the cost of loading the rough gravel for washing. The cost of placing in track includes cutting out old ballast, dressing up new ballast and surfacing; it does not include spiking, regaging, lining, renewing ties and building roadbed, this work being charged to Maintenance.

The work of reballasting the R. F. & P. was started December 1, 1908, and completed October 13, 1910, using 267,489 cubic yards of washed gravel ballast between M. P. 4 and 79.86, an average of 3,526 cubic yards to the double track mile.

Our renewals average about 33c per cubic yard at pit on account of not running plant to full capacity.

New York Central Railroad.

CLASS "A" TRACK.

Division.	*Location.*	*Depth of Ballast Under Tie.*	*Subgrade.*
Harlem	M. P. 64 to 76	Original ballast gravel 1909—8 inches stone added 1914—3 inches stone added	Where roadbed was rock 8 inches held surface, but where swampy would not hold surface
Hudson	Various	12 to 36 inches stone	Where there are rock cuts the 12-inch will hold surface, but account of track crossing so many bays it is necessary to raise fills every year
River	Various Double track, 50 million tons per year	Original ballast cinder and gravel, top ballast 12 inches of stone	Where there are rock or dry fills and on hard roadbed, 12 inches hold surface. Where there is clay subsoil no depth yet put in will maintain good surface

Division.	*Location.*	*Depth of Ballast Under Tie.*	*Subgrade.*
Rochester	Falls Road	7 to 15 inches 19 tests Practically all gravel—a few sections in stone	Hard Clay. This line is remote from gravel pits and the average depth of gravel would be 12 inches, which is the minimum amount on which line can be obtained as ballast is added only as absolutely necessary
Rochester	Auburn	4 to 24 inches of gravel 16 tests	This is an old road well maintained. The 4 inches of gravel has sand subgrade. The 24 inches of gravel is on clay subgrade
Mohawk	Main line Washout at Hoffmans	12 inches stone 24 inches gravel	This is a fair example of Mohawk Division, which has largely a clay subgrade. Maintenance of surface and line quite expensive
Western	Main line	7 to 12 inches stone on top of 24 inches of gravel	This line is in gravel pit territory and was liberally ballasted with gravel. Two-thirds of the territory was ballasted with 8 to 12 inches of stone. Balance 6 to 8 inches of stone. So far with equal results, but the lesser depth is new
Adirondack	Mountain section	6 to 8 inches stone on top of 8 inches of cinder and slag	Sand or rock subgrade. Excellent results for amount of business, consisting largely of summer passenger travel. The track, however, is 105-pound rail.

CONCLUSIONS.

(1) Investigations now being carried on by the field parties of the Division of Valuation indicate that there is a much greater depth of ballast actually existing in track than has previously been supposed and that while many standard plans of trunk line railroads show 12 inches of ballast, the actual depth existing in their main lines is much greater.

(2) Recommendations of Ballast Committee, covering depth of ballast of Class "A" track, should be changed to read as follows:

> "On fills or roadbed material, subject to deformation, by the application of live load, the minimum depth of ballast, under bottom of tie, should be 24 inches. Through rock-cuts or on material which will not be deformed by application of live load, the minimum depth of ballast under bottom of tie should be 12 inches, this 12 inches to serve as a cushion and not for the purpose of distributing the load transmitted from tie to roadbed uniformly."

(3) The Committee again unanimously recommends that the test outlined in the 1913, 1914 and 1915 reports be made under regular traffic. (Complete outline of the proposed test is given on page 1015 of Volume 16 of the Proceedings.)

RECOMMENDATIONS FOR NEXT YEAR'S WORK.

The Committee recommends that for the year 1916 the same subjects be assigned to the Ballast Committee as were assigned last year.

Respectfully submitted,

COMMITTEE ON BALLAST.

Appendix A.

STONE BALLASTING BY CONTRACT.

By John Evans, Division Engineer, Michigan Central Railroad.

On the greater part of the stone ballasting on maintenance work done by the Michigan Central since the opening of the working season in 1909, the labor of putting the stone under the track has been handled by contract. A total of approximately 90 miles of double track has been ballasted in this way, distributed over the seasons of 1909, 1910, 1911 and 1913. No stone ballasting was done in 1912 or 1914.

There has been practically no change in the method of procedure since the practice of doing this work by contract was introduced. The contract provides unit prices per foot of track for skeletoning out the old ballast to the bottom of the ties; lifting the track to the grade stakes, and surfacing, lining and trimming. All work not covered by the contract prices, such as unloading the stone, putting in and spacing ties, making a preliminary lift on gravel or cinders, widening banks, etc., is done either by the railroad forces or by the contractor on force account. In either case the unloading of the stone is done under the railroad company's supervision, and the contractor is allowed extra compensation when, on account of shortage or surplus in the distribution, he has to move stone more than 300 feet to complete the finished ballast section. The railroad company provides bunk cars at its own expense for the contractor's men and supplies all tools and equipment needed in the work. It also furnishes free transportation for the men over its own lines.

The track is given a minimum lift of 6 inches on stone. The contractor makes lifts up to and including 8 inches at the contract price for lifting and for lifts over 8 inches an extra allowance per foot of track for each additional inch of lift is made. In cases where the stakes as set by the engineer show a lift of more than 6 inches for any considerable length of track, the lift to within 6 inches of the top of the stakes is made with gravel or cinders. The contractor is allowed extra compensation on a force account basis where the throw in lining track to the center stakes exceeds 1 inch.

The railroad company places an experienced trackman on the work as inspector. This man looks over the track after it has been surfaced, lined and trimmed, and either accepts it or notifies the contractor to do such additional work on it as may be necessary to make it acceptable. After the track has been accepted by the inspector the railroad company is responsible for its maintenance.

The work turned out under the above arrangement has been entirely satisfactory. The track has ridden well when finished and has retained its line and surface fully as well as it has in the best work done by our own forces. We are doing no stone ballast work at the present time, owing to financial conditions, but it is practically certain that our future work of this kind will be handled by contract. As a matter of fact, the contract system of doing track maintenance work is expanding with us and we are extending its application from time to time to new items with satisfactory results.

The men employed on the work are Italians and the contractor is an Italian with wide experience in business dealings of all kinds with his countrymen. He keeps in close touch with the labor situation throughout the country, and his knowledge and experience result in the finding of a better class of men and in getting more and better work out of them. Since starting in this work he has developed several good Italian track foremen.

The contractor, being financially concerned with the amount of work done, has a more effective interest in increasing the output than our own foremen have, regardless of how capable or conscientious they may be. Under this system small concessions can be made to the men in the way of increased pay, whereas wage rates paid by the railroad company are not adjustable. For this reason, local shortages in the labor market do not affect the size of the contractor's gangs as seriously as they do the railroad company's. Furthermore, a small increase in pay is usually more than offset by the additional effort which it results in.

Doing ballasting by contract relieves our roadmasters and assistant roadmasters of the greater part of the supervision of this work at the time of the year when their attention is badly needed for other branches of maintenance.

A possible improvement in our method from the railroad company's standpoint would be to have the contractor supervise the unloading of the stone and be responsible for its proper distribution. In this way the clause providing for an extra allowance in case stone has to be moved more than 300 ft. could be done away with. This should work no hardship on the contractor, because it is our experience that very little stone has had to be moved more than the specified distance. There have been several occasions where the contractor has made claims on account of the alleged improper distribution of the stone. In most cases these claims were not allowed, because they did not appear to be justified by the terms of the contract, or to be based on sound argument. If the contractor were unloading the stone, all opportunity for argument from this source would be done away with.

The proportion of the work done under contract could be increased and possibly the cost of the work reduced by having the contractor put in what ties are needed at the time of ballasting at a unit price per tie. I think it not improbable that this will be tried out in some of our future work. The ballasting done during the season of 1913 included 12 miles of double track on the East division of the main line about 55 miles west of Detroit. On this particular job the total number of men, including force account and contract work, varied from 110 to 140. The skeletoning gang numbered about 15 men, and the lifting gang 50. The remainder of the men were in a gang which worked between the skeletoning and lifting gangs, putting in and spacing ties, widening banks, etc.

The lifting gang did all the track raising, both on gravel and stone. It also surfaced, lined and trimmed the track. The lifting on stone was done in stretches of single track one mile long; that is, no lifting was done until stone was distributed ahead for one mile of track. The lifting of this mile was ordinarily one day's work for the lifting gang. After being raised, the track was allowed to stand for not less than three days before surfacing, lining and trimming was started. Between the time the track was lifted and the time it was finished a speed limit of 30 miles per hour was in effect. After the mile of track had been surfaced, lined and trimmed it was looked over by the inspector, and, if accepted, the speed restriction was removed.

The contract provided that for a stone ballast lift not to exceed 8 inches, and laborers receiving 17½ cents per hour, the contractor would be paid the following prices per linear foot of single track ballasted:

Skeletoning track	2.62c	per	foot
Lifting track	3.50c	"	"
Surfacing and trimming	5.54c	"	"
Total	11.66c	"	"

The above rates would increase or decrease with the rates paid for labor.

Force account, without any additional percentage for supervision or use of tools, was allowed the contractor for work of widening the roadbed where necessary to retain the standard ballast section. Force account was also allowed for putting in any ties renewed during the ballasting operations.

For ballast lifts exceeding 8 inches the contractor was allowed ¾ cent per foot for each inch or fraction of an inch in excess of 8 inches.

The railroad company bore the cost of distributing the ballast and plowing same down, also the cost of road train's service incidental to such work, the above work being done with the company's forces.

Appendix B.

EFFICIENCY OF VARIOUS STONE AND GRAVEL BALLASTS.

Five samples of gravel were obtained and put through various screens and the percentage passing through each screen determined. The "number" of screen referred to in the tests is the size of the mesh; for example, "1/10" inch screen has a size of mesh of one-tenth of an inch. Percentages shown in tests refer to weight. All samples were dry when tested and contained one cubic foot. Photographs in actual size of samples tested accompany this report.

TEST NO. 1.

Railroad "A" (Sample No. 1) Class A Railroad.

Source of Supply—From gravel pit of glacial formation; pebbles forming gravel most of igneous formation. Gravel is washed. No specifications required for screening. Pit owned by private company.

Amount passing through 1/10 in. screen....	25.9 per cent.	(Clean Sand)
Amount passing through ¼ in. screen and retained on 1/10 in. screen...........	28.7 per cent.	(Pebbles)
Amount passing through ½ in. screen and retained on ¼ in. screen	23.7 per cent.	(Pebbles)
Amount passing through 1 in. screen and retained on ½ in. screen	16.3 per cent.	(Pebbles)
Amount retained on 1 in. screen.........	5.4 per cent.	
Total	100.0 per cent.	

Railroad "A" has considerable track ballasted with gravel similar to sample tested and has obtained good results under heavy traffic. Percentage of sand is considered too high for best results.

TEST NO. 2.

Railroad "A" (Sample No. 2).

Source of Supply—Same as Sample No. 1.

Amount passing through 1/10 in. screen.....	9.8 per cent.	(Clean Sand)
Amount passing through ¼ in. screen and retained on 1/10 in. screen	18.6 per cent.	(Pebbles)
Amount passing through ½ in. screen and retained on ¼ in. screen	37.6 per cent.	(Pebbles)
Amount passing through 1 in. screen and retained on ½ in. screen	27.7 per cent.	(Pebbles)
Amount retained on 1 in. screen	6.3 per cent.	
Total	100.0 per cent.	

Sample No. 2 is considered by Railroad "A" much superior to Sample No. 1, and excellent results have been obtained from track ballasted with this gravel. Track put up on the gravel is free from dust.

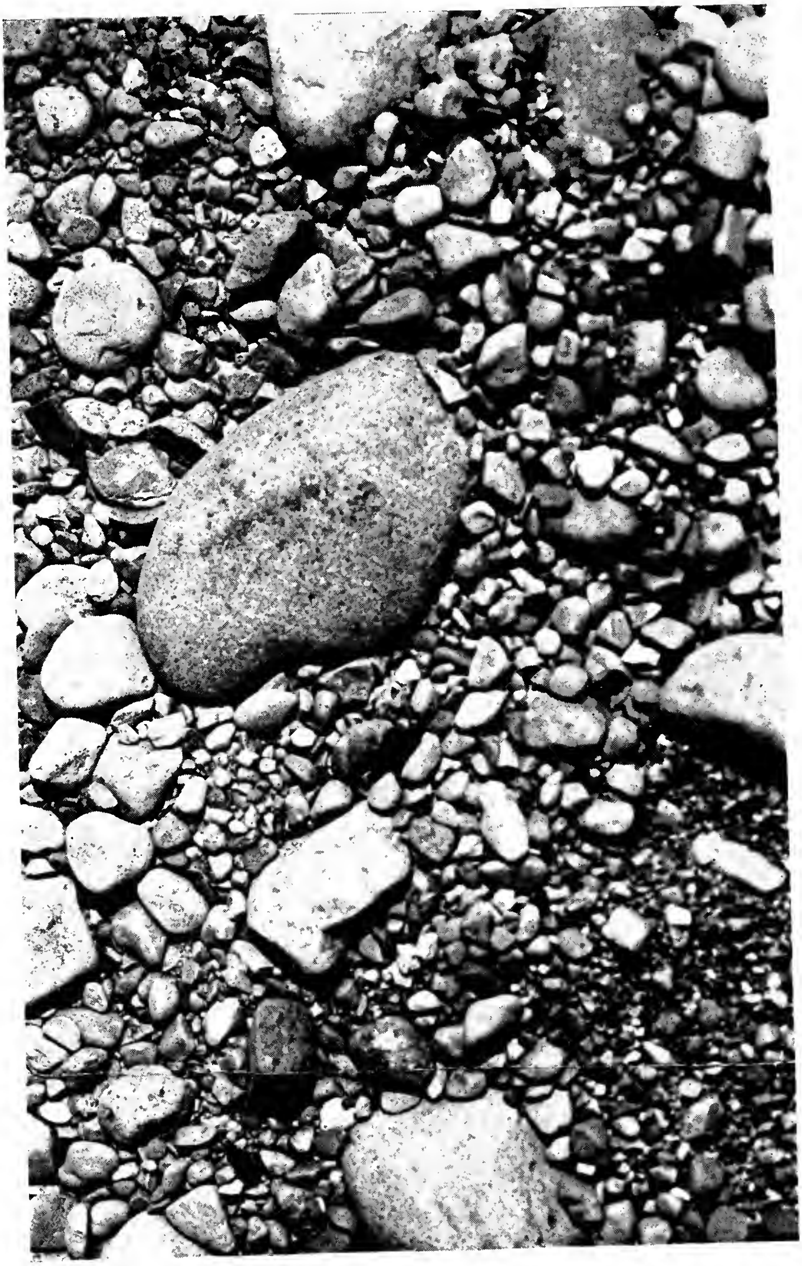


FIG. 27.
Test No. 1—Sample No. 1.
Railroad "A" (actual size).

Fig. 28.
Test No. 1—Sample No. 2.
Railroad "A" (actual size).

TEST NO. 3.

Railroad "B"—Class A Railroad.

Source of Supply—From gravel pit of glacial deposit; pebbles and boulders of igneous formation. Gravel is washed and larger boulders are crushed.

Amount passing through 1/10 in. screen	0.6 per cent.	(Dust)
Amount passing through ¼ in. screen and retained on 1/10 in. screen..............	2.4 per cent.	(Pebbles and Crushed Boulders)
Amount passing through ½ in. screen and retained on ¼ in. screen	19.8 per cent.	
Amount passing through 1 in. screen and retained on ½ in. screen	64.0 per cent.	
Amount retained on 1 in. screen............	13.2 per cent.	
Total	100.0 per cent.	

Road "B" reports that it has considerable track up on ballast similar to this sample, and has secured excellent results in line and surface under heavy traffic. Finer gravel has been used, but gravel like sample tested is much preferred.

Cost per cubic yard, 25 cents f. o. b. pit located along line of railroad.

TEST NO. 4.

Railroad "C"—Class A Road.

Source of Supply—River bed—glacial formation; pebbles of igneous formation. Gravel is washed. No specifications required for screening.

Amount passing through 1/10 in. screen....	26.3 per cent.	(Clean Sand)
Amount passing through ¼ in. screen and retained on 1/10 in. screen..............	48.6 per cent.	(Pebbles)
Amount passing through ½ in. screen and retained on ¼ in. screen	20.4 per cent.	(Pebbles)
Amount retained on ½ in. screen..........	4.7 per cent.	(Pebbles)
Total	100.0 per cent.	

Road "C" reports that it has 25 miles of track ballasted with this gravel, similar to sample, and has secured good results under heavy freight traffic. Track ballasted with washed gravel from same source having less per cent. sand gives better results.

Cost, 30 cents per cubic yard, f. o. b. pit located along line of railroad.

TEST NO. 5.

Railroad "D"—Class A Railroad.

Source of Supply—From gravel pit of glacial deposit; pebbles forming gravel of igneous formation. Gravel is washed. Pit owned by private company.

Amount passing through 1/10 in. screen.....	43.4 per cent.	(Clean Sand)
Amount passing through ¼ in. screen and retained on 1/10 in. screen..............	25.3 per cent.	(Pebbles)
Amount passing through ½ in. screen and retained on ¼ in. screen	15.0 per cent.	(Pebbles)
Amount passing through 1 in. screen and retained on ½ in. screen	12.0 per cent.	(Pebbles)
Amount retained on 1 in. screen............	4.3 per cent.	
Total	100.0 per cent.	

Railroad "D" reports having considerable track ballasted with gravel like the sample tested, and has obtained good results, but prefers coarse gravel with small per cent. of sand, on account of the disagreeable feature from the dust coming from fine gravel.

Cost, 25 cents per cubic yard f. o. b. pit located along line of railroad.

FIG. 29.
Test No. 3.
Railroad "B" (actual size).

FIG. 30.
Test No. 4.
Railroad "C" (actual size).

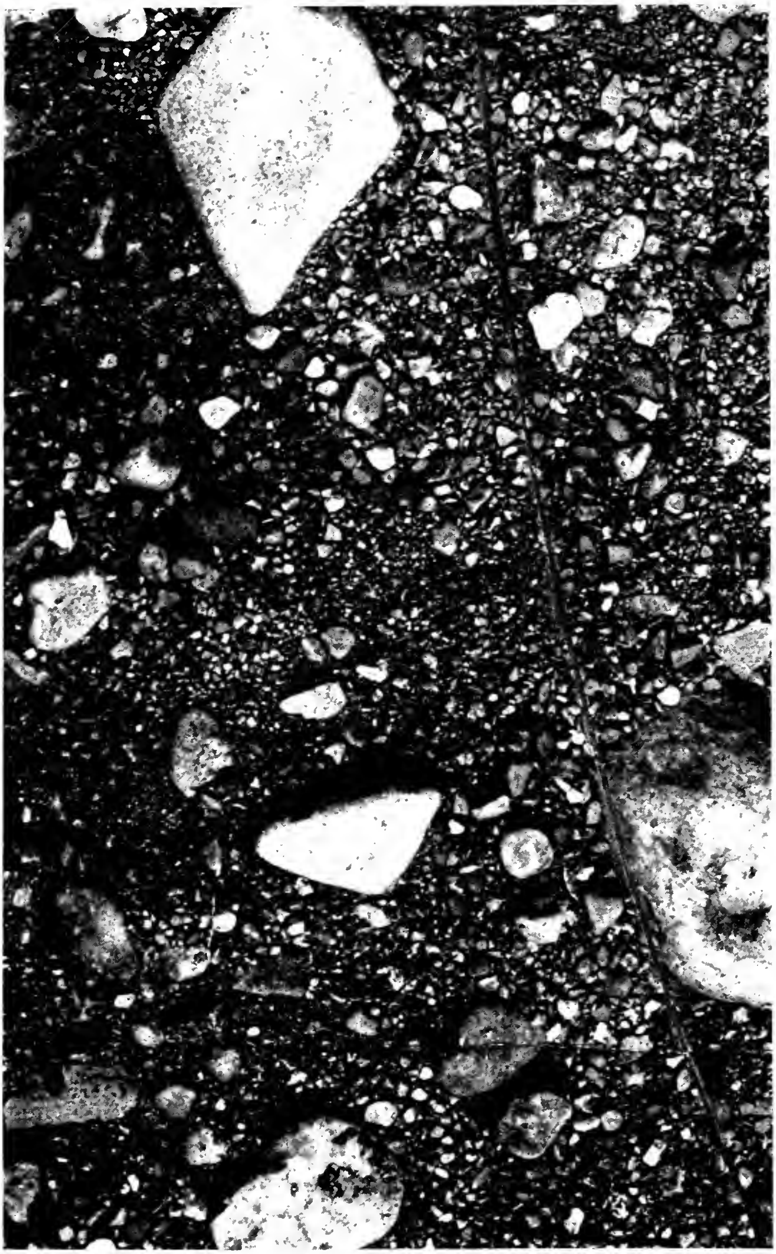


FIG. 31.
Test No. 5.
Railroad "D" (actual size).

Appendix C.

GRAVEL WASHING PLANT—BROOKHAVEN GRAVEL COMPANY, BROOKHAVEN, MISS.

GENERAL OUTLINE OF REPORT.

1. Organization Company.
2. Location of Pit.
3. Character of Deposit.
4. Physical Properties.
    (a) Land,
    (b) Buildings,
    (c) Tracks,
    (d) Equipment.
5. General arrangement and operation of pit.
6. Operation Washing Plant.
7. Estimated cost per cubic yard to wash gravel.
8. General Discussion.

1. Organization Company. Brookhaven Gravel Company, organized and financed by Hibernia Bank of New Orleans. Initial investment made during receivership proceeding, $80,000.00.

2. Location of Pit. Seven and one-half miles northeast of Brookhaven, Miss., with Illinois Central Railroad track connection.

3. Character of Deposit.

(a) 2 ft. to 6 ft. Stripping,
(b) 6 ft. to 8 ft. Cementing Gravel (Sample A),
(c) 30 ft. Railroad Ballast, practically no clay (Sample B),
(d) 2 ft. Sand,
(e) 75 ft. Railroad Ballast, practically no clay (as far as tested),
(f) Washed Ballast (See Sample C).

4. Physical Properties.

(a) The land covers 480 acres and is owned by the Illinois Central Railroad, who purchased it about year 1895 for $37.50 per acre. The Brookhaven Gravel Company hold a 15-year lease on pit, with stipulation in contract that they furnish sand and different classes of gravel to Illinois Central Railroad, loaded on cars at plant, at stated prices per cubic yard.

(b) Buildings—

(1)	Washing Plant (See Exhibit Nos. 6, 2, 8, 9)..	$21,000.00
(2)	Boiler and Engine Room (Sheet Iron, 50 ft. x 60 ft.), estimated cost................	800.00
(3)	Office and Commissary (1 SF, 30x80) (See Exhibit No. 12), estimated cost..........	1,000.00
(4)	Two Water Tanks (8 ft. x 12 ft. x 168, 4 small coal bins), estimated cost	1,500.00
(5)	Six small dwellings (negro), 15x30, about $150 each, and 3 dwellings (white), about $500 each, estimated cost	2,400.00
(6)	One Barn (1 SF 30x40), 4 small sheds, estimated cost	1,000.00
	(Total Cost—See No. 7.)	

(c) Tracks, 10 miles 56 and 60-lb. rail (ties, rail and fastenings in good shape).

(d) Equipment—

(1) 1 Stationary Steam Engine (about 150 HP.).
(2) 3 Small Stationary Steam Engines (about 10 HP.).
(3) 2 Pumps (about 7x12x12).
(4) 3 Centrifugal Pumps (Kingsford, 4x6 inches).
(5) 1 Winch.
(6) 1 Track Scale, 100 tons.
(7) 2 Locomotives, 3-driver and 2-driver.
(8) 2 Locomotive Type Steam Shovels (Atlantic).
(9) 1 Dirt Spreader (Jordan-hand).

5. General Arrangement and Operation of Pit Facilities.

Explanation on sketch A gives detail of manner in which pit is operated at the present time.

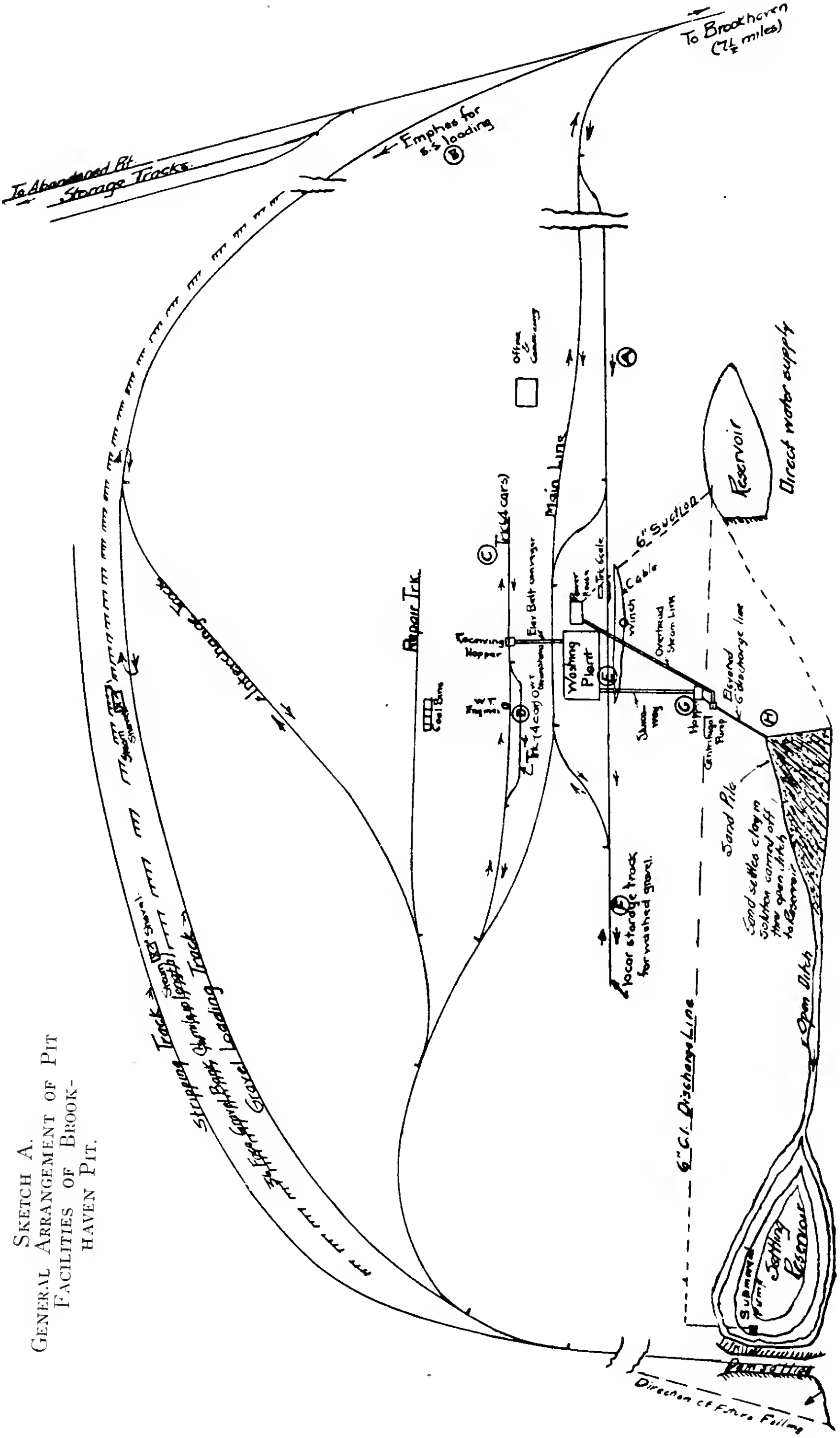
The gravel company has a contract with the Road Commission of Louisiana to furnish cementing gravel for use in road building. With this market for cementing gravel, it enables them to work the shovel used on stripping, to take out full depth of cementing gravel, working the other shovel behind and below first out, taking out railroad ballast. The Illinois Central Railroad accepts for track ballasting, bank run gravel, obtained from this 30 ft. (see Exhibit 6) face, in addition to ballast obtained from washing plant. Exhibit 3 shows the bank after being blasted, which indicates the mixture being loaded.

6. Operation of Washing Plant.

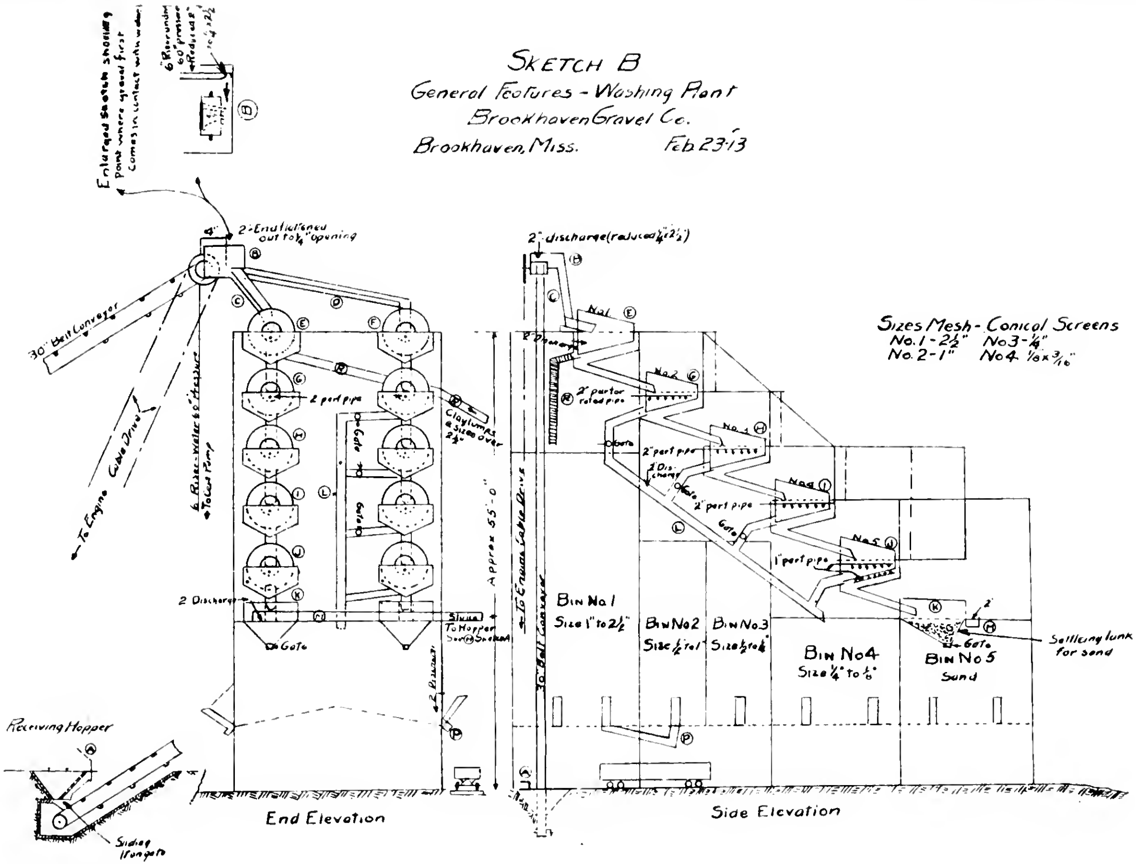
In explanation of sketch A, a bank run gravel is unloaded into receiving hopper. The gravel is then fed to belt conveyor by means of sliding iron gate, controlled by hand lever (A) (see Sketch B). Belt conveyor delivers gravel at point (B), where it leaves belt it is hit by four jets of water under 20 to 40 pounds pressure. The force of these jets is such as to brake the union between the clay and gravel. (This water is obtained by use of 7x12x12 pump drawing from reservoir and discharging through centrifugal pumps (4 in. x 6 in.). The dissimilated mass of gravel, sand and clay is then delivered through chutes (C) and (D) to conical screens (revolving about 20 r. p. m.). As operations are similar, will take one set (5) screens for explanation. At (E) the mass is again struck by 2-inch jet of water fed in direction indicated by arrow. The lumps and boulders (above 2½ inches) are separated at (E) and waste through chute, (R) (1) Exhibit 9, the screened portion passing on to next screen (G), at which point it is again played upon by a spray of water from a 2-inch perforated pipe, running the length of screen. In like manner the screened portion passes on through the remaining screens (A), (I) and (J). At (I) the gravel is all removed, leaving only the water carrying clay in solution and sand in suspense to deliver to settling tank (K). The water striking in this tank releases greater per cent. of sand, the sand settling and the clay in solution passing on via sluiceway (M) (see (2) (Exhibit No. 9) to hopper, whence it is forced by means of a centrifugal pump to final discharge point (see (H) Sketch "A").

By means of connecting chutes, as shown in sketch "B," the various sizes of gravel obtained from screens Nos. 2, 3, 4 and 5 can be separated into individual bins, or if desired can be combined and run into one bin (No. 4). This is the case when concrete or ballast gravel is desired.

When the washed ballast gravel is desired, vertical sliding gates in bins 4 and 5 are opened to feed in proportion to per cent. of sand and gravel required and the mixture loaded into car by means of com-



SKETCH A.
GENERAL ARRANGEMENT OF PIT FACILITIES OF BROOKHAVEN PIT.



SKETCH B
General Features - Washing Plant
Brookhaven Gravel Co.
Brookhaven, Miss. Feb 23 '13

municating chute (B) (Sketch B). To facilitate and make the feed uniform, a jet of water is forced against gravel near gate on inside bin.

The capacity of the plant is 120 yards washed gravel per hour—1,200 yards per ten-hour day.

7. Estimated Cost per Cubic Yard to Wash Gravel.

(a) Estimated daily expense—

Interest on original investment, $80,000, at 6 per cent.	$ 15.00
Maintenance washing plant, $21,000, at 10 per cent.	7.00
Maintenance two steam shovels, $24,000, at 6 per cent.	4.60
Maintenance two locomotives, $20,000, at 6 per cent.	3.80
Maintenance one dirt spreader, $300, at 10 per cent.	.10
Maintenance engines, pumps, etc., $30,000, at 6 per cent.	5.80
Maintenance buildings, water tanks, $6,700, at 10 per cent.	2.10
Depreciation 10 miles 56 and 60-lb. rail and accessories, $20,000, at 10 per cent.	6.40
Depreciation 20,000 ties, $8,000, at 20 per cent.	5.10
S. S. and engine supplies	20.00
	$ 69.90

LABOR.

Crews	$24.00	
2 locomotive engineers	8.00	
2 locomotive firemen	5.00	
2 switchmen (negro)	3.00	
1 stationary engineer	3.00	
1 winch operator	2.00	
1 centrifugal pump operator	2.00	
1 master mechanic	5.00	
4 laborers washing plant	8.00	
2 laborers unloading gravel	2.50	
1 track foreman	2.50	
16 laborers, $1.25	20.00	
1 weighman	3.00	
Local office force—		
Chief clerk and bookkeeper	6.00	
General supervision	25.00	
		119.00
Estimated total daily expenses		$188.90

(b) Working capacity, 1,200 cubic yards day for $188.90 equals 15.7c per cubic yard.

Taking average 1,000 cubic yards day for $188.90 equals 18.9c per cubic yard.

The material the Brookhaven company are washing contains about 50 per cent. clean gravel, sample (B), consequently giving a cleaner grade of washed gravel than that which would be obtained from a material composed entirely of a cementing gravel (sample A).

The washed gravel accepted by the Illinois Central Railroad for ballast runs from 25 to 35 per cent. sand.

This plant at present has no crusher to crush large stones, but if there were enough large stones in a pit to warrant it, a crusher could be added at small cost.

REPORT OF COMMITTEE V—ON TRACK.

J. B. Jenkins, *Chairman;*
Geo. H. Bremner,
H. M. Church,
Garrett Davis,
W. R. Dawson,
J. M. R. Fairbairn,
A. L. Grandy,
G. W. Hegel,
T. H. Hickey,
E. T. Howson,
L. J. F. Hughes,
E. L. Ingram,
T. T. Irving,
J. R. Leighty,

G. J. Ray, *Vice-Chairman;*
H. A. Lloyd,
A. C. Mackenzie,
P. C. Newbegin,
F. B. Oren,
R. M. Pearce,
F. W. Pfleging,
H. T. Porter,
E. Raymond,
W. G. Raymond,
L. S. Rose,
H. R. Safford,
C. H. Stein,
A. H. Stone,

Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Track respectfully submits its report to the seventeenth annual convention.

Meetings of the whole Committee were held in Chicago on May 23 and November 12, in addition to the meetings held by the various Sub-Committees.

In addition to the seven subjects assigned by the Board of Direction at the beginning of the year, your Committee was requested by the President to co-operate with Mr. Hegel of the Chicago Junction Railway Company in making tests of tie plates subject to action of brine drippings. This was taken up as subject No. 8, and in furtherance of the investigation Mr. Hegel's name was added to the membership of the Track Committee.

REVISION OF MANUAL.

Sub-Committee No. 1.

W. G. Raymond, *Chairman;*
E. T. Howson,
L. J. F. Hughes,
E. L. Ingram,
J. R. Leighty,

A. C. Mackenzie,
G. J. Ray,
H. T. Porter,
H. R. Safford,
C. H. Stein.

Your Committee has made a critical examination of the subject-matter of the chapter on Track in the Manual, and considers, in view of the thorough and comprehensive revision which was made last year, that no further changes should be recommended until after the new edition of the Manual has been published.

ECONOMICS OF TRACK LABOR.

Sub-Committee No. 2.

H. R. Safford, *Chairman;*	E. T. Howson, *Vice-Chairman;*
Geo. H. Bremner,	A. C. Mackenzie,
H. M. Church,	P. C. Newbegin,
Garrett Davis,	F. B. Oren,
W. R. Dawson,	W. G. Raymond,
J. M. R. Fairbairn,	C. H. Stein,
A. L. Grandy,	A. H. Stone.

This report is necessarily one of progress only, because the magnitude of the subject, undertaken by the Committee this year, is such that we can report only having started, in a systematic way, to collect data from test sections which will form a basis for the Committee's subsequent study.

The Sub-Committee has had three meetings, which were fairly well attended, the last taking place at Montreal on September 13.

The work which the Committee has done this year may be briefly stated as follows:

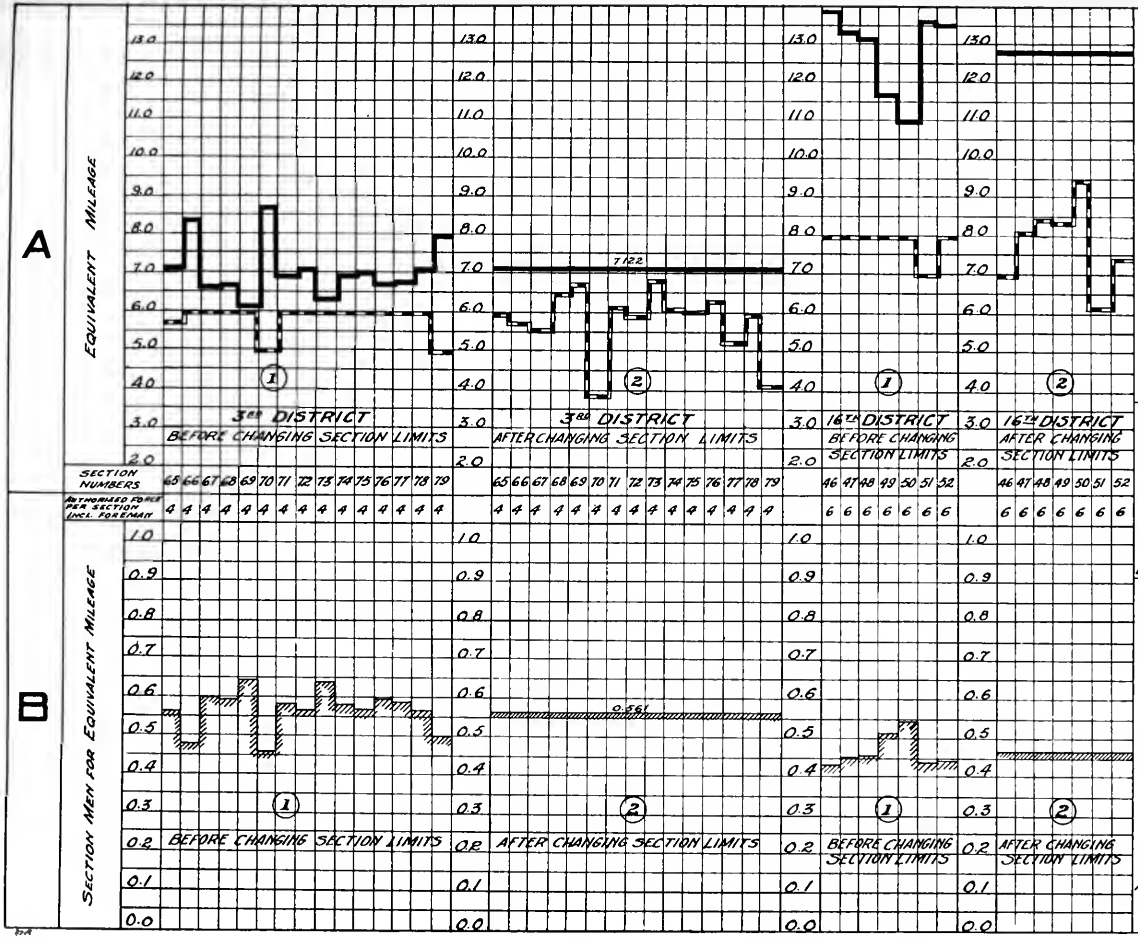
(1) It has received from eighteen railroads very good data in the form of records of test sections, which data has now extended over a period of twelve months. This data has been submitted in accordance with the form prepared last year and placed in the hands of the members of the Association.

(2) The Sub-Committee sent out, under date of August 19, through Secretary Fritch, a further appeal to not only the railroads which had signified their intention of co-operating, and which have kept the desired record for a year, but to a number of other roads which we had not been able heretofore to interest, and we are hoping that our appeal will bring forth good results. Attached to this report is a copy of the circular letter above referred to.

(3) The Sub-Committee prepared a chart, a copy of which is attached hereto, outlining a suggested method of analyzing results of track sections. This chart enabled a relationship to be established between units of labor performed and the physical characteristics.

The Sub-Committee, at its meeting in Montreal, on November 13, decided to divide the results of the years 1914-15, which have been submitted by the railroads keeping test sections, among the various members present; each one will take the records of certain roads and make an analysis of the results, and, at the next meeting of the Sub-Committee these results will be discussed and an effort made to reach some conclusion, but it may be expected that another year's record should be taken of these test sections before any tangible results can be reached, owing to the numerous factors which enter into this problem and which vary from year to year.

It is felt by the Sub-Committee that the first step to be taken in analyzing the test section records will be with the view to establishing values of certain physical characteristics, expressed in units of labor or



Equated Track Mileage Value

1½, Miles of Passing Track = 1 Mile of Main Track
2, All other Sidings = " " " "
10, Switches = " " " "
12, Derails (Interlocked) = " " " "
10, Single Rail Crossings = " " " "
4, Interlocked Rail " = " " " "
15, Highway " = " " " "
Light Rail Add 0.2 per Mile of Main Track
High Speed. 0.1 " " " "
Heavy Traffic- 0.1 " " " "

CHART SHOWING GRAPHICALLY, METHOD AND RESULTS IN CONNECTION WITH THE STUDY OF EQUATING TRACK SECTIONS AND EQUALIZING DISTRIBUTION OF TRACK FORCES.

DEVELOPED BY TRACK COM.—AM. RY. ENGR. ASSN.

This Chart is Based upon Summer Force Allowance

Diagrams "A" Represent Equated Mileage of Main Track Sections

"B" Represent the Summer Force in Men per Mile of Equated Track

① A&B Show Equated Mileage & Summer Force before Changing Section Limits

② A&B Show Equated Mileage & Summer Force after Changing Section Limits

Equivalent Mileage of Section Shown ▬▬▬
Miles of Main Track " ▬ ▬ ▬
Authorized Force (men per Equated Mile) " ▨▨▨

man-hours. After this feature has been covered, the next step would seem to be the application of these results to the subject of adjusting section lengths.

Out of this second subject will naturally spring a study of the situation for the purpose of establishing, on a broader basis, a method of apportioning maintenance of way expenses with reference to larger districts, special attention being given to the matter of attempting to work out values with reference to traffic and climatic conditions. In other words, the problem will be to attack the whole question in a logical manner, starting with the simplest factors.

One of the railroads, represented on the Sub-Committee, has already undertaken to make a systematic study of the subject of establishing proper lengths of sections, by making allowance for the various things which influence expenditure of labor. The attached chart (page 371) shows the method by which this matter was taken in hand. Of course, certain assumptions were made in this particular instance, as indicated in the upper right-hand corner of the chart, which may be found inaccurate when the conclusive work of the Committee has been finished, but granting that they may not be entirely correct, the application of them will certainly yield some result in the way of a more equitable distribution of labor between the various sections. The chart is self-explanatory and needs no further discussion, and is submitted merely as information, hoping that it may stimulate interest in this general subject.

As to the work of the Sub-Committee for next year, it would recommend that it be permitted to continue the subject in hand, without taking on any other work, as the Sub-Committee is becoming more and more impressed with the magnitude of the subject and feels that all of its time can well be devoted to it.

CIRCULAR TO ROADS NOT REPORTING SPECIAL RECORD TRACK SECTIONS.

Chicago, Ill., August 19, 1915.

Dear Sir:—About a year ago the Track Committee undertook a special study of the subject of equating track values and for that purpose prepared a special form on which such data was to be kept. Eighteen railroads responded to the request of the Committee and have kept this data on about 65 sections during the past year. Your road is not submitting this information and the Committee again renews its appeal for co-operation, believing that the benefits which have been and will be obtained will result in considerable value to all officers interested in track maintenance.

It may interest you to know something of the progress of the Committee's work. It now proposes to start an analysis of the information received to date in the manner indicated in the attached print, preparing a chart for each test section, which it is felt will clearly and conveniently show the information needed to determine the relative value of the more important factors in the problem. You will note this chart shows the actual number of hours of labor spent for each feature for the twelve-month period. It also shows the physical characteristics of the particular section under test. The analysis of this data will give a basis for equating the physical characteristics of the test sections in terms of equivalent miles of main track.

In this connection it may be of interest to note a chart which has been developed by one of the railroads, represented on the Committee, which shows the situation on two of its important lines as regards the distribution of labor, the actual length of sections and the ratio of labor to such matters as length of sidetracks, number of railroad crossings, highway crossings, number of switches, etc. It is illustrative of the irregularities which are found in the distribution of section forces without sufficient allowance being made for the above-mentioned conditions, and it is assumed that this chart is fairly representative of such conditions on most railroads.

On this chart is indicated the assumed basis for equating the physical characteristics, and the application of this basis developed a great many irregularities in ratio of forces employed to equivalent miles of main track. These differences called for special investigation, and it was found that in a number of instances the limits of the sections could be changed so as to give a consistent ratio of forces employed to equivalent miles.

The Committee hopes that you will see your way clear to have this record of test sections kept on your lines, feeling that the results of the Committee's work will be of value to your line as well as to the railroads in general. In this connection, it is interesting to note that one railroad has already found this record to be of great value in developing certain data in connection with an important rate case.

I am enclosing a copy of the special form and will be pleased to send you further supply should you undertake to compile this data.

Yours very truly,
(Signed) E. H. Fritch,
Secretary.

RELATION BETWEEN WORN FLANGES AND WORN SWITCH POINTS.

Sub-Committee No. 3.

C. H. Stein, *Chairman;*	H. A. Lloyd,
Geo. H. Bremner,	P. C. Newbegin,
W. R. Dawson,	F. W. Pfleging,
E. L. Ingram,	H. T. Porter.

The subject assigned was, "Study the relation between worn flanges and worn switch points with a view to correcting the causes and decreasing the number of derailments due to the combination of worn switch points and worn flanges on wheels."

Your Committee has been conducting some investigations since this work was assigned us on June 3, 1915, and during the period to date we have examined at least a thousand switch points, in order to determine if the proposed rule suggested by the Committee last year was adaptable to the conditions, and would result in determining whether a switch point had reached the condition where it should be removed from the track.

The rule as suggested was as follows:

A switch point should be removed when it is so worn that the greatest distance from the worn switch point to a straight line 24 in. long from any point on the gage line of the switch rail to a point on gage line of the stock rail equals ½-in.

We have applied this rule to a number of badly worn switch points, which had reached the condition where it was necessary to remove them from the track. In no single case had the application of the aforesaid rule indicated that it was necessary to remove these points from the track. As a matter of fact, however, the condition had been reached where it would have been undesirable to allow these points to remain in service any longer.

An alternative rule proposed by Mr. Leighty read as follows:

When the line of wear makes an angle with the gage line projected, equal to, or gretaer than, "A" = ½-in., "B" = 8 in., the point shall be removed.

The application of Mr. Leighty's rule works out no better than that suggested by the Committee.

There came under observation a certain switch point on the inside of an approximately 9-deg. curve with 6 in. of elevation, where it was very difficult to keep an engine or car on the track after the switch point had been in the track but a very few months. The application of the Committee's alternative 24-in. rule to this situation did not show that the point should come out of the track. You will note that on a 2-ft. chord, the offset, or middle ordinate, was only ¼-in.; on a 4-ft. chord, however, it was ½-in., as nearly as measurements could be taken. This switch point, however, was in such shape that it had to be removed from the track in this particular location. In hundreds of other locations, however, this switch point would have lasted for months, or even for years. In the case of this particular point, even a perfect wheel would not adjust itself to the turnout curve without climbing over the point at a definite and fixed location.

It is therefore apparent that the degree of wear that subjects a switch point to removal differs for every known condition. There are so many more or less vital factors involved and to be considered in the determination of any fixed rule as to the safe limit of wear upon a switch point, that it is our belief that any such general rule might be easily outweighed or lost in the preponderance of exceptions and assumptions.

Generally, track conditions and certain contributary defects of equipment, not practicable to eliminate for the time being at least, must, to an undefined point, be taken into practical account in determining the limit of wear. As observed, the switch point is in a sense a fixed object, subject to frequent and easy inspection, while passing wheels are moving objects, subject to long trips over home or foreign roads, and subject also to insufficient or perhaps indifferent examination and liability of worn or sharp flanges, imperfect tram, bent axles, or stiffly rotating or rigid trucks, all of which points have a bearing upon the car safely passing over the switch point.

The M. C. B.'s rule fixes within certain limits the permissible flange wear, as well as the gage of wheels, and the combination of a partly worn wheel and a partly worn point, with or without a modifying or contributary condition, may or may not result in a derailment. It is fair to assume that generally, where a switch point approaches the limit of permissible wear, the balance of the switch lead or main track portion thereof is measurably worn, and that factor such as gage of track, gage of wheels, wheel centers, track centers, or rigid wheel base, wheel loading, condition of loading, freedom of rotary motion of the truck or trucks, curvature, superelevation, etc., tending to increase or decrease the side pressure of the flanges or the vertical loading, also contribute in assisting the wheels to mount the point. This may be further modified by the speed of the car, train or engine, the stiffness of the rail and the nature of the service the switch is supposed to perform. In fact, there does not seem to be any theoretical basis upon which a definite rule could be established, and the practical tentative rule of a ½-in. ordinate, in 24-in. chord, as the limit in any position throughout the lead along the gage line seems sufficiently general and practical to cover ordinary conditions. On the other hand, there are ample cases where even this limit would not be permissible, and certain conditions where the limit might be safely increased. It makes a very great difference whether the switch lead is from a straight main track or from the high side, or to the low side of the curve, as well as the degree of curve and the switch angle and frog angle. Also whether switch leads from a lateral track or from a base line or yard track.

It might be safe for the service intended and generally used in a yard, but not safe for certain classes of road engines which may never be called upon to use the switch, owing to condition of curvature or clearances.

In high-speed tracks no element of risk may be taken nor made, nor is economy considered, while for laterals or yard tracks under slow speed, more reasonable wear, without undue risk, may be obtained, taking consideration of the nature and frequency of the service, intricacy of track system, power employed, etc.

It is our opinion that it is going to be impossible to formulate any rule that will, even in a remote sense, cover the conditions aimed at. As in the past, it is going to be necessary for us to rely upon the judgment of the track foreman and supervisor to determine when a switch point in a given location has reached the point where it must be removed from the track. Any rule that we might adopt would doubtless lead to extravagance in some directions and entire neglect to prevent accidents at others. The latter fact being due to the necessity in any case of taking into consideration the local conditions obtaining.

Your Committee recommends that it be relieved from further consideration of the subject.

SPECIFICATIONS AND DESIGNS FOR CUT- AND SCREW-SPIKES.

Sub-Committee No. 4.

G. J. Ray, *Chairman;*	T. T. Irving,
H. M. Church,	F. B. Oren,
Garrett Davis,	R. M. Pearce,
J. M. R. Fairbairn,	E. Raymond.

The subject assigned to this Committee was, "Review specifications and present designs for cut- and screw-spikes."

A circular letter was sent to roads represented in the Association to ascertain the extent to which the Association's specifications have been used in the purchase of the spikes and for the further purpose of securing information as to recommended changes in the specifications and designs for both cut- and screw-spikes and data concerning dimensions and specifications of screw-spikes now in use. A tabulated statement of the replies received is presented herewith.

CUT-SPIKES.

From the tabulated list of replies received from the members, it will be noted that but two or three of the roads reporting are using the American Railway Engineering Association specification for cut-spikes. A careful investigation of the general points in the specifications in use shows that these specifications are not materially different from the American Railway Engineering Association specifications.

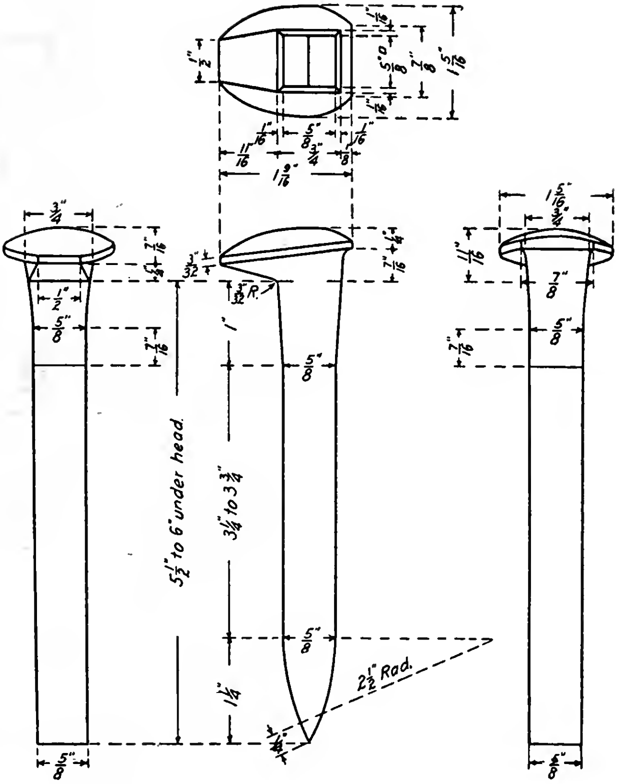
The latter specification was adopted by the American Railway Engineering Association after careful study of a similar set of replies from the members of the Association. Your Committee does not at this time see any good reason for changing the present standard specifications other than to make a few minor changes which will not materially affect the adopted standard. We submit herewith design for a cut-spike, which we recommend as a standard to be adopted by the Association.

The head of the cut-spike is designed to take the blow of the hammer directly over the axis of the spike and thus minimize the damage to spike-heads and danger of breaking the head off during very cold temperatures.

The tilting downward of the nose gives a stronger, more rugged construction, and assists in giving an easier clearance in the spike machine. It also permits the pulling of the spike more readily with the clawbar.

The reinforcement is symmetrical; that on the back of the neck having been used originally as it now is with many roads to force the spike forward against the base of the rail when driving, but we have added the reinforcing on the front of the neck in order to give additional metal to withstand rail wear and necking of spikes, which has been prevalent with the old flat plate.

It is required that the physical test be made on the finished spike. There seems to be a tendency to have the test made on the bars from



Proposed American Railway Engineering Association Standard Cut Track Spike.

TABULATED REPLIES—CUT SPIKES.

Company or Organization	Official Reporting and Title	SPECIFICATIONS		PHYSICAL PROPERTIES AND TESTS								STANDARD SIZES				Ties Bored		REMARKS
		Area specifications	Changes recommended and contemplated	Ultimate strength not less than	Elastic limit not less than	Elongation not less than	Reduction of area	Action of material	Action of spike	O. H. or Bess.	Sulphur Carbon etc.	Size of body	Length over all	Shape of point	Shape of head	Treated	Untreated	
1. Nashville, Chattanooga & St Louis........	Hunter McDonald, Chief Eng.	No	None	54,000-64,000	½ ultimate strength	25% meas. in 8"	Steel with ult. str. over 64,000 not less 26% in 8"	180° without fracture	Head flattened in direction of length without fracture	Soft Bess.	....	9-16"	5½"	Standard		Yes, when used	No	*Expect to adopt A-R-E-A specifications. No treated ties except on bridges.
2. Duluth & Iron Range........	W. A. Clark, Chief Engineer	No	None	....	....	....	....	....	....	....	....	9-16"	5½"	Chisel	1 7-16" x 1¼"*	Not used	No	*Ill. Steel standard.
3. Chicago & Alton	H. T. Douglas, Jr., Chief Engineer	No Harriman Lines Std. 1004	None	55,000-65,000	....	25% in 8"	....	....	Bent flat on themselves without fracture	....	....	9-16"	5¾"	Chisel	1 7-16" x 1 3-16"	Not used *	No	*If ties were treated would have them bored.
4. Cleveland, Cincinnati, Chicago & St. Louis	Hadley Baldwin, Asst. Chief Eng.	No	....	55,000-65,000	....	25% in 8"	....	....	180° rad. ⅝" without fracture	Soft steel	Carbon not over .15%	⅝"	6 1-16"	Chisel	1 7-16" x 1⅝"	....	......	*If wrought iron not less than 55,000#. Elong. not less than 18% 8". Heads bent backwards shows firm join to body.
5. Missouri, Kansas & Texas......	L. F. Lonnbladh, Chief Engineer	Recommended for adoption	....	....	....	....	....	....	....	....	....	9-16"	5½"	Chisel	....	....	......	Manufacturer's standards.
6. Canadian Pacific	J. M. R. Fairbairn, Asst. Chief Eng.	No	....	50,000-70,000	½ ultimate	20% in 8"	Not less than 55% at point of fracture	....	180° flat on itself without fracture	....		......	....	....	....	....	......	*Carbon .12 to .25%; Mang. not over .50%; Silicon .05; Phos. .04; Sul. .04.
7. Denver & Rio Grande.......	A. O. Ridgway, Chief Engineer	No	None	55,000-65,000	....	25% in 8"	....	....	180° flat on itself without fracture	....	....	⅝"	6"	Chisel	1⅝" x 1⅜"	Not used	No	
8. Pennsylvania Lines West....	Robert Trimble, Ch. Eng. M. W.	....	....	55,000 *	½ ultimate	1,500,000 Ultimate tens. in 2"	Not less than 40% at point of fracture	....	180° flat on itself without fracture	....	....	⅝"	6⅝"	Chisel	1½" x 1 5-16"	....	......	*Basic O. H. Phos. not over 0.05%.
9. Central of New Jersey......	Jos. O. Osgood, Chief Engineer	....	....	52,000	....	35% in 2"	....	....	....	....	....	⅝"	6"	....	....	....	......	
10. Norfolk & Western..........	J. E. Crawford, Chief Engineer	No	Ulti. strength should be specified between two limits-spike may be too hard	54,000-64,000	....	25% in 8"	....	....	180° flat on itself without fracture	O. H.	Carbon not over .15%	⅝"	6"	....	1 5-16" x 1½"	....	No	At some points, heads become so corroded that more metal may be advisable in the head.
11. Northern Pacific	W. L. Darling, Chief Engineer	....	....	55,000	½ ultimate	20% in 2"	Not less than 40% at point of fracture	....	180° flat on itself without fracture	O. H.	....	9-16"	6"	Chisel	1 7-16" x 1 3-16"	....	......	
12. Pere Marquette	A. L. Grandy, Chief Engineer	....	....	....	....	....	....	....	....	....	....	9-16"	5½"	....	....	....	No	Manufacturer's standard.
13. Chicago, Burlington & Quincy...	T. E. Calvert, Chief Engineer	No	Prefer Illinois Steel specif.	54,000-64,000	½ ultimate	25% in 8"	....	....	180° flat on itself without fracture	Soft Bess.	Carbon not over .15%	⅝"	5½"	Chisel	....	....	......	
14. Indiana Harbor Belt........	....	No	No															

15. Maine Central	G. F. Black, Eng. M. W.	No	......	54,000-64,000	½ u'ti-mate	......	......	......	180° flat on itself without fracture	......	......	9-16" 9-16"	5½" 5½"	Chisel Goldie	1¼" x 1 7-16" 1¼" x 1½"	...... Not used	No No	
16. New York, Ontario & Western......	J. H. Nuelle, Chief Engineer	No	Ult. strength not less than 60,000	60,000	½ u'ti-mate	20% in 2"	Not less than 40% at point of fracture	......	180° flat on itself without fracture	O. H.	......	⅝"	6"	Chisel	......	......	No	
17. Cleveland, Cincinnati, Chicago & St. Louis Peoria & Eastern	E. S. Rose, Val. Engineer	No	No	......	......	......	......	......	......	......	......	⅝"	5¾"	Goldie	1½" x 1⅜"	......	No	Spikes purchased apparently satisfactory to specifications mentioned. Have used Goldie spike for several years.
18. Rock Island...	Garrett Davis Division Eng.	No	No	55,000-65,000	......	25% in 8"	......	......	180° flat on itself without fracture	Ill. Steel standard	......	9-16" x ⅝"	5 13-16" x 6 1-16"	......	Plain hook	......	No	
19. Erie.........	......	No	No	60,000-70,000	½ ultimate	20% in 8"	......	......	180° over bar of same size without fracture	Medium steel	......	9-16"	5½"	Chisel	1 7-16" x 1 3-16"	......	No	No ordinary spikes in treated ties.
20. Boston & Albany	F. B. Freeman, Chief Engineer	No	......	55,000-65,000	......	25% in 8"	......	......	180° rad. ⅝" without fracture	Soft steel	Carbon not over .15%	⅝"	6 1-16"	Goldie	1⅝" x 1 7-16"	......	No	If wrought iron is used, tensile strength not less than 50,000 and elongation 18% in 8".
21. El Paso & Southwestern......	J. L. Campbell, Eng. M. W.	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	Standard goods used.
22. Duluth, Winnipeg & Pacific.	J. L. Pickles, Chief Engineer	No	No	......	......	......	......	......	......	......	......	......	......	......	......	......	No	Standard goods used.
23. St. Louis Southwestern......	C. D. Purdon, Chief Engineer	No	No	See Carne	gie catal	ogue	......	......	......	......	......	9-16"	5½"	Chisel	Hook	......	No	Think point could be improved.
24. Carolina, Clinchfield & Ohio.	Ward Crosby, Chief Engineer	No	No	......	......	......	......	......	......	......	......	⅝"	6"	Chisel	1⅝" x 1⅜"	......	No	
25. Western Maryland.........	G. H. Friend, Division Eng.	No	No	Mild Steel	—Manuf	acturer's s	pecifications	......	......	......	......	⅝"	6"	......	1 9-16" x 1¼"	......	No	
26. Elgin, Joliet & Eastern......	A. Montzheimer, Chief Engineer	No	Specifications good	......	......	......	......	......	......	......	......	9-16"	5½ under head	Chisel	1 7-16" x 1¼"	......	No	
27 Chicago Great Western......	C. G. Delo, Chief Engineer	......	......	......	......	......	......	......	......	......	......	9-16"	5½"	......	......	......	......	
28. Pennsylvania Lines West...	W. C. Cushing, Ch. E. M. W	......	......	See Penna	Lines	N. W. ab	ove	......	......	......	......	......	......	......	......	......	......	
29. Richmond, Fredericksburg & Potomac	S. B. Rice, Eng M. W.	Yes	No	See A-R-	E-A spe	cifications	......	......	......	......	......	⅝"	5⅝"	......	1 9-16" x 1 5-16"	......	No	
30 Lehigh & New England	......	Yes	No	......	......	......	......	......	......	......	......	⅝"	5½"	Chisel	Oval	......	No	
31. Seaboard Air Line...	W. D Faucette, Chief Engineer	No*	No	......	......	......	......	......	......	......	......	9-16"	5½"	......	1⅜" x 1¼"	Not used	No	Expect to adopt A-R-E-A providing for wrought iron
32 Northern Pacific	A. M. Burt, Ch. E. M. W	No	No No changes contemplated	See N. P	above.	......	......	......	......	......	......	......	......	......	......	Yes before treated	No	
33. Grand Trunk...	M. S. Blaiklock, Eng. M. W	......	No changes contemplated	60,000	50% ultimate strength	22% in 2"	Not less than 40%	......	180° on itself without fracture	O. H.	Phos.-Sul. not over .05%	9-16"	6⅛"	Chisel	1¼" x 1 7-16"		No	*Head bent back cold to show no sign of fracture. Body twisted 1½ turns
34 Canadian Pacific	John G. Sullivan, Chief Engineer	......	No No changes contemplated	......		......						9-16"	6⅛"	Chisel	1¼" x 1½"			*We have bored and adzed some treated ties

TABULATED REPLIES—CUT SPIKES—Continued.

Company or Organization	Official Reporting and Title	SPECIFICATIONS		PHYSICAL PROPERTIES AND TESTS								STANDARD SIZES				Ties Bored		REMARKS
		Area specifications	Changes recommended and contemplated	Ultimate strength not less than	Elastic limit not less than	Elongation not less than	Reduction of area	Action of material	Action of spike	O. H. or Bess.	Sulphur Carbon etc.	Size of body	Length over all	Shape of point	Shape of head	Treated	Untreated	
35. Bingham & Garfield......	H. C. Goodrich, Chief Engineer	C. F. I. standard	No No changes contemplated	......	......	......	......	......	......	......	......	9-16"	5½" x 6"	V	Oblong	.....	No	
36. Virginian ...	......	No	No changes contemplated	55,000-65,000	50% ultimate strength	25% in 8"	......	......	180° on itself without fracture Heads bent back	Soft steel	......	⅝"	6"	Goldie	......	......	No	
37. San Antonio & Aransas Pass..	H. H. Temple, Supt. M. W.	......	No	......	......	......	......	......	......	......	......	9-16"	5½"	Wedge	......	......	No	
38. Pittsburgh Lake Erie.....	J. A. Atwood, Chief Engineer	No	No	55,000-65,000 Wrt. Irn. 50,000	......	25% in 8" W.I. 18% in 8"	......	......	Bend 180° on ⅝" rad. without fracture	Soft steel	Car. not over 0.15%	⅝"	6 9-16"	Chisel	1⅝" x 1 7-16"	Yes	......	
39. Rock Island ...	C. A. Morse, Chief Engineer	No	None	55,000-65,000	......	25% in 8"	......	......	Bend 180° on itself without fracture	......	......	⅝"	6 7-16"	Chisel	1 5-16" x 1½"	Yes*	......	*Also adze ties to the amount of 750,000 per year-or the output of one machine.
40. Queen & Crescent	Curtis Dougherty Chief Engineer	No	No None	55,000	50% ultimate strength	20% in 2"	Not less than 40%		Bend 180° on itself without fracture*	O. H	......	⅝"	6"	Chisel	1 5-16 x 1½"	......	No	Twisting cold 1½ turns. Must show no sign of fracture.
41. New York, New Haven & Hartford	W. J. Backes, Eng. M. W.	No, but very similar	Yes, as tracing sent out for approval	55,000	50% ultimate strength	20% in 2"	Not less than 40%	......	Bend 180° on itself without fracture	O. H.	......	......		Chisel	......	......	No	*5 13-16", 6 5-16", 7 3-16".
42. Lake Erie & Western .	J. K. Conner, Chief Engineer	N. Y. C. lines standard	No None	55,000-65,000	......	25% in 8"	......	......	Bend 180° on ⅝" rad. without fracture	Soft steel	Not over 0.15 car	⅝"	6 1-16"	Chisel	1⅝" x 1 7-16"	No	No	Head bent back cold to show no sign of fracture. If W. I. is used tensile strength no less than 50,000# Elong. 18% io 8".
43. Lake Shore & Michigan Southern ...	G. C. Cleveland, Chief Engineer	N. Y. C. lines standard	No None	55,000-65,000	......	25% in 8"	......	......	Bend 180° on ⅝" rad. without fracture	Soft steel	Not over 0.15 car.	⅝"	6 1-16"	Chisel	1⅝" x 1 7-16"	No	No	Head bent back cold to show no sign of fracture. If W. I. is used tensile str. not less than 50,000, Elong. 18% in 8"
44. Baltimore & Ohio	Earl Stimson, Eng. M. W.	No By O.R.R. Spec. No. 58 B	......	50,000-65,000	......	25% in 8"	......	......	180° on itself without fracture	......	......	⅝"	6"	Chisel	1½" x 1 5-16"	......	......	Head bent back to show no sign of fracture.
45. Western Maryland..........	M. C. Byers, Asst. to Pres.	No	No None	......	......	......	......	......	......	......	......	⅝"	6"	Chisel	1¼" x 1 9-16"	......	......	Manufacturer's specifications.
46. Boston & Maine.	F. A. Merrill, Eng. M. W.	No-Goldie	No None	......	......	......	......	......	......	......	......	19-32"	5¾"	Goldie	1¼" x 1½"	......	No	
47. Norfolk & Western	W. R. Dawson, Ast. to Gen. Man.	No. Use a forged steel	No	......	......	......	......	......	......	......	......	⅝"	6"	Chisel	1½" x 1 5-16"	......	No	
48. Texas & Pacific.	C. H. Chamberlain, Chief Eng.	*	No	......	......	......	......	......	......	......	......	9-16"	5½"	Chisel	Standard	......	No	
49. Delaware, Lackawanna & Western.....	G. J. Ray, Chief Engineer	Yes	No	55,000	50% ultimate strength	20% in 2"	Not less than 40%	180° without fracture	......	O. H.	......	⅝"	6"	Chisel	......	Yes	......	

which spikes are manufactured; therefore, we recommend the following changes in the Specifications for Ordinary Track Spikes:

PHYSICAL PROPERTIES AND TESTS.

Present.	Proposed.
Elongation, not less than 20 per cent. in 2 in.	Elongation, not less than 20 per cent. in 2 in., or if test is made on bar, 25 per cent. in 8 in.
When the head of the spike is bent backward cold, it shall show no signs of fracture.	When cold, the head of the spike must bend backward till the underside is in line with the body without sign of fracture.

WORKMANSHIP AND FINISH.

Present.	Proposed.
The length under the head shall not be less, nor over one-quarter (¼) of an inch more, than the dimension shown.	The length under the head shall not be less than the dimension shown, nor shall it be greater than one-quarter (¼) of an inch more.

SCREW-SPIKES.

From the replies received from the members of the Association, and from our study of the specifications for screw-spikes formerly adopted, we do not feel warranted in recommending any changes whatever in the present specifications.

We submit herewith a design for a screw-spike which we believe the Association will be warranted in adopting as a standard. This form of spike is now in use by two or three roads making more or less use of screw-spikes and, so far as information is available, they have given satisfactory results.

It will be noted that the distance from the underside of the head to the beginning of the thread is variable. This distance will vary with the thickness of the tie plate and rail base.

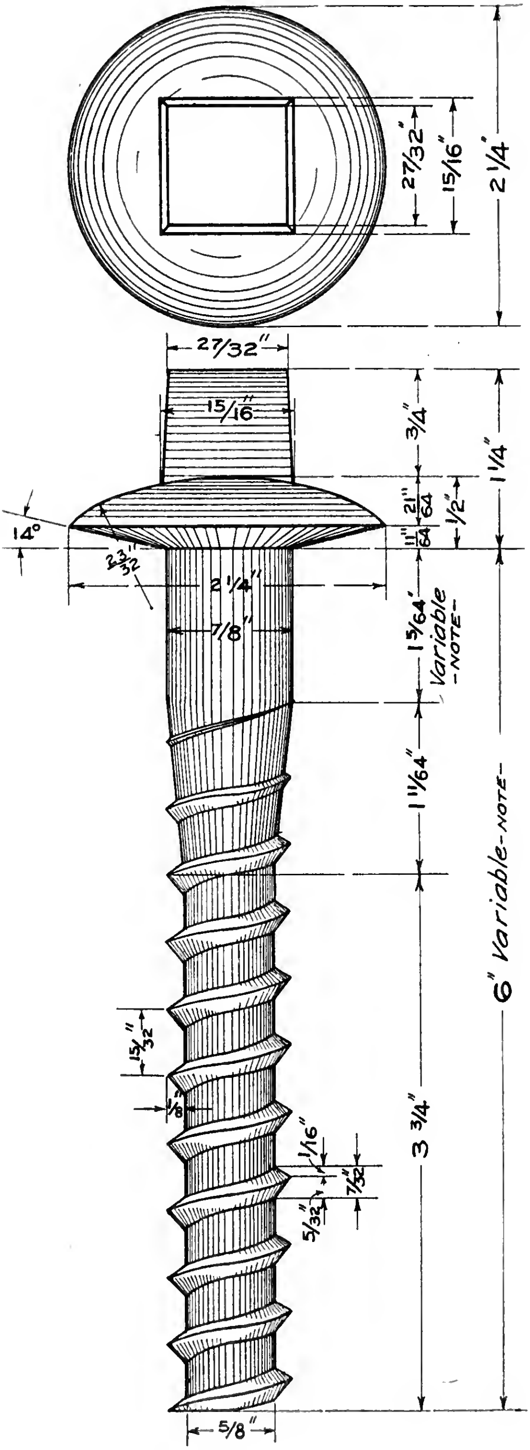
It is well known by all concerned that the use of the screw-spike is very limited at the present time. Your Committee feels that now is the time to adopt a standard form of screw-spike so as to eliminate, as far as possible, the different forms of thread which are sure to be used as the use of screw-spikes becomes prevalent. After a form of thread has once been adopted and generally used on any road, it would be a very serious thing to change the form of pitch of the thread, as new spikes could not be placed in old holes without destroying the thread in the wood.

The other features of the spike are not so important and may be varied at will without serious results.

TABULATED REPLIES—SCREW SPIKES.

	Company or Organization	Official Reporting and Title.	SPECIFICATION		PHYSICAL PROPERTIES AND TESTS								STANDARD LENGTH, ETC.									
			Area Specification	Changes recommended or contemplated	Ultimate strength less than	Elastic limit not less than	Elongation not less than	Reduction of area not less than	Action bending 180° raw material	Action bending 90° finished material spikes	Open-hearth	Carbon-Manganese Phosphorus-Sulphur shall not exceed	Length over all	Length under head	Size of shank under head	Size of shank at threads	Length of taper	Dist. from under side of head to taper	Size of top of head	Size of top of head	Dia. of hd. over all	Pitch of thread
1.	Chicago & Alton	H. T. Douglas, Jr., Chief Engineer		None in use																		
2	Duluth & Iron Range	W. A. Clark, Chief Engineer		None in use																		
3.	Cleveland, Cincinnati, Chicago & St. Louis	Hadley Baldwin, Asst. Chief Eng.		None in use																		
4	Nashville, Chattanooga & St Louis	Hunter McDonald, Chief Engineer		None in use except on few bridges. No.																		
5	Missouri, Kansas & Texas	L. F. Lonnbladh, Chief Engineer		None in use																		
6.	Canadian Pacific	J. M. R. Fairbairn, Asst. Chief Eng.		None in use																		
7	Denver & Rio Grande	A. O. Ridgway, Chief Engineer		None in use No																		
8.	Pennsylvania Lines West	Robert Trimble, Ch. E. M. W.	No specifications		Few spikes purchased under ordinary specifications for experimental purposes								8¼"	6¼"	1"	¾"	1¼"	1¼"	1¾"	13-16"	2"	
9.	Central of New Jersey	Jos. O. Osgood, Chief Engineer	No C.R.R.N.J																			
10	Norfolk & Western	J. E. Crawford, Chief Engineer		None in use																		
11.	Northern Pacific	W. L. Darling, Chief Engineer		None in use																		
12.	Pere Marquette	A. L. Grandy, Chief Engineer		None in use																		
13.	Chicago, Burlington & Quincy	T. E. Calvert, Chief Engineer		None in use																		
14.	Chicago Great Western	C. G. Delo, Chief Engineer		None in use																		
15.	Indiana Harbor Belt			None in use																		
16.	Maine Central	G. F. Black, Eng. M. W.		None in use except for experiment																		
17.	New York, Ontario & Western	J. H. Nuelle, Chief Engineer		None in use																		
18	Peoria & Eastern	L. S. Rose, Val. Engineer		None in use																		
19.	Rock Island	Garrett Davis, Division Engineer		Same as No 38	—See letter from Mr. Ray 10-21-1915.																	
20.	Erie			None in use									6 23-32"	5½"	⅞"	⅝"	1 7-32"	1"	13-16" x ¾"		1⅞"	
21.	Boston & Albany	F. B. Freeman, Chief Engineer		None in use																		

22.	El Paso & Southwestern	J. L. Campbell, Eng. M. W.																				
23.	Duluth, Winnipeg & Pacific	J. L. Pickles, Chief Engineer		None in use																		
24.	St. Louis Southwestern	C. D. Purdon, Chief Engineer		None in use									Why not specify pitch of thread to secure uniformity									
25.	Carolina, Clinchfield & Ohio	Ward Crosby, Chief Engineer	No	None in use																		
26.	Western Maryland	G. H. Friend, Division Engineer		None in use																		
27.	Elgin, Joliet & Eastern	A. Montzheimer, Chief Engineer		None in use Specifications good																		
28.	Pennsylvania Lines West	W. C. Cushing, Ch. E. M. W.																				
29.	Richmond, Fredericksburg & Potomac	S. R. Bice, Eng. M. W.		None in use																		
30.	Lehigh & New England			None in use																		
31.	Seaboard Air Line	W. D. Faucette, Chief Engineer	No	None in use																		
32.	Northern Pacific	A. M. Burt, Ch. E. M. W.	None in use	except for experiment																		
33.	Grand Trunk	M. S. Blaiklock, Eng. M. W.	None in use	No changes contemplated	O.H.-60,000 Phos.-.05% Sulp.-.05%	50% Ult. Str.	22% in 2"	40%	Flat on itself without fracture	To show no sign of fracture	O. H.											
34.	Canadian Pacific	John G. Sullivan, Chief Engineer	½ mile for experimental purposes		65,000		12% in 2"	30%			Basic O. H.	Car. 30 to 40% P. H. .04; Mon. .65; Sul. .04; Sil. .18										
35.	Bingham & Garfield	H. C. Goodrich, Chief Engineer		No report																		
36.	Virginian		Yes	None										6"	⅞"							
37.	Queen & Crescent	Curtis Dougherty, Chief Engineer	No	None No changes contemplated	60,000	50% Ult. Str.	22% in 2"	40%	Flat on itself without fracture	To show no sign of fracture	O. H.		7¼"	6"	⅞"	⅝"	1 11-64"	1 29-64"	15-16"	27-32"	2¼"	
38.	Rock Island	C. A. Morse, Chief Engineer	No	No changes contemplated None	52,000 to 62,000		1,500,000 Ultm. Str. in 8"		Bend over bar of same diameter without fracture	To show no sign of fracture	O. H.		6 23-32"	5½"	⅞"	⅝"	½"	½"	¾"	13-16"	1⅞"	
39.	Pittsburgh & Lake Erie	J. A. Atwood, Chief Engineer	No	No	57,610-1st Test 56,780-2nd Test	39,000-1st Test 39,420-2nd Test	30%	61%-1st Test 65% 2nd Test				C. =13-S= .029 to .129 P.= .018-M= .41	6½"	...	¾"						1 7/16"	
40.	San Antonio & Aransas Pass	H. H. Temple, Supt. M. W.		None in use																		
41.	Vandalia	Maurice Coburn, Prin. Asst. Eng.		Same as Penna. Lines																		
42	Baltimore & Ohio	Earl Stimson, Eng. M. W.	Very similar	No	60,000	35,000	1,500,000 Ten. St. Min. 22% in 2"	2,200,000 Ten. St. Min. 35%		Head hammered buck to show no fracture		Sulphur and Phosphorus .05	7¼"	6"	⅞"	⅝"	1 11-64"	1 5-64"	27-32"	15-16"	2¼"	15-32"
43.	Delaware, Lackawanna & Western	G. J. Ray, Chief Engineer	Yes	No	60,000	50% Ult. Str.	22% in 2"	40%	Flat on itself without fracture	To show no sign of fracture		Sulphur and Phosphorus .05	7¼"	6"	⅞"	⅝"	1 11-64"	1 5-64"	27-32"	15-16"	2¼"	15-32"



PROPOSED AMERICAN RAILWAY ENGINEERING ASSOCIATION STANDARD SCREW SPIKE.

Note.—Varies with thickness of Rail Base and Tie Plate.

INCREASED THICKNESS OF WHEEL FLANGE.

DESIGN OF MANGANESE FROGS AND CROSSINGS

Sub-Committee No. 5.

J. R. LEIGHTY, *Chairman;*	E. L. INGRAM,
H. M. CHURCH,	A. C. MACKENZIE,
T. H. HICKEY,	E. RAYMOND,
E. T. HOWSON,	L. S. ROSE,
L. J. F. HUGHES,	A. H. STONE.

The two subjects, "Report on guard rails and flangeways and effect of increase of ⅛-in. thickness of wheel flanges," and "Continue the study of the design of manganese frogs and crossings," were assigned to a single Sub-Committee for the reason that there was danger of some conflict in the requirements of the design of manganese frogs and crossings and in the flangeway requirements for thicker wheel flanges.

Your Committee has no recommendations to make at this time excepting that these two subjects be reassigned for consideration next year.

TYPICAL PLANS FOR DOUBLE SLIP CROSSINGS. DOUBLE CROSSOVERS AND GUARD RAILS.

Sub-Committee No. 6.

H. T. PORTER, *Chairman;*	R. M. PEARCE,
A. L. GRANDY,	G. J. RAY,
T. T. IRVING,	L. S. ROSE.
H. A. LLOYD,	

DOUBLE SWITCH LUG.

During the present year we have, in addition to our regular assignments, designed a double switch lug, plan of which has been submitted. It is our opinion that with this lug a switch may be operated safely by using either rod as a throw rod and the other as a lock rod. This lug is so designed that it will not be necessary to have rights and lefts and it will reinforce the point sufficiently to prevent locking of switch with any obstruction, of sufficient size to be dangerous, behind the point.

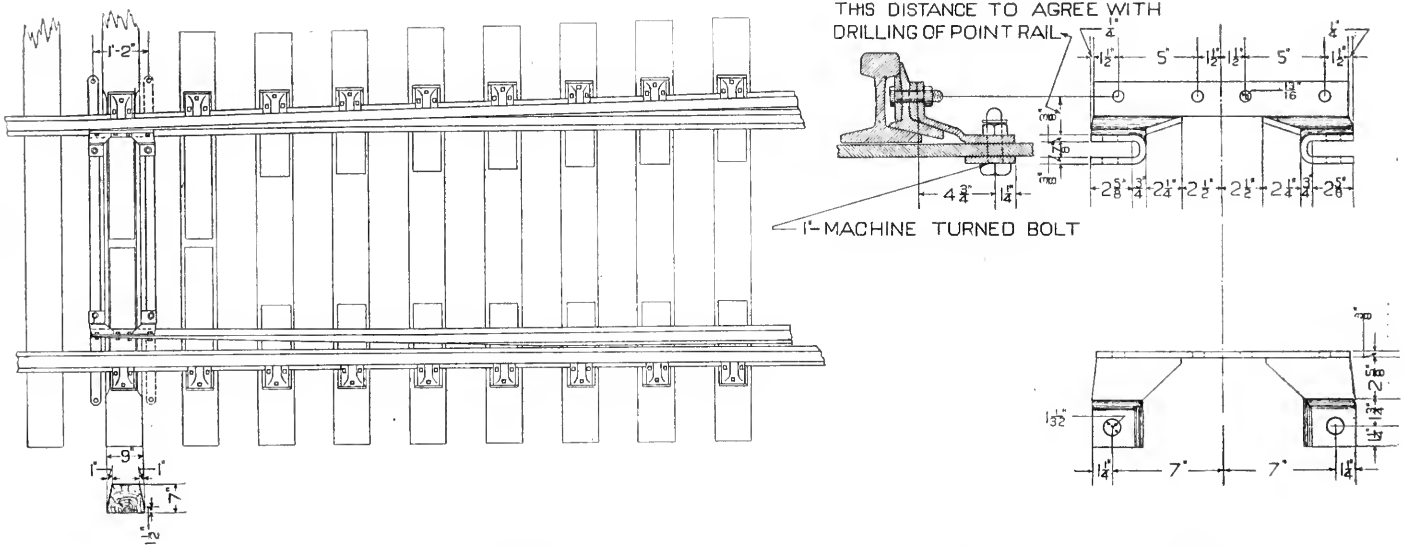
The spacing of bolt holes for this lug corresponds to that already adopted and published in the Manual.

The use of this switch lug will permit throwing the switch by either rod with equal safety and give sufficient space between to minimize trouble from snow and ice.

DOUBLE CROSSOVERS OR SCISSORS.

At the 1914 convention progress was reported on plans for double crossovers or scissors, and at the 1915 convention drawings of typical layouts for Nos. 8, 11 and 16 double crossovers for 13-foot track centers were submitted. Attention was called to the unsymmetrical arrangement of crotch frogs, the object of which was to properly guard the frog

THICKNESS OF METAL MAY BE INCREASED AND LUG OTHERWISE REINFORCED IF SO DESIRED



PROPOSED DOUBLE SWITCH LUG

and crossing points, which is difficult and sometimes impossible with the symmetrical arrangement. Attention was also called to the possibilities of using parts of these drawings when different track centers were required, thus making it possible to use the same layout in part for either 12 or 14-foot centers. These drawings were received as information by the Association.

For the present year we have prepared drawings of typical layouts of Nos. 8, 11 and 16 double crossovers or scissors for 15-foot track centers. which were made to conform as nearly as possible with those for 13-foot track centers.

In all of the above plans we have followed as closely as possible the plans of frogs, switches and turnouts already adopted in order to avoid unnecessary conflict.

DOUBLE SLIP CROSSINGS.

At the 1914 convention we submitted as information typical plans of Nos. 8, 11 and 16 double slip crossings, also a plan by the Cleveland, Cincinnati, Chicago & St. Louis Railway for a No. 8 double slip crossing, the feature of which was the staggering of the switch points.

At the 1915 convention we submitted drawings of typical layouts for Nos. 8, 11 and 16 double-slip crossings to be operated by interlocking. Attention was called to the staggering of switch points to provide for interlocking rods. These plans were referred back for reconsideration and co-operation with members of the Railway Signal Association.

For the present year we have revised the plans of double slip crossings. The changes are in the location of the insulated joints and removing of all joints from a ten-foot section at the center.

All double-slip crossings of either design may be operated by hand or by interlocking, as may be desired.

In the above plans we followed closely as possible the plans of frogs, switches and turnouts that have been adopted.

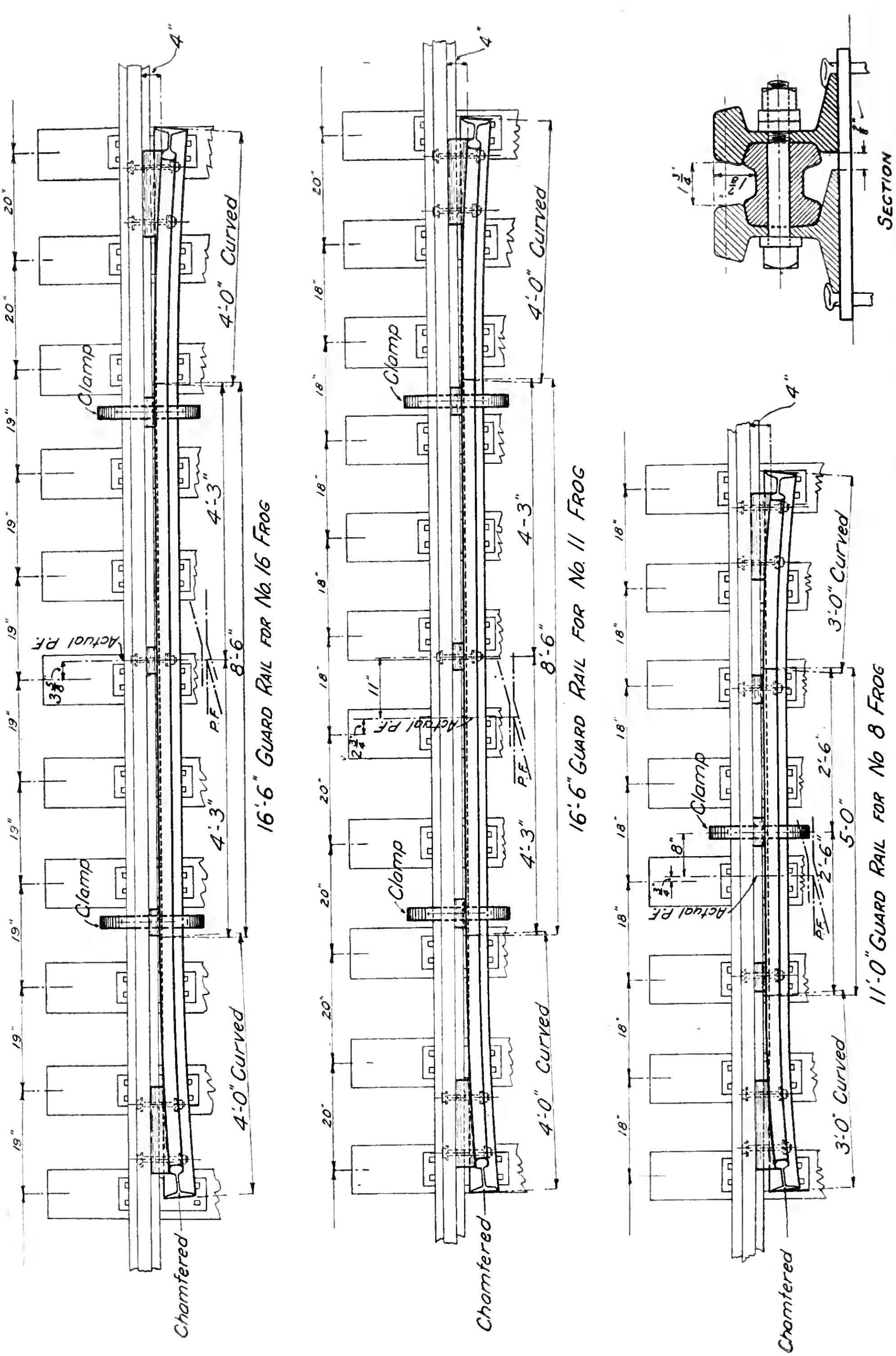
The double lug has not been taken into consideration on these plans, as it has not been adopted, but should it be, it could be applied with a few minor changes.

FROG GUARD RAILS.

Your Committee has compiled data of present practice of American railroads as to dimensions of frog guard rails and offers a definition and specifications for frog guard rails together with plans for 11 ft. 0 in. guard rail for No. 8 frog and 16 ft. 6 in. guard rail for Nos. 11 and 16 frogs. We recommend the adoption and publication in the Manual of the definition, specifications and plans.

DEFINITION.

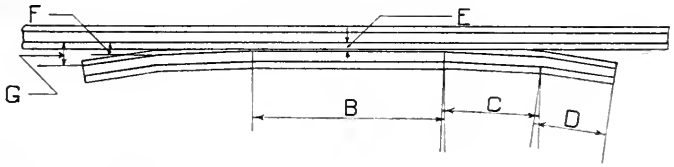
Frog Guard Rail.—A rail or other device to guide the wheel flange so that it is kept clear of the point of frog.



Typical Plan of Frog Guard Rails.

SUMMARY OF DIMENSIONS OF FROG GUARD RAILS IN USE ON AMERICAN RAILROADS.

DIAGRAM OF GUARD RAIL.



Length.	B.	C.	D.	E.	F.	G.	Radius of C.	Radius of D
25'0"	0	12½'	0	1¾"	5½"	....	Curved	....
20'0"	16'2"	1'11"	0	1¾"	4"	....	Straight	....
16'6"	7'0"	3'3"	1'6"	1⅞"	3"	4"	Straight	Straight
	6'0"	5'3"	0	1¾"	4½"	....	Curved	....
	4'0"	4'9"	1'6"	1⅞"	3"	4"	Straight	Straight
	3'6"	6'6"	0	1¾"	4"	....	88' R	Straight
15'0"	12'0"	1'6"	0	1¾"	9"	....	2'4" R	....
	11'2"	1'11"	0	1¾"	4"	....	Straight	....
	11'0"	2'0"	0	1⅞"	6"	....	Straight	....
	10'4"	2'4"	0	1¾"	3¼"	....	18'6" R	....
	10'0"	2'6"	0	1¾"	4"	....	Straight	....
	9'6"	2'9"	0	1¾"	4"	....	Straight	....
	9'0"	1'6"	1'6"	1¾"	2½"	4¾"	Curved	Curved
	9'0"	3'0"	0	1¾"	4¾"	....	18' R	Curved
	9'0"	3'0"	0	1⅞"	5"	....	18'1½" R	....
	8'0"	3'6"	0	1⅞"	6"	....	Curved	....
	8'0"	2'9"	9	1¾"	3"	5"	Straight	1'0" R
	7'6"	3'9"	0	1¾"	5"	....	104' R	....
	7'0"	4'0"	0	2"	4½"	....	Curved	....
	7'0"	4'0"	0	1⅞"	5½"	....	24' R	....
	7'0"	4'0"	0	1⅞"	5"	....	24' R	....
	7'0"	4'0"	0	1¾"	6"	....	30' R	....
	7'0"	4'0"	0	1¾"	4½"	....	Straight	....
	7'0"	4'0"	0	1¾"	4½"	....	38' R	....
	7'0"	4'0"	0	1¾"	5"	....	29'6½" R	....
	7'0"	4'0"	0	1¾"	4"	....	Curved	....
	5'0"	5'0"	0	1¾"	4½"	....	Straight	....
	5'0"	5'0"	0	1¾"	4"	....	66'6" R	....
	5'0"	5'0"	0	1¾"	4½"	....	26'8⅝" R	....
	5'0"	4'0"	1'0"	1⅞"	2⅞"	....	Straight	Straight
	5'0"	3'0"	2'0"	1¾"	2½"	4¼"	Straight	Straight
	4'6"	4'0"	1'3"	1⅞"	3"	4½"	Straight	Straight
	4'0"	4'6"	1'0"	2"	3⅛"	5½"	Straight	3' R
	4'0"	4'6"	1'0"	1¾"	3"	6"	Straight	Straight
	4'0"	4'6"	1'0"	1¾"	3"	5"	Straight	Straight
	4'0"	4'7"	11"	1⅞"	3¼"	4"	Straight	Straight
	4'0"	4'3"	1'3"	1¾"	2¾"	6"	108'4⅝ R	3'10⅝" R
	3'6"	5'9"	0	1¾"	2¾"	....	88' R	....
	3'6"	4'3"	1'6"	1¾"	2¾"	5"	Straight	Curved
	3'0"	6'0"	0	1⅞"	5½"	....	69'3⅜ R	....
	3'0"	6'0"	0	1¾"	4"	....	96'0" R	....
	3'0"	6'0"	....	....	....	....	16' R	....
	3'0"	3'0"	3'0"	1⅞"	2¾"	5½"	Straight	Curved
	3'0"	0'6"	5'6"	1¾"	0	4"	15' R	Straight
	2'0"	5'6"	1'0"	1⅞"	3"	6"	219'7¾ R	3'0" R
	0'0"	7'6"	0	1¾"	5"	....	104' R	....

SUMMARY OF DIMENSIONS OF FROG GUARD RAILS IN USE ON AMERICAN RAILROADS—Continued.

Length	B.	C.	D.	E.	F.	G.	Radius of C.	Radius of D.
12'0"	10'0"	1'0"	0	1¾"	4"	....	Straight	....
	8'0"	2'0"	0	1⅞"	6"	....	Straight	....
	0'0"	6'0"	0	1¾"	5"	....	66.6 R	....
11'0"	6'5"	2'3½"	0	1¾"	4"	....	Straight	....
	5'0"	3'0"	0	1¾"	5"	....	16'6" R	....
	5'0"	2'3"	0'9"	1⅞"	3"	5"	Straight	Straight
	4'0"	3'6"	0	1⅞"	3¾"	....	39'3" R	....
	4'0"	3'6"	0	1¾"	4½"	....	26'8⅝ R	....
	4'0"	3'6"	0	1⅞"	....	....	24'0" R	....
	4'0"	2'0"	1'6"	1⅞"	2⅞"	5"	Straight	Straight
	4'0"	2'0"	1'6"	1¾"	2 11/16"	4½"	Straight	Straight
	4'0"	1'8"	2'4"	2"	3"	4"	Curved	Straight
	3'2"	2'8"	1'3"	1¾"	2¾"	6"	Straight	4'7¼" R
	3'0"	4'0"	0	1¾"	1'0"	....	9'3" R	....
	3'0"	4'0"	0	1¾"	4"	....	49'9" R	....
	3'0"	2'9"	1'3"	1¾"	3¾"	4"	28'0" R	....
	2'3"	2'6½"	1'10"	1⅞"	2⅞"	4⅞"	39'0" R	Straight
10'0"	6'2"	1'11"	0	1¾"	4"	....	Straight	....
	6'0"	2'0"	0	1¾"	5"	....	7'6½"	....
	5'0"	2'6"	0	1¾"	4"	....	Straight	....
	4'4"	2'10"	0	1¾"	5"	....	14'10"	....
	4'0"	3'0"	0	1¾"	4¾"	....	18'0"	....
	4'0"	1'6"	1'6"	1¾"	2½"	4¾"	Curved	Curved
	3'0"	3'6"	0	1¾"	....	....	27'0"	....
	3'0"	1'6"	2'0"	1¾"	2¾"	5¾"	Straight	Straight
	2'0"	4'0"	0	1¾"	4"	....	42'9"	....
	2'6"	3'9"	0	1⅞"	4"	....	Straight	Straight
	1'6"	4'3"	0	1¾"	4"	....	Curved	Straight to 30' to C.
	0	4'0"	1'0"	1⅞"	2⅞"	....	Curved	
9'0"	3'0"	3'0"	0	1¾"	4"	....	Straight	....
8'3"	5'3"	1'6"	0	1⅞"	3⅞"	....	Straight	....
	5'0"	1'7½"	0	1¾"	4"	....	Straight	....
	4'5"	1'5"	6"	1⅞"	3"	4"	Straight	Straight
	4'5"	1'11"	0	1⅞"	4"	....	Straight	....
	4'5"	1'11"	0	1¾"	4"	....	Straight	....
	3'8"	2'3½"	0	1¾"	4"	....	Straight	....
	3'3"	2'6"	0	1⅞"	4"	....	Straight	....
	3'0"	2'7½"	0	1⅞"	4"	....	Straight	....
	2'0"	1'10½"	1'3"	1¾"	2¾"	4"	19'2½"	....
8'0"	4'0"	2'0"	0	1¾"	4⅛"	....	Straight	....
7'6"	3'0"	2'3"	0	1¾"	4"	....	3'0"	....
	2'10"	2'4"	0	1¾"	3½"	....	18'6"	....
	2'6"	2'6"	0	1⅞"	4"	....	Straight	....

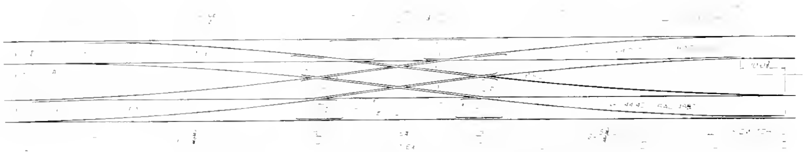
SPECIFICATIONS.

(1) Rail: No. 2 rail may be used.

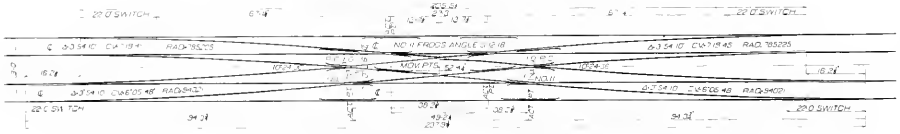
(2) Base of guard rail to be planed to provide a clearance of ⅞-inch between base of main rail and base of guard rail.

(3) Flangeway: Flangeway to be 1¾ inches on standard gage track.

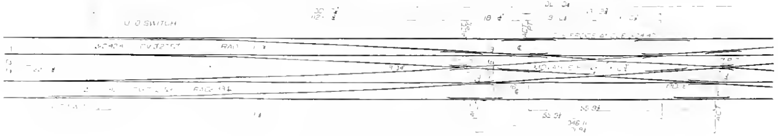
(4) Separators: Separators shall be of {malleable iron.
cast-steel.



TYPICAL LAY-OUT OF NO. 8 DOUBLE CROSSOVER

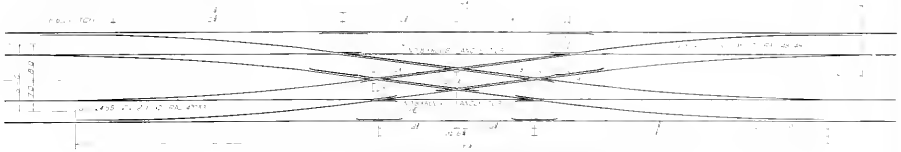


TYPICAL LAY-OUT OF NO. 11 DOUBLE CROSSOVER

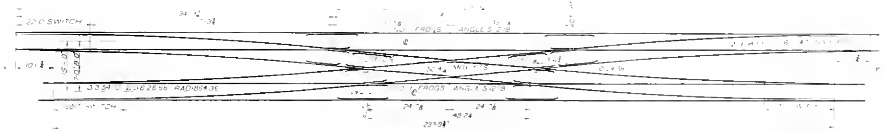


TYPICAL LAY-OUT OF NO. 16 DOUBLE CROSSOVER

GENERAL PLANS (13 FT. TRACK CENTERS).

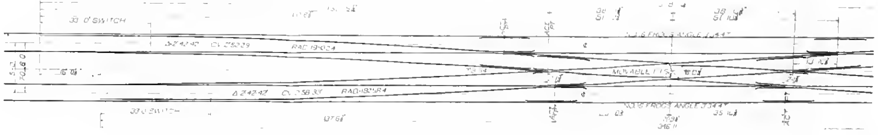


TYPICAL LAY-OUT OF NO. 8 DOUBLE CROSSOVER



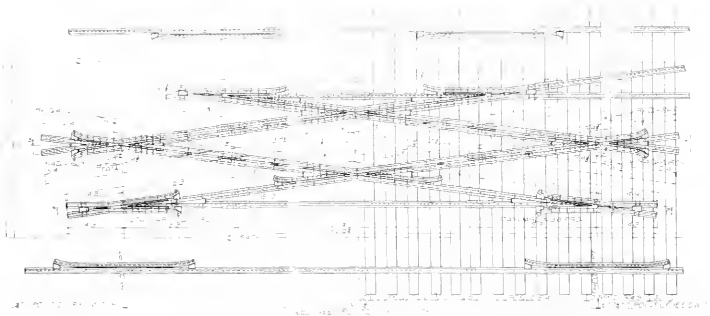
TYPICAL LAY-OUT OF NO. 11 DOUBLE CROSSOVER. (FOR 15 FT. TRACK CENTERS)

GENERAL PLAN.



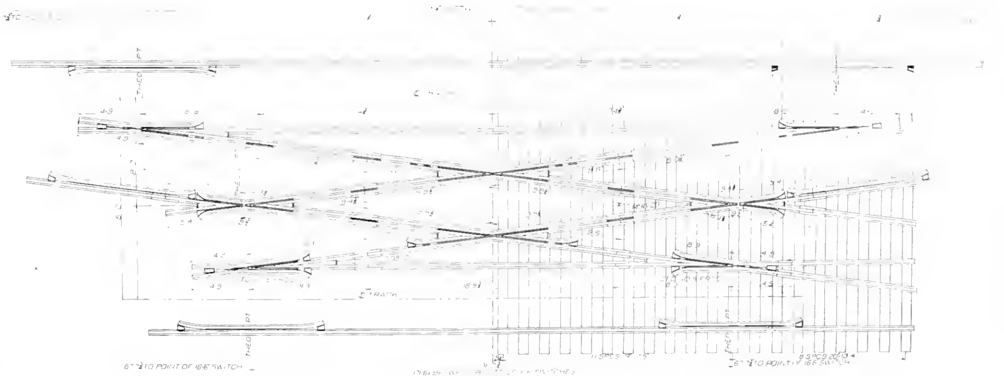
TYPICAL LAY-OUT OF NO. 16 DOUBLE CROSSOVER (FOR 15 FT. TRACK CENTERS)

GENERAL PLAN



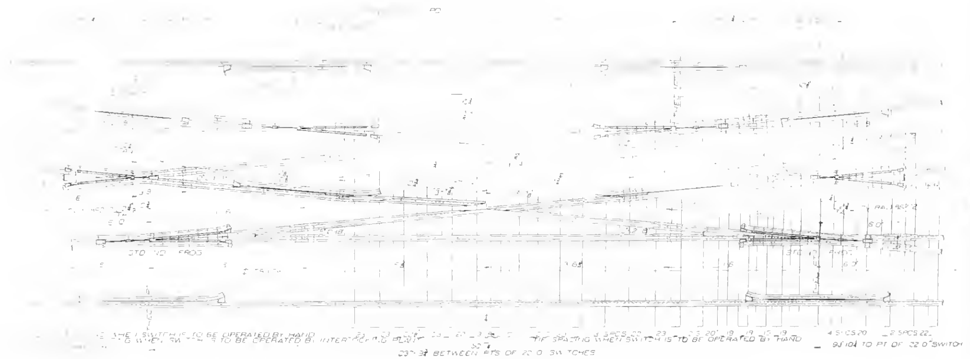
TYPICAL LAY-OUT OF FROGS FOR NO 8 DOUBLE CROSSOVER

FOR 13 FT TRACK CENTERS



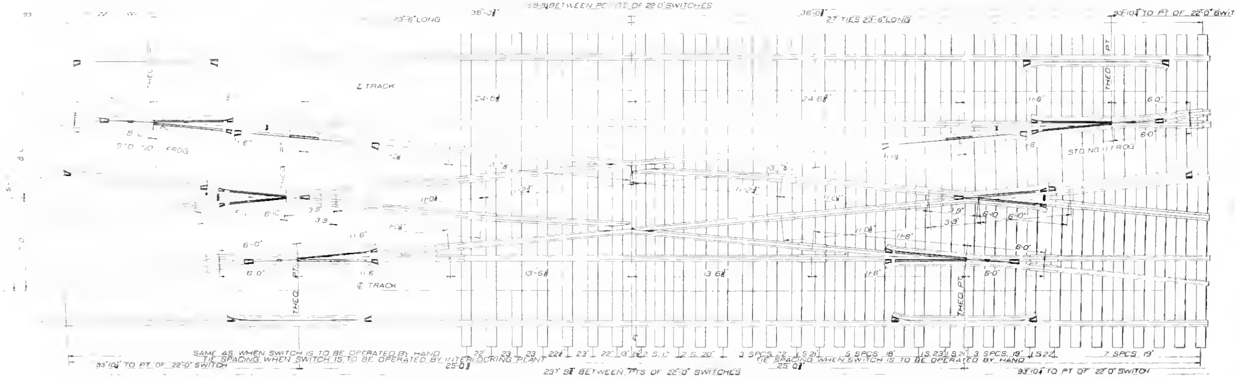
TYPICAL LAY-OUT OF FROGS FOR NO. 8 DOUBLE CROSSOVER

FOR 15 FT. TRACK CENTERS



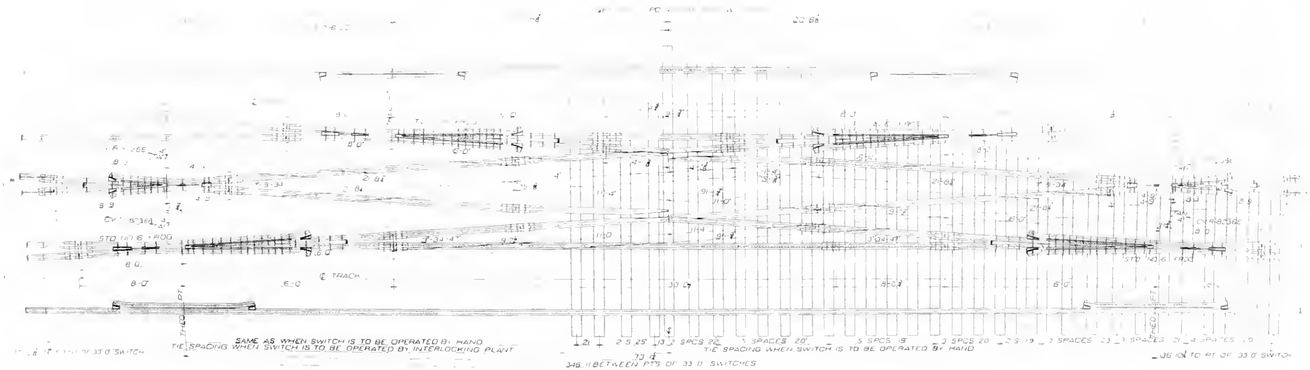
TYPICAL LAYOUT OF FROGS FOR NO. 1 DOUBLE CROSSOVER

FOR 13 FT TRACK CENTERS



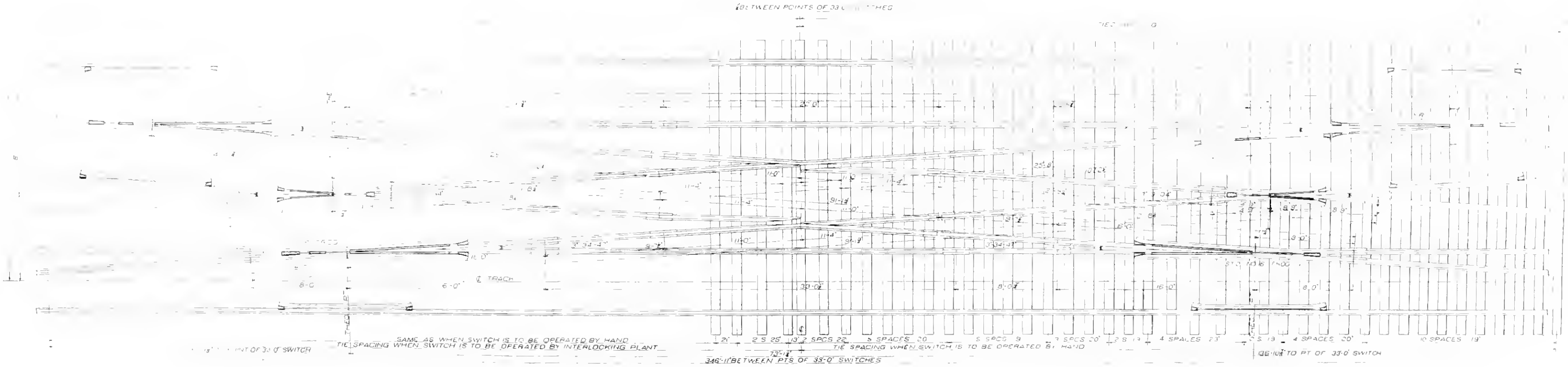
TYPICAL LAY-OUT OF FROGS FOR NO 11 DOUBLE CROSSOVER

FOR 15 FT. TRACK CENTERS

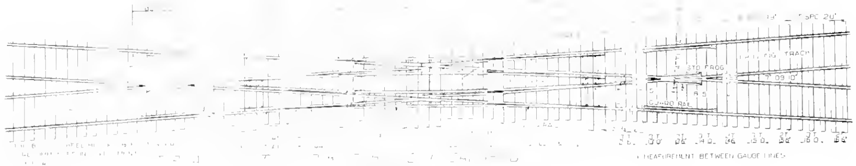


TYPICAL LAY-OUT OF FROGS FOR NO 16 DOUBLE CROSSOVER

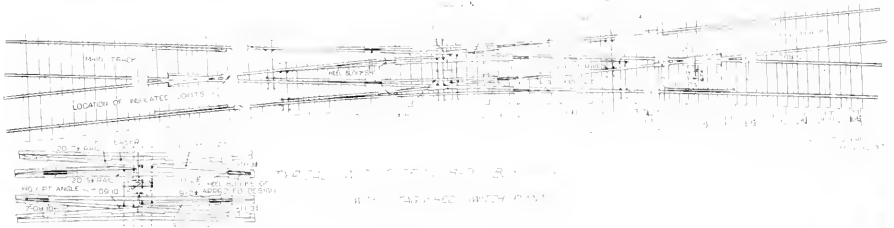
FOR 13 FT TRACK CENTERS



TYPICAL LAY-OUT OF FROGS FOR NO. 16 DOUBLE CROSSOVER
FOR 15 FT. TRACK CENTERS



MEASUREMENT BETWEEN GAUGE LINES

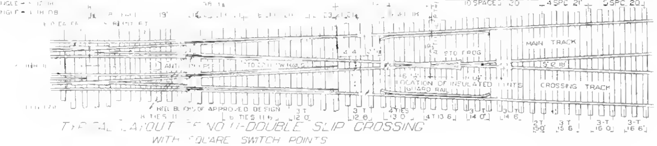


WITH STAGGERED SWITCH POINTS

[illegible] PIECES			BILL OF TIMBER				B.M.
[illegible]	TIES 7×9×11'-0"	8	TIES 7×9×13-0	4	TIES 7×9×15-0	12	TIES 7×9×
12	11 6	8	13 6	6	15 6		
6	12 0	6	14 0	6	16 0		
6	12 6	8	14 6	6	16 6		

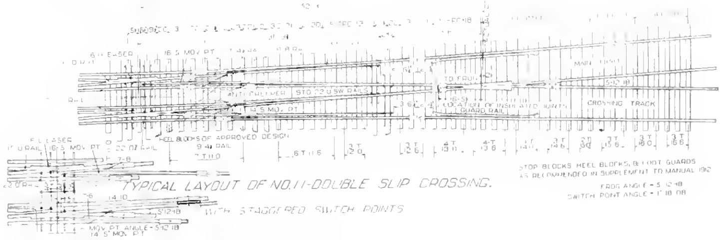
STOP BLOCKS, HEEL BLOCKS, & FOOT GUARDS AS RECOMMENDED IN SUPPLEMENT TO MANUAL 1912

FROG ANGLE = 5°12'18"
SWITCH POINT ANGLE = 1°18'08"



TYPICAL LAYOUT OF NO. 11-DOUBLE SLIP CROSSING
WITH SQUARE SWITCH POINTS

[illegible] PIECES			BILL OF TIMBER				B.M.
[illegible]	TIES 7×9×11-0	8	TIES 7×9×13-0	4	TIES 7×9×15-0	12	TIES 7×9×
[illegible]	[illegible]	8	13 6	8	15 6		
6	[illegible]	6	14 0	6	16 0		
[illegible]	[illegible]	6	14 6	6	16 6		



TYPICAL LAYOUT OF NO. 11-DOUBLE SLIP CROSSING.
WITH STAGGERED SWITCH POINTS

STOP BLOCKS, HEEL BLOCKS, & FOOT GUARDS AS RECOMMENDED IN SUPPLEMENT TO MANUAL 1912

FROG ANGLE = 5°12'48"
SWITCH POINT ANGLE = 1°18'08"

TYPICAL LAYOUTS OF NOS. 8, 11 AND 16 DOUBLE CROSSOVERS, 13- AND 15-FT. CENTERS. GENERAL PLANS.

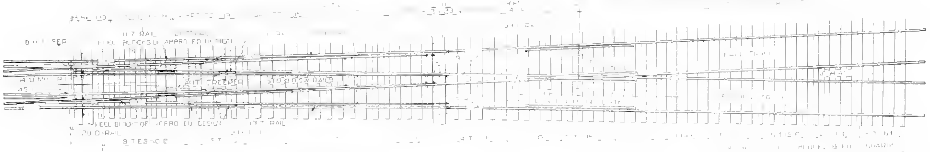
TYPICAL LAYOUTS OF FROGS FOR NOS. 8, 11 AND 16 DOUBLE CROSSOVERS, 13- AND 15-FT. CENTERS.

TYPICAL LAYOUTS OF NOS. 8, 11 AND 16 DOUBLE SLIP CROSSINGS WITH SQUARE SWITCH POINTS.

TYPICAL LAYOUTS OF NOS. 8, 11 AND 16 DOUBLE SLIP CROSSINGS WITH STAGGERED SWITCH POINTS.

TYPICAL LAYOUT OF [illegible] DOUBLE SLIP CROSSING

[illegible]



TYPICAL LAYOUT OF NO 16-DOUBLE SLIP CROSSING

(5) Foot Guards: Sold metallic foot guards shall be
cast-iron.
malleable iron.
cast-steel.

Strap foot guards shall be of rolled steel. Wooden foot guards when used shall be of sound white oak.

(6) Bolts: Bolts shall conform to the recommended specifications for frog bolts.

(7) Rail braces may be used in place of clamps.

(8) Length of guard rail: For all new work, 11-foot guard rails are recommended for frogs up to and including No. 10; 16½-foot guard rails for No. 11 frogs and over.

TESTS OF TIE PLATES SUBJECT TO ACTION OF BRINE DRIPPINGS.

Sub-Committee No. 7.

E. T. Howson, *Chairman;*
Geo. H. Bremner,
A. L. Grandy,
G. W. Hegel,
T. H. Hickey,
T. T. Irving,
F. W. Pfleging,
G. J. Ray.

Late in June. G. W. Hegel, Chief Engineer, Chicago Junction Railway, advised the President of the American Railway Engineering Association that he was contemplating making a careful test of the resistance of tie plates to brine drippings and offered to co-operate with this Association in making these tests. This subject was accordingly referred to the Track Committee, and Sub-Committee No. 7 was organized to co-operate with Mr. Hegel, who afterward became a member of the Track Committee and of this Sub-Committee.

The track on which the tests will be conducted is in the yards of the Chicago Junction Railway, Union Stock Yards, Chicago. This track is subjected to the almost continual movement of refrigerator cars and the resulting corrosion of track fastenings is especially severe. Preparations are now being made for the installation of tie plates of rolled steel, wrought-iron, malleable iron and American ingot iron. As the test is not primarily to determine the merits of the relative designs of tie plates, but rather of materials, only one design of each metal will be installed. With the exception of the American ingot iron plates, all tie plates are being purchased in the open market.

A certain proportion of each type of plate will be dipped in oil and will be oiled at regular intervals during the tests. Another portion will be dipped in hot tar before placing in the track, while the remainder will be inserted without preparation of any kind.

These plates are now being secured (October, 1915) and will be placed in the track within a short time. New rail will be laid and all ties with a life less than the expected duration of the test will be renewed in order that track conditions may be uniform. Representative plates of each kind of material will be retained for chemical and physical tests and other plates will be removed from the track from time to time during the progress of the test to determine the extent to which the plates are affected by this corrosive action.

The Committee hopes to be able to present considerable information in its report next year.

CONCLUSIONS.

Your Committee recommends the following:

Receiving as a progress report:

(1) The report on Economics of Track Labor.

(2) The report on Tests of Tie Plates Subject to Action of Brine Drippings.

For adoption:

The report on the relation between worn flanges and worn switch points.

For adoption and publication in the Manual:

(1) Design for Double Switch Lug.

(2) Typical Layouts of Nos. 8, 11 and 16 Double Crossovers, 13- and 15-ft. centers. General Plans.

(3) Typical Layouts of Frogs for Nos. 8, 11 and 16 Double Crossovers, 13- and 15-ft. centers.

(4) Typical Layouts of Nos. 8, 11 and 16 Double Slip Crossings with Square Switch Points.

(5) Typical Layouts of Nos. 8, 11 and 16 Double Slip Crossings with Staggered Switch Points.

(6) Typical Plan of Frog Guard Rails.

Your Committee recommends for next year's work:

(1) Continue the Study of Economics of Track Labor.

(2) Review the entire subject of frogs, switches, turnouts, crossings, etc., giving special attention to the use of tie plates, risers, etc., and recommend such changes in plans as may be needed to bring them up to the best practice.

(3) Continue the tests of tie plates under action of brine drippings.

(4) Consider recommendation of additional standards and specifications for manganese frogs and crossings.

(5) Report on effect of increase of ⅛-inch thickness of wheel flanges.

(6) Report on reduction of taper of tread of wheel to 1 in 38 and on canting the rail inward, also concerning the reduction of the present limit of allowable flat spots on wheels, conferring with the Master Car Builders' Association.

Respectfully submitted,

COMMITTEE ON TRACK.

REPORT OF COMMITTEE VI—ON BUILDINGS.

M. A. Long, *Chairman;*	G. H. Gilbert, *Vice-Chairman;*
G. W. Andrews,	C. H. Fake,
J. P. Canty,	A. T. Hawk,
D. R. Collin,	E. A. Harrison,
W. H. Cookman,	P. B. Roberts,
C. G. Delo,	W. S. Thompson,
W. T. Dorrance,	*Committee.*

To the Members of the American Railway Engineering Association:

Your Committee on Buildings respectfully submits herewith its annual report.

(a) REVISION OF MANUAL.

The only item in the Manual that we recommend be changed is the item under "Engine Houses." The following should be added:

"When there is an engine house without turntable and no 'Y' track or other means of turning provided, such engine house should preferably be equipped with smoke jacks at each end of each stall."

(b) FREIGHT HOUSE SCALES.

The weighing of package freight at freight houses is very important from a revenue standpoint, and the railroads are installing a greater number of scales, and giving serious consideration to the weighing of all package freight, except possibly standard packages of known weight. There are some points where practically all the freight handled is of standard package freight, and at such houses very few scales are needed.

There are three classes of freight terminals, the largest being where both inbound and outbound houses are arranged in the same layout. At such points the following arrangement of scales is recommended:

Inbound and Outbound Houses in Same Layout.

In outbound houses it is desirable to have a scale at every second door opening, or a maximum of seventy-five (75) feet between scales, these to be located on the team side.

In inbound houses it is desirable to have scales placed one hundred (100) feet centers as the maximum and located on the team side.

Combination Inbound and Outbound Houses.

In layouts where one house handles both inbound and outbound freight and where the business is heavy and diversified, the scales should be located preferably at every third door opening, or a maximum of 75 feet apart. Where this number of scales are used, they should be ample to take care of inbound weighing. Scales should be located on the team side of the house.

Combination Freight and Baggage Rooms.

At small outlying stations, where there is a combination baggage and freight room, one dormant scale, approximately two tons capacity, located preferably at one side of the door nearest the team side, is recommended, as at this point it will be less liable to damage from trunks or large packages.

Platforms.

In large houses, scale platforms should be as small as practicable to accommodate the trucks used, and usually not over 6 feet by 8 feet, except at certain localities, where one or two large scales are necessary to handle freight that is especially bulky.

Capacity.

Scales for houses handling freight only should have a minimum capacity of four (4) tons. Higher capacity scales cost very little more and are economical from an operating and maintenance standpoint, as they will stand up better under the abuse they are usually subjected to.

Type of Scale.

Dial scale, properly maintained, has a great many advantages over the beam type.

(c) ASHPITS.

The ashpit is the most expensive structure on a railroad, from a maintenance standpoint. Therefore, a great deal of thought should be given to the design.

The usual procedure at an ashpit is to drop the hot ashes into the pit and this heats up the walls and other parts of the structure. Then cold water is thrown on the ashes to cool them. This rapid cooling causes contraction in the material of which the structure is built, and when repeated many times, weakens and sometimes destroys the structure. Another destructive element is the sulphuric acid produced by the water and sulphur in the ashes. This destroys the steel parts (coming in contact with it) at a rapid rate. Most ashpits are built of concrete, in which limestone is a principal ingredient. Hot ashes cause this limestone to swell and disintegrate, and in a short time the concrete will begin to spall off. Firebrick facing has been used, but on account of the nature of the work and the tools used, experience shows that they are soon knocked off. Slag has been used in place of stone, and makes a good substitute. Gravel also makes a good substitute, and if trap rock is available, it is better than either of the above materials.

Various Types of Pits.

(1) At outlying districts, where few engines are handled. cast-iron ties, approximately 12 inches high, are used to prevent burning wood ties. These should be located on spur tracks.

(2) Pit located between the track rails, approximately 3 feet deep and length to suit the business handled, the cinders are shoveled out on the track level and loaded by hand into cars or loaded into barrows and wasted at a convenient place. In some instances these pits are fitted with buckets, which are handled by pillar crane, and sometimes by traveling or gantry crane, and loaded into cars.

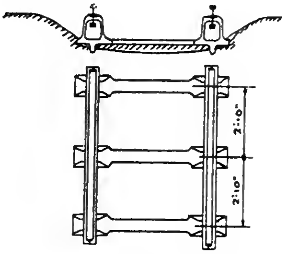


FIG. 1. CAST-IRON TIE PIT.

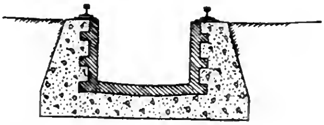


FIG. 2. TRACK PIT.

(3) Pit similar to Type 2, one side open, pit 3 feet deep, with depressed track alongside, the top of car approximately level with base of rail on the cinder track.

(4) Depressed pit filled with water, into which the cinders are dropped, one feature being to design the pit so that cinders will drop

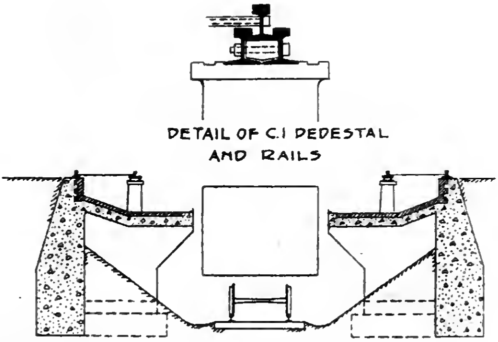


FIG. 3. DEPRESSED ASH CAR TRACK.

directly into the water and reach the main body of the pit freely, another feature being the easy removal of the cinders by grab bucket operated either by a gantry or locomotive crane.

(5) Pit equipped with bucket or car located under the track and hoisted by mechanical means, the cinder bucket or car running on rails placed on an incline, car being run high enough to dump in a car located on a track parallel to and approximately 25 feet centers from ash track.

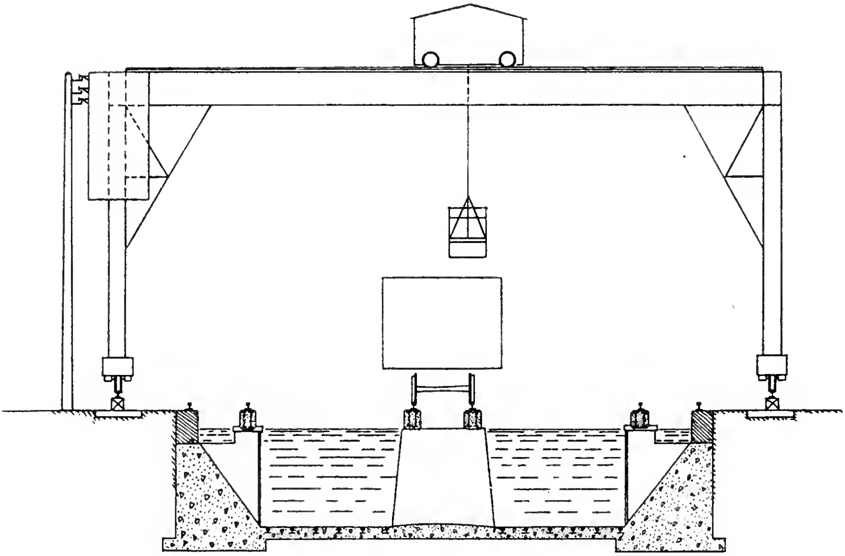


FIG. 4. WATER PIT WITH GANTRY CRANE.

All types of pits should be equipped with water supply to wet down the hot cinders.

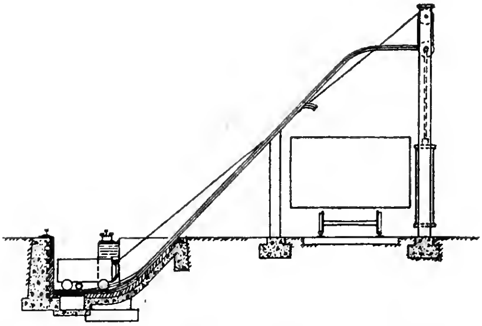


FIG. 5. TRACK PIT WITH BUCKET, POWER OPERATION.

The available records are not kept in such shape that it is possible to determine the relative economy of various types of pits, but where a large number of engines are handled, the water type pit, with locomotive or gantry crane with grab bucket, is recommended.

(d) COALING STATIONS.

The Committee has no additional information to offer on coaling stations, the report last year being as complete as we could make it, except for the question of storing coal in summer for winter consumption to relieve revenue cars during the winter season.

The Committee recommends this subject be continued for another year, and that they be instructed to consider the storing and handling of stored coal.

Respectfully submitted,

COMMITTEE ON BUILDINGS.

REPORT OF COMMITTEE XVIII—ON ELECTRICITY.

GEORGE W. KITTREDGE, *Chairman;*	J. B. AUSTIN, JR., *Vice-Chairman;*
D. J. BRUMLEY,	C. E. LINDSAY,
R. D. COOMBS,	W. L. MORSE,
A. O. CUNNINGHAM,	W. S. MURRAY,
WALT DENNIS,	J. A. PEABODY,
R. H. FORD,	FRANK RHEA,
GEORGE GIBBS,	J. R. SAVAGE,
G. A. HARWOOD,	MARTIN SCHREIBER,
E. B. KATTE,	H. U. WALLACE,

Committee.

To the Members of the American Railway Engineering Association:

Your Committee presents herewith its annual report for the year 1915.

The following outline of work was assigned to your Committee by the Board of Direction:

(1) *Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.*

(2) *Continue the study of the subject of clearances of third rail and overhead structures, conferring with other Committees.*

(3) *Continue the study of electrolysis and insulation and its effect upon reinforced concrete structures.*

(4) *Report on water power for electrical railway operation.*

(5) *Continue the study of maintenance organization and relation to track structures.*

No meeting was held during the year, such work as was done having been accomplished by correspondence.

(1) CLEARANCES.

The Sub-Committee on Clearances has brought up to date as of December 31, 1915, data regarding overhead clearances on various electrified roads in the United States, as shown in Table 2, pp. 402-405, and also data regarding third rail clearance on various electrified roads as shown in Table 1, page 401.

(2) TRANSMISSION LINES AND CROSSINGS.

Messrs. R. D. Coombs, G. A. Harwood and E. B. Katte have continued serving as representatives of your Association on the National Joint Committee on Overhead and Underground Line Construction. This Joint Committee has not yet completed its work on the revision of the crossing specifications, nor completed any other new specification.

Your Association's delegates were actively engaged with the Joint Committee on preparation of the revised specifications for crossings, when the progress of the National Joint Committee's work was arrested and held in abeyance by the fact that the United States Bureau of Standards was about to issue a Safety Code which included specifications for crossings. Therefore no definite report will be made by the National Joint Committee until the Safety Code is issued and subjected to study by the National Joint Committee.

It is hoped that the National Joint Committee will take up its interrupted work early in 1916.

(5) ELECTROLYSIS.

Messrs. Brumley, Katte and Murray have continued as your Association's representatives on the National Joint Committee on Electrolysis, and report that they have no report to make to the Committee on Electricity until the preparation of a report by the National Joint Committee on Electrolysis.

No meeting of the National Joint Committee on Electrolysis was held during 1915, but sub-committees have been at work preparing various sections of the report, and it is expected that galley proofs of the report will be ready for final check early in 1916.

(3) INSULATION; (4) MAINTENANCE ORGANIZATION; (6) RELATION TO TRACK STRUCTURES.

Your Committee has nothing new to report on the above subjects.

RECOMMENDATIONS.

(1) The Committee recommends that the revised data regarding overhead and third rail clearances be received as information.

(2) The Committee recommends that representatives continue to serve on the National Joint Committee on Electrolysis and the National Joint Committee on Overhead and Underground Line Construction, and that the statistical data furnished by the Sub-Committee on Clearances be kept up to date.

(3) Your Committee also recommends that during the coming year the subject of report on water power for electrical railway operation be taken up and report considered and submitted.

(4) That consideration be given any new information that may develop in reference to Maintenance Organization and Relation to Track Structures, and asks for such other instructions as seem necessary or desirable.

Respectfully submitted for the Committee by

GEO. W. KITTREDGE,
Chairman.

TABLE 1. DATA REGARDING THIRD RAIL CLEARANCES.

Name of Company	Plan No.	Top or Under Contact	Protected	Uses Steam Equipment	Structures Clear Prop. Lines	Mileage in Operation	Mileage Planned for Immediate Future	Mileage Using Steam Equipment	Mileage Clearing Proposed Lines	
Albany Southern	1	Top	No	Yes	Yes	53 5	None	50.5		1-Mile O. H. included in total.
Aurora, Elgin & Chicago	2	"	"	"	No	95 00	None	95 00		7.70 Miles O. H. trolley
Baltimore & Ohio	10231	"	Partly	"		7.00	None	7 00		Rail protected only at stations
Boston Elevated Ry		"	No.	No		29.81	5 6	None		
Brooklyn Rapid Transit	5	"	About 30%	"		142 975	Consid'able	None		49.83 Miles O. H. trolley
Central California Traction	309	Under	Yes	For Emergency only	Yes	70.00	None	None		27 mi. O. H. trolley inc. in 70 mi.
Detroit River Tunnel Co	V 88	Under	Yes	Yes	"	25.70	None	25.70		2.7 miles O. H. trolley included in total
Grand Rapids, Grand Haven & Muskegon		Top	No	No		46 00	None	None		10 miles O. H. trolley included in total
Hudson & Manhattan		"	Yes	"	No	20.00	None	None		Subway
Interborough Rapid Transit	S- 989-A M-3790-A	"	"	"	"	205.85	187.04	None		Elevated 117.98, Subway 85.34
Lackawanna & Wyoming Valley		"	No	Yes	"	43 00	None	43.00		5 miles O. H. trolley
Long Island		"	Yes	"		207.97	None	207.97		
Metropolitan West Side, Chicago		Top	No	No	No	51 08				Elevated
Michigan United		"	"	"		219.00	None	None		O. H. and underground conductors at crossings only
Northwestern Elevated, Chicago	6	"	"	"	"	60.00		10.00		16 miles O. H. sliding contact
Northern Elec. Ry., Chico, Cal.	17	"	Through station grounds only	For emergency only	"	142.00	None	None		18.79 miles O. H. trolley and Pantagraph
New York State Railways		Under	Yes	Yes		105.56	None	98 62		8.95 miles O. H. trolley
New York Central	26	"	"	"	Yes	254 8		254.8		3.2 miles O. H conductors not included in total
Penn R. R., Manhattan Div		Top	Yes	No		97 49	None	None		
Penn R. R., New York Div		"	"	Yes	Yes	29 20	None	22 70		
Penn R.R., West Jersey & Seashore	23	"	"	"	"	150 26	None	150.26		8 65 mi. O. H. trolley inc. in total
Pensylvania R. R.							111 5			Philadelphia and vicinity
Puget Sound Electric Ry		Top	No	No	No	37 50	None	None		10 mi. O. H. trolley inc. in total
Philadelphia & Western	5-1-12	"	Yes	"	"	34.00	None	None		15 0 miles trolley in yards
Philadelphia Rapid Transit Co.		Under	"	"		18 61	None	None		Subway and Elevated Lines
Scioto Valley Traction Co.	8-2-11	Top	No	"		65 00	None	None		3.86 miles trolley—Urban
South Side Elevated, Chicago		"	"	"		36.50	None	None		
Wilkesbarre & Hazelton	24	"	Yes	Yes	Slight	31.00	None	29 50		1.50 miles O. H. trolley
						2278.805	304.14	995 05		

TABLE 2. DATA REGARDING OVERHEAD CLEARANCES.

Revised December 31, 1915.

Name of Company	Conductor	Height Above Rail	Electric Single Track	Steam Equipment Handled	Clearance Diagram	Current and Voltage	Contact Device	Special Const. at Crossings Other Roads	Remarks
Boston & Maine	4|0 Grooved	Stand. 22'0" Min. 15'6"	21.31 Mi.	21.31 Mi.	Submitted	Sing. Phase A-C. 11,000	Pantagraph	Print	Berkshire St. Ry. at No. Adams=20'0" 15'6"=Stand. for Hoosac Tunnel
Erie Ry. Co	3|0 Grooved	Max. 24'0" Stand. 23'0" Min. 16'0"	38	34	None Submitted	11,000	"	None	
Grand Trunk Ry. St. Clair Tunnel	4|0 and 300,000 C.M. Grooved	Rail to Wire 22'0" Yd. 16'6" in Tunnel Rail to Wire 15'4" in Tunnel	12	Handled over 12 mi. Operated over 9¾ mi. approx.	Submitted	A.-C. 3,300 Sing. Phase	"	"	Note—Steam Loco. not operated through Tunnel or approaches thereto
Great Northern Ry Cascade Tunnel	2=4|0 Groov. = 7'C to C.	Yards 22'6" Tunnel 17'4" 8'C. to C.	7	7	Diagrams Submitted	6600 25 Cyc.	Trolley	"	
New York Central Over Head	8 & 0	So. 144 St. Max.=15'3" Min.=15'1" No. 144 St Max.=15'5" Min.=15'3"	3.2	3.2		D-C 660	Shoe	"	Running position=15'1", Low=14'7⅞" to 14'9¼", (N Y.C) High=15'5⅞" to 15'6"
N. Y. N. H. & H Main Line	4|0 8	23'0" 22'0" 15'6"	500	500	Diagram Submitted	A-C 11000	Pantagraph	Yes	
Penna. Ry. Over Head Manhattan Division	25# Rail T-Shaped	15 2' 15.2' 15.2'	1.18	None	Submitted	D-C 650	Pantagraph	None	
Southern Pacific Ry. Oakland, Alameda & Berkeley	4|0 Standard Groove	22'0" 22'0" 17'6"	120	80	None Submitted	D-C 1200	Roller Pantagraph	Double Insulation with Grounded Section	
The Lake Shore Electric Ry. Co.	4|0 Grooved	Max. 22'0" Stand. 18'0" Min. 14'0"	218	Practically all from Outside Connections	All New Work	D-C 650 (Trolley) 18000 Trans.	Trolley	None	
Norfolk Southern R. R. Electric Division	4|0 Grooved	Max. 21'0" Stand. 21'0" Min. 19'4"	46	24	Submitted	D-C 550 volt A-C 13200 (25 Cycle)	Trolley		

TABLE 2—Continued. DATA REGARDING OVERHEAD CLEARANCES.

Revised December 31, 1915.

Name of Company	Conductor	Height Above Rail	Electric Single Track	Steam Equipment Handled	Clearance Diagram	Current and Voltage	Contact Device	Special Const. at Crossings Other Roads	Remarks
Aurora, Elgin & Chicago Ry.									
Bangor Ry. & Elect. Co.	2|0 8 & 0	Max. 23'0" Stand. 19'0" Min. 15'0"	65.91 Mi.	None	None Submitted	D-C 600	Trolley		
Brooklyn Rapid Transit. New York Consolidated R. R.	2|0 Round	Max. 21'6" Stand. 18'0" Min. 12'0"	20.616	None	Outline of Equipment	D-C 575	"		Freight handled by Elec. Locos.
Butte, Anaconda & Pacific Railway Co.	4|0 Grooved	Max. 22'0" Stand. 22'0"	95.0	95.0 Mi.	None Submitted	D-C 2400	Pantagraph		
Chicago & Milwaukee	3|0 Grooved	23'6" 20'0" 14'9"	173	None	Plan of Pole Line Const.	D-C 600	Trolley	Standard Insulated Trolley Crossings	
Chicago. Lake Shore & South Bend Ry. Co.	Copper and Steel 4|0 Grooved	22'6" 21'0" 17'6"	101.7	101.7	None	6600 Sing. Phase	Pantagraph	None	
Detroit United Ry.	2|0 & 3|0 Grooved Round & 8	22'6" 18'6" 14'0"	820.6343	100.33	Stand. Line Const.	D-C 600	Trolley	Built according to Specs. of Michigan Ry. Comm.	
Fonda, Johnstown & Gloversville Ry.	4|0 Grooved	21'0" at Steam Crs'gs 18'0" 15'0"	80	50	None Submitted	D-C 600	Trolley	None	
Fort Dodge, Des Moines & So. Ry.	3|0 & 4|0 Grooved	24'0" 23'0" 21'0"	130	130	None Submitted	D-C 1200	"	None	
Galveston Elect. Co.	2|0 Hard Draw Copper Round	22'0" 18'0" 17'0"	38.79	None	None	600 D-C	"		
Iowa & Illinois Ry.	4|0 Round	23'0" No Stand. in State 17'6"	38	36	Have none	D-C 600	"	Double Spans All Poles heavy and back guy	
Montreal & Southern Counties Ry.	4|0 Grooved	23'0" 22'0" 15'0"	57.5	25.23	None	600 Volts	"	None	
N. Y. N. H. & H. (N. Y. W. & B.)	4|0 8	23'0" 22'0" 18'0"	53	53	Submitted	A-C 11,000	Pantagraph	Yes	
New York State Railways	4|0 Round	22'0" 20' to 18' 12'0"	582.81	138.62	None Submitted	D-C 650	Trolley	22' with trolley guard	

TABLE 2—Continued. DATA REGARDING OVERHEAD CLEARANCES.

Revised December 31, 1915.

Name of Company	Conductor	Height Above Rail	Electric Single Track	Steam Equipment Handled	Clearance Diagram	Current and Voltage	Contact Device	Special Const. at Crossings Other Roads	Remarks
Niagara, St. Catharines & Ontario Ry. Co.	4|0 Grooved	Stand. 22'6" Min. 19'0"	94	80	None Submitted	D-C 600	Trolley	Catenary Const.	
Northern Ohio Traction Co.	4|0 Grooved	22'0" at R. R. Cross'gs 18'0"	236	None	None	600 Volts	"	None	
Oakland, Antioch & Eastern Ry.	4|0 Grooved	Max. 22'0" Stand. 20'0" Min. 19'0"	100	None	Submitted	D-C 1200	"		
Oregon Electric Ry.	4|0 Grooved	23'0" 22'0" 16'0"	194.5 inc. 2nd track sidings	See Note	None Submitted	D-C 8m||600 V 186.5m|| 1300 V.	"		During Extensions steam used on all lines except 1.4 mi. in City
Pacific Elect. Railway Los Angeles, Cal.	3|0 & 4|0 D. G.	Steam Crossings 22'0" 22'0" 19'0"	1049.620 Mi.	18.664 Mi.	Diagram Submitted	D-C 600–1200	"	Insulated Crossings	
Pacific Northwest Traction Co.	2|0 & 3|0 Round 2|0 Grooved 3|0	21'0" 20'0" 19'0"	25.842	25.842	Submitted	600 D-C	"	23' clearance over steam lines	
Penn. R. R. Co. (Phila.-Paoli Elect.)	3|0 & 1|0	23'0" 22'0" 16'0"	93.6	93.6	Attached	2000 amper. 11,000 volts (70 Amp. per car)	Pantagraph	None	
Piedmont & Northern Ry. Co									
Portland Railway Light & Power Co., Oregon	4|0 8	23'0" 18'0" 14'6"	299.193	None	A. R. E. A. Stand.	D-C 650	Trolley	Patented O.-H. Frogs	184.402 City Lines 114.791 Interurban
Quebec Railway Light & Power Co.	2|0 Round	21'0"	39	39	None Submitted	D-C 550	"	Built according to Specs. Canadian Rail. Comm.	
Rock Island Southern Ry.	4|0 8 Grooved	23'3"	61.5	61.5	None	11,000 D-C	Pantagraph	None	
Rock Island Southern R. R.	3|0 8 Grooved	22'0"	15	None	None	600 D-C	Trolley Wheel	None	
Southern Traction Company. (Interurban lines only)	4|0 Grooved	23'0" 19'0" 17'0"	154.97	None	5' from outside of rail	1200 D-C	Trolley	None	Southern Traction Interurban lines extend from Dallas to Waco and from Dallas to Corsicana, Texas
Spokane, Portland & Seattle Ry.	4|0 Grooved	23'0" 22'0" 16'0"	167.1	None	None	D-C 1300	"	Yes Plans Submitted	

TABLE 2—Continued. DATA REGARDING OVERHEAD CLEARANCES.

Revised December 31, 1915.

Name of Company	Conductor	Height Above Rail	Electric Single Track	Steam Equipment Handled	Clearance Diagram	Current and Voltage	Contact Device	Special Const. at Crossings Other Roads	Remarks
Tarrant County Traction Co.	4|0 Grooved	Max. 23'0" Stand. 19'0" Min. 17'0"	29.303	None	Dist. from center of track to face of Poles =7'6"	600 D-C	Trolley	National Trolley Guard	
Texas Traction Company....	4|0 Grooved	23'0" 19'0" 17'0"	73.617	None	5' from outside of Rail	600 D-C	"	None	Texas Traction Interurban lines extend from Dallas to Denison, Texas
The Ohio Electric Ry.......	4|0 Grooved and Round	22'0" 21'0" 18'0"	620	40	See Note	D-C 600 to 650	"	A. E. R. E. Assn.	Pole line 8'0" from c. l. of track; building =10 ft.
The Rhode Island Co.... ..	2|0 & 4|0 Both Round & Grooved	At R. R. Crossings 22'0" 19' to 20' Under Br. 13'0"	400	5	None Submitted	D-C 600	"		
Toledo & Western Ry.... ..	4|0 8	21'0" 18'0" 18'0"	81	81	None Submitted	D-C 600	"	Basket the line over Foreign Lines 21'6" Trolley above Steam Road Tracks	
Twin City Lines .... Minneapolis, Minn.	2|0 3	22'6" 18'0" 12'4"	425	1.5	Have none	D-C 600	"		
Union Traction Co. of Indiana	2|0 & 3|0 8 and Groove	22'0" 18' to 22' At Bridge 15'0"	52 City 375 Interurban	2	Standard Line Const'n	D-C 600 to 650	"		
United Railways Co., Portland, Oregon...............	4|0 Grooved	23'0" 21'0" 19'0"	39.28	None	None Submitted	D-C—600—12.28 Mi. D-C-1200—27.0 Mi. 1200	"	Limited Insulation	
W., B. & A. R. R............	4|0 Copper 8	21'0" 19'0" 15'0"	88.52	20.05	None		"	None	
Waterloo, Cedar Falls & Northern.............	4|0 Interur. Grooved 2|0 City, Round	City 22'0" 18'6" 16'0" Interurban 23'0" 21'0" 18'6"	112.24	90.29	None Submitted	D-C 650-1300	"	A.E.R.E.A. Standard	
Youngstown & Southern	3|0 Grooved	Stand. 18'0"	20	None	None Submitted	D-C 625	"	None	Strictly Interurban
Michigan Railway	4|0 & 2|0	Stand. 19'0"	40.65		None Submitted		"		
Norfolk & Western.........	3|0 & 2|0	Stand. 24'0"	94.82	94.82	None Submitted	A-C 11,000	Pantagraph		

REPORT OF SPECIAL COMMITTEE ON GRADING OF LUMBER.

Dr. Hermann von Schrenk, *Chairman;* B. A. Wood, *Vice-Chairman;*
W. McC. Bond, W. H. Norris,
D. Fairchild, J. J. Taylor,
Committee.

To the Members of the American Railway Engineering Association:

Your Committee last year called attention to the practical difficulties of distinguishing between various species of Southern Yellow Pine, and to the fact that it has been generally recognized that it makes little practical difference from what species of pine a structural timber is cut so long as certain density requirements are met, in addition to the usual heart and sap requirements.

During the past year, after a very exhaustive series of investigations conducted by the United States Forest Service, in co-operation with the manufacturers of Southern Yellow Pine, the American Society for Testing Materials adopted a rule establishing two classes of Southern Yellow Pine, called "dense" pine and "sound" pine. This rule is practically that formulated by the United States Government and used in the purchase of timber for the Panama Canal. Since the adoption of the rule by the American Society for Testing Materials, the same has been endorsed and accepted as a whole by the Southern Pine Association, which includes the largest manufacturers of Southern Yellow Pine. Your Committee has followed the investigations made by the Government and by the American Society for Testing Materials, and has co-operated with the committees who considered these matters, and is strongly of the opinion that the rule as adopted offers a very practical solution of an exceedingly vexing problem. The detailed investigations made by the Government, upon which the new rule was based, are fully set forth in the 1915 report of the Committee of the American Society for Testing Materials, and those interested are respectfully referred to that report for detailed information.

After a careful consideration of the matter, your Committee has approved the new rule, and presents the same to the members of this Association, with the recommendation that the same be adopted as standard.

Attention is called to the fact that two classes of Southern Yellow Pine are established—dense pine and sound pine. These terms replace the botanical designations hitherto used, namely, longleaf and shortleaf pines. The terms dense and sound pines refer strictly to qualities of density and weight in their relation to strength values. Fig. 1 illustrates in a striking manner the necessity for some designation other than the botanical designation. The four wood samples shown in this figure are botanical longleaf pine.* It will be noted that the modulus of rupture in these four pieces varies from 11,110 to 4,660 lbs. The upper two pieces fall within the new grade "dense pine," and the lower two pieces fall within the grade "sound pine."

The adoption of the new grading rule by this Association would not change any of the standard rules for structural timbers, except that in the specifications as now printed in the Manual, the term "longleaf" would be changed to read "dense pine" and the term "shortleaf" to read "sound pine." The classification "dense pine" will include all of the high-grade pieces of what has hitherto been called "longleaf" and exclude the pieces of longleaf pine of inferior strength. It would also include a comparatively small percentage of the strongest pieces of shortleaf pine. At the present time, the standard specification for structural timbers as printed in the Manual designate that certain timbers shall be longleaf and that others may be shortleaf. There has been no method, however, which could be used to determine whether any particular timber was longleaf or shortleaf. The new rule ignores the difficult problem of determining the botanical species and substitutes therefor a basis of physical measurement which can be readily applied and which will not be subject to personal opinion or individual judgment.

DEFINITION FOR SOUTHERN YELLOW PINE.†

Southern Yellow Pine.—This term includes the species of yellow pine growing in the Southern States from Virginia to Texas, that is, the pines hitherto known as longleaf pine (*Pinus palustris*), shortleaf pine (*Pinus echinata*), loblolly pine (*Pinus taeda*), Cuban pine (*Pinus heterophylla*) and pond pine (*Pinus serotina*).

Under this heading two classes of timber are designated: (a) dense Southern Yellow Pine, and (b) sound Southern Yellow Pine. It is understood that these two terms are descriptive of quality rather than of botanical species.

(a) Dense Southern Yellow Pine shall show on either end an average of at least six annual rings per inch and at least one-third summerwood, or else the greater number of the rings shall show at least one-third summerwood, all as measured over the third, fourth and fifth inches of a radial line from the pith. Wide-ringed material excluded by this rule will be acceptable, provided that the amount of summerwood as above measured shall be at least one-half.

The contrast in color between summerwood and springwood shall be sharp and the summerwood shall be dark in color, except in pieces having considerably above the minimum requirement for summerwood.

In cases where timbers do not contain the pith, and it is impossible to locate it with any degree of accuracy, the same inspection shall be

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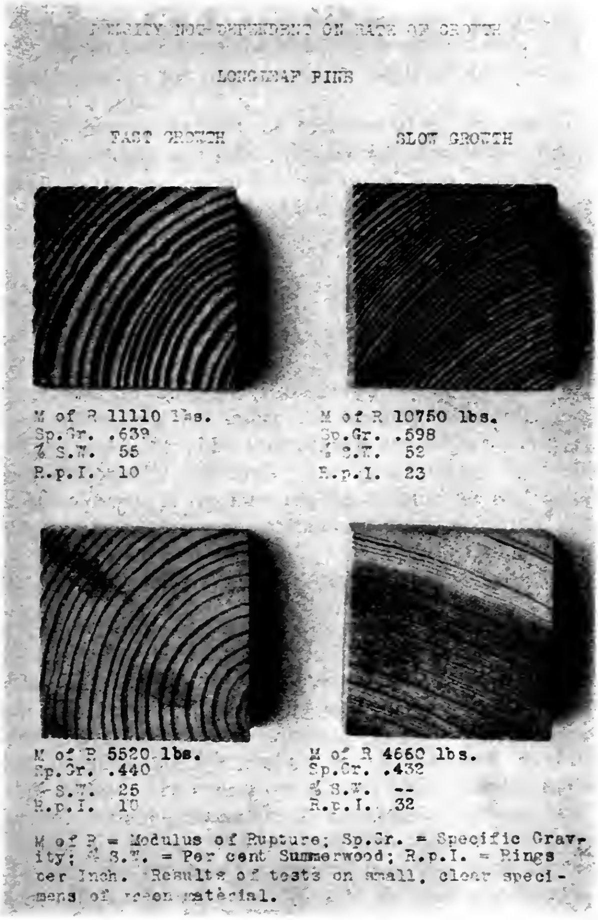
*The wood samples and data are furnished through the courtesy of the United States Forest Service.

†Adopted and copyrighted by the American Society for Testing Materials, August, 1915. Reprinted by permission.



M of R = Modulus of Rupture; Sp.Gr. = Specific Gravity; % S.W. = Per cent Summerwood; R.p.I. = Rings per Inch. Results of tests on small, clear specimens of green material.

FIG. 1.

made over 3 inches on an approximate radial line beginning at the edge nearest the pith in timbers over 3 inches in thickness and on the second inch (on the piece) nearest to the pith in timbers 3 inches or less in thickness.

In dimension material containing the pith but not a 5-in. radial line, which is less than 2 by 8 in. in section or less than 8 in. in width, that does not show over 16 sq. in. on the cross-section, the inspection shall apply to the second inch from the pith. In larger material that does not show a 5-inch radial line the inspection shall apply to the 3 inches farthest from the pith.

The radial line chosen shall be representative. In case of disagreement between purchaser and seller, the average summerwood and number of rings shall be the average of the two radial lines chosen.

(b) Sound Southern Yellow Pine shall include pieces of Southern pine without any ring or summerwood requirement.

GRADING RULES FOR HEMLOCK LUMBER.

In last year's report (Bulletin 174, page 907), we presented tentative Grading Rules for Hemlock Lumber. These have been discussed during the past year, and certain changes are herewith suggested.

It is recommended that under the heading, "General Instructions," paragraphs 3, 4 and 6 should be omitted, and that paragraphs 4, 5, 7, 8 and 9 should be renumbered respectively, 3, 4, 5, 6 and 7. With these three omissions, the Committee recommends the adoption of the Grading Rules for Hemlock Lumber this year as standard practice.

SPECIFICATIONS FOR BRIDGE TIMBERS TO BE CREOSOTED.

Your Committee has been at work, in co-operation with the American Society for Testing Materials, with a view of preparing specifications for bridge timbers to be creosoted. The Committee of the American Society for Testing Materials made a tentative recommendation last year, which your Committee, however, is unable to endorse. It is believed that specifications for timbers to be creosoted, as far as their quality and strength are concerned, should be similar to timbers to be used untreated, with the exception of the relation of heart- and sapwood. Where timbers are to be creosoted, a certain amount of sapwood is desirable; in fact, the recent investigations made on some of the German Government railways seem to indicate that the ideal condition is obtained when a complete ring of sapwood surrounds the heartwood. Keeping these factors in mind, the Committee has prepared the following specifications, which are presented as information.

In formulating these new specifications the Committee has simply taken the standard specifications for structural timber as printed in the Manual, and omitted all reference to the requirements as to heartwood and heart face, and has substituted for the heart requirements a clause permitting sapwood. The most recent investigations have plainly shown that sapwood and heartwood have exactly the same strength, with equal moisture content. The suggested specifications therefore practically represent the standard as printed in the Manual, with the exception that it now gives a specification which will give the best results when chemically treated.

PROPOSED SPECIFICATIONS FOR SOUTHERN YELLOW PINE BRIDGE AND TRESTLE TIMBERS TO BE TREATED.

(TO BE APPLIED TO SINGLE STICKS AND NOT TO COMPOSITE MEMBERS.)

General Requirements.

1. Except as noted, all timber shall be sound, sawed to standard size, full length, square cornered and straight; close grained and free from defects such as injurious ring shakes and cross grain, unsound or loose knots, knots in groups, decay, or other defects that will materially impair its strength.

Standard Size.

2. "Rough timbers sawed to standard size" means that they shall not be over ¼-inch scant from the actual size specified. For instance, a 12 by 12-inch timber shall measure not less than 11¾ by 11¾ inches.

Standard Dressing.

3. "Standard dressing" means that not more than ¼ inch shall be allowed for dressing each surface. For instance, a 12 by 12-inch timber after being dressed on four sides shall measure not less than 11½ by 11½ inches.

Quality.

4. All timbers shall be dense pine as defined by the American Society for Testing Materials' rule for dense pine.*

Stringers.

5. Knots greater than 1½-inch in diameter will not be permitted in any section within 4 inches of the edge of the piece, but knots shall in no case exceed 4 inches in their largest diameter. There shall be no restrictions as to the amount of sapwood allowed.

Caps and Sills.

6. Shall be free from knots over 2½ inches in diameter. There shall be no restrictions as to the amount of sapwood allowed.

Posts.

7. Shall be free from knots over 2½ inches in diameter. There shall be no restrictions as to the amount of sapwood allowed.

Longitudinal Struts and Girts.

8. Shall be square cornered and sound and shall be free from large knots or other defects that will materially injure their strength. There shall be no restrictions as to the amount of sapwood allowed.

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*In case the definition for "dense pine" is adopted by this Association, the reference to "definition" should be changed.

Longitudinal X Braces, Sash and Sway Braces.

9. Shall be square cornered and sound and shall be free from any large knots or other defects that will materially injure their strength. There shall be no restrictions as to the amount of sapwood allowed.

Ties and Guard Rails.

10. Shall be free from any large knots or other defects that will materially injure their strength. There shall be no restrictions as to the amount of sapwood allowed.

SUMMARY.

In summarizing the work of the Committee, we would recommend:

1. That the definition for quality of Southern Yellow Pine be adopted as standard.

2. That the Grading Rules for Hemlock Lumber, as printed in Bulletin 174, be adopted as standard, with the omissions as indicated in this report.

Your Committee suggests as subjects for investigation during the coming year:

1. Further investigation with reference to specifications for Douglas fir timbers, to be carried on in co-operation with the American Society for Testing Materials and other organizations.

2. Investigation and report with reference to the lasting power of pines and other coniferous woods, as influenced by the resin content of timber. This work to be done in co-operation with the American Society for Testing Materials and other engineering bodies and the Federal Government Bureau now engaged in extensive investigations dealing with this subject.

3. The revision of specifications for rules already issued. Several organizations or manufacturers have materially simplified their rules, or are in the process of doing so. The Committee believes that some of the rules already adopted are too cumbersome, and that with further work very material shortening may be obtained which will result in a wider application to maintenance of way work.

Respectfully submitted,

COMMITTEE ON GRADING OF LUMBER.

REPORT OF COMMITTEE XI—ON RECORDS AND ACCOUNTS.

W. A. CHRISTIAN, *Chairman;*
F. J. BACHELDER,
LESTER BERNSTEIN,
W. S. DANES,
G. D. HILL,
HENRY LEHN,
J. H. MILBURN,
J. W. ORROCK,
J. C. PATTERSON,
H. C. PHILLIPS,
M. C. BYERS, *Vice-Chairman;*
J. H. PRIOR,
J. H. REINHOLDT,
R. C. SATTLEY,
GUY SCOTT,
HUNTINGTON SMITH,
H. M. STOUT,
FRANK TAYLOR,
J. M. WEIR,
W. D. WIGGINS,
Committee.

To the Members of the American Railway Engineering Association:

The Board of Direction assigned the following subjects to your Committee:

(1) *Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.*

(2) *Report on the use of small forms on cardboard or other suitable material for use of fieldmen in making daily reports, to the end that supervision may be facilitated and efficiency encouraged.*

(3) *Continue the study of feasible and useful subdivisions of Interstate Commerce Commission Classification Accounts Nos.* 202 *and* 220, *with a view of securing uniformity of labor costs, separating the items in accordance with such forms as are promulgated by the Interstate Commerce Commission during the year.*

(4) *Investigation of methods for reproducing maps and profiles on drawing linen for permanent record.*

The following Sub-Committees were appointed to deal with the several subjects assigned:

Sub-Committee (1): G. D. Hill, Chairman; F. J. Bachelder, W. S. Danes, J. H. Milburn, J. W. Orrock, J. C. Patterson, Frank Taylor.

Sub-Committee (2): H. C. Phillips, Chairman; Guy Scott, J. M Weir, R. C. Sattley, W. D. Wiggins.

Sub-Committee (3): Henry Lehn, Chairman; Lester Bernstein, J. H. Reinholdt, Huntington Smith, H. M. Stout.

Sub-Committee (4): W. A. Christian. Chairman; M. C. Byers, J. H. Prior.

A meeting of the General Committee was held in Chicago, on November 19, 1915, the following members being present: W. A. Christian, Chairman; Lester Bernstein, J. H. Reinholdt, Huntington Smith, H. M. Stout, W. D. Wiggins.

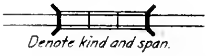
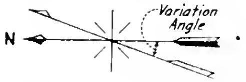
The following report is respectfully submitted:

(1) REVISION OF MANUAL.

After careful study of this subject, your Committee has no further changes to suggest in the Manual other than the recommendations submitted in its report of 1915.

The Committee hesitates to recommend any changes in the adopted Conventional Signs for the reason that the pamphlet has had wide distribution and the symbols shown therein have been extensively used on maps, profiles and other drawings already submitted to the Interstate Commerce Commission.

However, the Committee submits below a list of symbols which it considers preferable to those now in the Manual, and desires an expression from the Association whether these symbols should be substituted for those adopted last year:

Railroad tracks—old tracks to remain..........	Use heavy black line
Foreign tracks	Use fine black line
Company property line to be "Company Property Boundary Line"	External ━━ . . ━━ . . Internal —— . . —— . .
Track pan....................................	(Track Pan.)
Use symbol of trestle..........................	
True magnetic meridian	
Pipes	(Ownership, size and kind.)

Your Committee submits the following alphabetically arranged index, covering the list of Conventional Signs:

CONTENTS.

(2) USE OF SMALL FORMS ON CARDBOARD.

Your Committee reports progress on this subject, and hopes to be able to make a report thereon next year.

(3) SUB-DIVISIONS OF INTERSTATE COMMERCE COMMISSION ACCOUNTS.

Nos. 202 and 220.

Since the Interstate Commerce Commission have not promulgated any new forms having a bearing on Accounts Nos. 202 and 220, your Committee makes no further recommendations other than submitted in 1915.

(4) METHODS FOR REPRODUCING MAPS AND PROFILES ON DRAWING LINEN FOR PERMANENT RECORD.

The best known reproductions of tracings are as follows:

Ferro Prussiate—White line on Blue ground.
Pellet—Blue lines on White ground.
Ferro-gallic—Black lines on White ground.
Brown—White lines on Brown ground.
The photographic process.
The hectograph process.
The planograph process.
The lithographic process.

The first four are too well known to need any explanation. The photographic process is quite varied, but the one most generally used is where the photograph is made positive on paper without the use of the so-called negative. The hectographic process is one where the various colors of inks are used, and when applied to pads the ink being absorbed therein. The planograph process is one where the image is reproduced negatively on a coated plate and treated in chemical baths, allowing the high and low lights to stand in relief. This plate may be used in a printing press. The lithographic process is the latest in this country, and on account of its cheapness it is used for the reproduction of original tracings. It being a dry process throughout, the reproductions are naturally true to scale of the original.

In explaining this latter process, it might be said that a plate of any smooth substance, such as metal, glass or linoleum, is coated with a gelatine in which are placed certain chemicals after the gelatine is melted. To apply this gelatine the plate is placed in an inclined position and covered with the gelatine. After the plate is entirely covered, it is put in a horizontal position and allowed to cool. The original tracing is put in a vacuum frame and a print is made similar to a blueprint. This print then is applied to the gelatine plate, it being removed as fast as applied. There appears on the gelatine the image of the original in dark blue lines caused by the action of the chemical of the print and gelatine. Ink is then applied to the gelatine and adheres in proportion to the density of the lines of the original. This is the most important thing in this process. In other words, the reproductions are only good if the lines of the original are opaque. This process should be worked in a cool temperature. Reproductions by this process may be made on any material. Any portion of the original not wanted in the reproduction can be removed either on the so-called blueprint or plate. Any additions may be made in sections by making another print of same and pasting it on original blueprint before applying to pad.

Where originals, as in railroad alinement maps, are very long and wide, it is possible to reproduce these in any desired width or length. It is quite common on right-of-way sheets to reproduce the land schedules in their proper places, originals having been made on a typewriter using a black ribbon and having a black carbon reversed on the back of the original, thereby making letters opaque.

CONCLUSION.

Your Committee recommends that this report be accepted as information.

RECOMMENDATIONS FOR NEXT YEAR'S WORK.

(1) Prepare standard specifications for maps and profiles.

(2) Study various methods of reproducing maps and profiles on tracing linen for permanent records.

(3) Study the Interstate Commerce Commission classifications of "Investment in Road and Equipment" and "Operating Expenses." and report upon any desired changes.

(4) Make a comprehensive study of the problem of recording and reporting the cost of additions and betterments.

(5) Make a comprehensive study of the valuation forms now in use in America and recommend standard forms for both field and office use.

Respectfully submitted,

COMMITTEE ON RECORDS AND ACCOUNTS.

REPORT OF COMMITTEE XII—ON RULES AND ORGANIZATION.

G. D. Brooke, *Chairman;*	F. D. Anthony, *Vice-Chairman;*
L. L. Beal,	J. B. Carothers,
C. Dougherty,	A. J. Himes,
Ralph Budd,	R. P. Black,
S. E. Coombs,	B. Herman,
Jos. Mullen,	E. T. Reisler,

Committee.

To the Members of the American Railway Engineering Association:

INSTRUCTIONS.

The following instructions were assigned for the work of the past year:

1. *Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.*
2. *Report on clearance for maintenance of way structures under assignment from the Committee on Maintenance of the American Railway Association, conferring with other committees.*
3. *Continue the formulation of rules for the guidance of field parties.*
4. *Continue the study of science of organization.*

REVISION OF MANUAL.

After a careful review of the subject-matter in the Manual of 1911 and the supplements thereto, the following changes are recommended:

Omit rule 17, applying to Signal Supervisors, shown in the Supplement to Manual of 1913, which follows:

17. They must keep all interlocking pipe lines and trunking free from grass and weeds and all switches, frogs and movable parts of interlocking plants free from snow, ice and other obstructions.

In the Supplement to Manual of 1912, change rule 22 as follows:

Present Rule:

In making temporary connections in main tracks an old rail shall be cut and fastened to the new rail, using compromise joints where necessary.

Proposed Rule:

In making temporary connections in main tracks a new rail shall be cut and fastened to the old rail, using compromise joints where necessary.

This change is recommended with the view of preventing injury to the new rail by having the ends at uneven joints battered where connected to the old rail. The short piece of new rail can be used over and over again by moving it ahead.

In the Supplement to Manual of 1913 under "Switches and Frogs," substitute the word *turnouts* in Rules 32 and 34 for the word *switches,* and in Rule 33 for the words *switches and frogs.* These rules will then take this form:

32. Turnouts must be placed in accordance with the standard plans and as located by the Engineer.

33. Turnouts must be kept well lined and in good order. Particular care must be taken to maintain good surface through turnouts.

34. Turnouts must be inspected frequently to see that they are in working order and that all nuts, bolts and other fastenings are in place and properly tightened. Broken or damaged parts must be renewed promptly.

Omit the last sentence of Rule 39, under "Guard Rails," which follows:

The tops of the guard rails must be level with the tops of the main rails and must be securely held in place.

The rule will then take this form:

39. Frogs must be protected by guard rails, constructed and placed in accordance with the standard plans.

To the General Notice of the Rules Governing Construction Department Employés, Supplement to Manual of 1914, add the following rule, which has been adopted for the maintenance of way employés:

12. The use of intoxicants by employés while on duty is prohibited. Their use, or the frequenting of places where they are sold, is sufficient cause for dismissal.

Under "Organization," in the same supplement, after *Resident Engineer,* add *(or Title).*

CLEARANCE FOR MAINTENANCE OF WAY STRUCTURES.

This subject is covered in a separate report.

RULES FOR GUIDANCE OF FIELD PARTIES.

Progress is reported.

SCIENCE OF ORGANIZATION.

Progress is reported.

RECOMMENDATIONS FOR NEXT YEAR'S WORK.

Your Committee recommends that the following subjects be reassigned for next year:

1. Continue the formulation of rules for the guidance of field parties.
2. Continue the study of science of organization.

Respectfully submitted,

COMMITTEE ON RULES AND ORGANIZATION.

*PRELIMINARY REPORT OF COMMITTEE XII—ON RULES AND ORGANIZATION.

G. D. Brooke, *Chairman;*	F. D. Anthony, *Vice-Chairman;*
L. L. Beal,	J. B. Carothers,
C. Dougherty,	A. J. Himes,
Ralph Budd,	R. P. Black,
Jos. Mullen,	*Committee.*

To the Members of the American Railway Engineering Association:

INSTRUCTIONS.

The instructions to your Committee on Rules and Organization for the work of the current year included the following:

(2) Report on clearance for maintenance of way structures under assignment from the Committee on Maintenance of the American Railway Association, conferring with other committees.

Early in May the Committee received a request from President Trimble that the report on this subject be available for special consideration of the Board of Direction not later than October 1, in order that the Association's report might be placed in the hands of the Committee on Maintenance of the American Railway Association as early as practicable.

COMMITTEE MEETINGS.

Three meetings of the Committee were held for the consideration of the subject of clearances, the dates, places of meeting and attendance of which are given below:

Chicago, Ill., January 16, 1915: G. D. Brooke, *Chairman;* A. M. Burt, S. E. Coombs, C. Doughtery, Jos. Mullen, E. T. Reisler.

Cincinnati, Ohio, May 28, 1915: G. D. Brooke, *Chairman;* L. L. Beal, J. B. Carothers, C. Dougherty, B. Herman, Jos. Mullen, E. T. Reisler.

Detroit, Mich., July 16 and 17, 1915: G. D. Brooke, *Chairman;* J. B. Carothers, S. E. Coombs, C. Dougherty, B. Herman, A. J. Himes, Jos. Mullen, E. T. Reisler.

Representation from other Committees: Committee on Track: J. B. Jenkins, *Chairman;* H. B. Stuart for H. R. Safford. Committee on Iron and Steel Structures: A. J. Himes, *Chairman;* A. C. Irwin, C. E. Smith, H. B. Stuart. Committee on Electricity: S. E. Coombs for George W. Kittredge, *Chairman.* Committee on Roadway: W. M. Dawley, *Chairman;* represented by letter.

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*Not released for republication

On June 11, 1915, a communication was addressed to the Chairmen of the Committees on Roadway, Track, Buildings, Iron and Steel Structures, Electricity and Yards and Terminals, outlining the proposed work on the subject of clearances and requesting that these committees be represented at the Detroit meeting with a view of harmonizing this report with any work those committees have done pertaining to or affecting clearances. This resulted in representation from three of the committees and a communication from a fourth, as above indicated.

DATA AVAILABLE FOR STUDY.

The following sources of information have been drawn upon in determining the clearances recommended:

The Committee on Maintenance of the American Railway Association provided the Committee with two tabulated statements showing the present and recommended practices in the United States and Canada as to the clearances of high and low switchstands, platforms, signal masts, water columns, etc., as indicated by the replies to Circular No. 1335, and constituting, undoubtedly, the most complete information of the kind on record.

The information collected by the Committee on Iron and Steel Structures in connection with its study of the bridge clearance diagram and found in its reports for the years 1914 and 1915, Proceedings, Vols. 15 and 16.

An excellent article in the Railway Age Gazette of August 28, 1914, entitled "The Present Status of Clearance Legislation."

Accident reports of the Interstate Commerce Commission.

PRESENT STANDARD SIDE CLEARANCES.

An examination of Appendices B, C and D will show that the long-established horizontal clearance of 7 feet from the center line of the nearest track is losing favor. While a large number of roads still adhere to this standard for the bridge clearance diagram, and four of the roads report standards less than 7 feet, a large number report clearances greater than 7 feet, and of these, roads represented by about 30 per cent. of the mileage favor a clearance of 8 feet or more. It will be found, nevertheless, that clearances of 8 feet or more for switchstands, water columns, buildings, coal chutes, etc., in fact, for most other objects in close proximity to tracks, are now the standard practice on by far the greater number of roads embracing 75 per cent. of the mileage of the country.

With the increase in size of cars and locomotives, the roadbed and track have been strengthened to carry the greater rolling loads. This has been accomplished by heavier rail, closer spacing of ties, using a greater depth of ballast and better ballast, widening the roadbed to produce stability and constructing better ditches to drain the roadbed and track.

It was logical that along with this development the increase of standard clearances should be found advisable, and it is to be expected that the time-honored clearance of 7 feet will be used less and less as the strengthening of roadway and track to meet present-day traffic conditions progresses.

PRESENT ACTUAL SIDE CLEARANCES.

The side clearance of 7 feet for bridges and other objects along railroads was in general use 30 years ago and probably before that, and on a decreasingly small number of roads during that time a clearance less than 7 feet has been used. It is the natural outcome, therefore, that there are many clearances on a great many of the railroads of the country of 7 feet or less. On many of the Eastern roads, tunnels, bridges and other structures, multiple track systems and yards, built when clearance of from 6 to 6½ feet were considered good practice, are now in use. These small clearances are more general in the cities and closely-populated country districts where property is more valuable than in the more open country, and even if the space for increasing them was available, the cost of reconstruction would be enormous. It is at once clear that these constitute conditions which, while not altogether desirable, nevertheless are not serious obstacles to successful operation and must be made the best of in the future as they have in the past. Many of the roads which recommend clearances of 8 feet or more and have adopted them as their standards, have many restricted clearances such as are above described. There is no doubt, though, but that these roads have no present intentions of proceeding to increase these clearances, where the expenditures involved are excessive, for the sole purpose of securing the greater clearances; but when reconstruction is required on account of some other necessity or expedient the standard clearances will be adhered to. It must be clearly recognized that a large percentage of these restricted clearances must of necessity be maintained for years to come—in fact, indefinitely.

VERTICAL CLEARANCES.

It is clearly brought out in the data available that, both as to present and recommended standards, the roads are overwhelmingly in favor of a clearance of 22 feet above the top of the rail. This standard has been in general use for a number of years, and for a decade and a half comparatively few overhead structures of less clearance have been built, except where the grades of streets or other railroad tracks have made this clearance practicable. It can well be said, therefore, that the overhead clearance of 22 feet is generally accepted.

MINIMUM STANDARD CLEARANCES.

That standard clearances are advisable is well established by the general practice of the railroads of the country. That there are wide variations between the standards of the different roads is equally certain. The latter is the natural outcome of differences in geographic position and period of construction. A line in open, flat country can provide at comparatively small expense clearances which in cities or closely-settled country districts would be prohibitive. Some roads already have standards considerably in excess of the average or general practice. Other things being equal, it is axiomatic that up to certain limits, the greater a clearance the better it is, and there could be no good reason for reducing the established clearances of a road in order that they might conform to a lesser standard. The logical course, therefore, is to prescribe minimum clearances only and to place no restrictions whatever as to maximum clearances.

TRACK CENTERS.

A reference to Appendix B will indicate that the generally accepted distance between the centers of parallel main tracks is 13 feet. While a few roads favor a less distance and some others favor 14 feet, there can be no doubt but that 13 feet is the proper minimum for future construction.

COST OF INCREASING CLEARANCES.

The one principal objection to increasing present clearances of 7 feet or less is the heavy cost. Few railroads have prepared comprehensive estimates of the cost of such work, and to obtain this information for all the mileage of the country would in itself require quite heavy expenditures. The following extract from the Railway Age Gazette of August 28, 1914, contains the best general information on the subject obtainable and indicates the enormous cost of increasing clearances, both horizontal and vertical:

"Very little exact data regarding the cost of such work has been collected. Two years ago when the Martin bill was before Congress, estimates made by 115 roads, with 152,600 miles of main line, showed an approximate cost of $139,000,000 to comply with the lateral clearance requirement of 6 feet 11 inches; $135,000,000 to secure an overhead clearance requirement of 20 feet; $167,000,000 to secure a minimum distance of 12 feet 6 inches between tracks, and $5,600,000 to bring the equipment within the specified limit, or a total of approximately $450,000,000. Assuming a proportionate outlay for the entire mileage of the country, compliance with the Martin bill would cost the railways $716,000,000, or over $2900 per mile of main line.

"Estimates prepared more recently by 13 roads, with 34,895 miles of line, show a total cost of $74,857,250 to secure a minimum vertical clearance of 20 feet, or $2145 per mile for these roads. Likewise, 14 roads, with 28,736 miles of line, estimate that it would cost them $100,170,000, or $3486 per mile to secure a minimum clearance of 22 feet, while several roads considered this latter limit unpractical and made no estimate. Similar figures of the cost of meeting a laterial clearance requirement of 7 feet made by 14 roads, with 30,077 miles of line, totaled $59,136,349, or $1966 per mile. On the basis of a minimum lateral clearance of 8 feet, 12 roads, with 26,305 miles of line, estimated the cost of complying at $104,573,000, or $3975 per mile. While all the above figures are estimates, they show plainly that compliance with clearance legislation of this sort will be exceedingly expensive on any basis which may be adopted, and on the basis of the legislation so far enacted, it will not fall short of $2500 per mile for the entire country.

"Such legislation will affect not only the railways, but private industries as well. The above figures refer only to the expense that would have to be borne directly by the roads and do not include the cost of changes that would be made necessary about industrial plants, which would also reach a very high figure. One large corporation, which made a careful estimate of the cost of compliance with the proposed Martin bill, found that it would cost it alone over $1,600,000. It is entirely probable that the total cost to railways and industries would exceed $1,000,000,000."

CLEARANCE LEGISLATION.

A number of the States have passed laws prescribing horizontal and vertical clearances and in other States orders of the Railroad Commissions regulate them. Appendix E contains brief summaries of these laws and commission orders and will indicate the attitude of legislative bodies towards the subject. Attention is directed to the fact that legislatures and commissions are taking cognizance of the needs of the roads in regard to special clearances for platforms, yard tracks, etc., and of the necessity for exempting present clearances from the general rules established.

REASONS FOR INCREASED CLEARANCES.

1. Increasing safety to passengers and employés on moving trains.
2. Increasing safety to bridges and hence to trains, on account of reducing the danger of damage from shifted loads on moving trains.
3. Promoting greater efficiency in yard and road switching, as men work more freely when unhampered by objects close to the tracks.
4. Greater width of ballast and roadbed requires that objects be placed further from the center of tracks.
5. Reducing liability of damage to switchstands, water tanks, coal chutes and other appurtenances from derailed cars, shifted loads or objects projecting from trains.
6. Improving the appearance of the roadbed and track.

SAFETY OF EMPLOYÉS.

All legislation regulating clearances has been for the purpose of increasing the safety of employés riding on trains. Any future legislation of similar character will undoubtedly be passed on the same grounds. Tables 1 and 2, containing statistics taken from the Interstate Commerce Commission accident reports, are of interest in this respect. From Table 1 it will be seen that a very small percentage of the total injuries to employés is caused by coming in contact with objects over or alongside tracks, and that the tendency is for the percentage of deaths from this cause to decrease—it averaging 3.2 from 1904 to 1909, inclusive, and 2.9 from 1910 to 1914, inclusive. Table 2 gives an analysis of the deaths and injuries due to employés on trains striking objects along tracks. It will be seen that if accidents due to bridges and buildings could be eliminated the number of deaths would be small indeed.

Even a casual examination of these tables and of the other personal injury reports of the Interstate Commerce Commission will reveal that the opportunities for saving life and reducing personal injuries by increased clearances are comparatively small, and the conclusion cannot be escaped that if funds were available for the purpose of increasing the safety of employés the returns to be secured from a general increase of clearances would be very low indeed.

EQUIPMENT CLEARANCES.

During the 30 years or more that the 7-foot clearance has been the accepted standard, the size of the average box car has increased in width approximately 2 feet. The increase in the size of the average car is undoubtedly a large factor in the movement for increased side clearances. It is logical to inquire therefore whether the adoption of greater clearances will not be followed by corresponding increases in the size of cars. The answer of experience is in the affirmative. Therefore, it is the opinion of this Committee that: *Any attempt to establish a clearance diagram will be wholly futile unless there be established at the same time a corresponding maximum width for the size of railway equipment.*

Such an equipment diagram would not, of course, limit the size of locomotives or special equipment to be used entirely on the railroads owning them.

BASIS ON WHICH CLEARANCES ARE RECOMMENDED.

When a railroad selects a certain type of locomotive as its standard freight engine, the idea of replacing all the engines in service with that type is not even considered. When, in order to improve the quality of steel rails, the American Railway Association developed two new rail sections, there was no wild rush to replace all the rail in all the tracks of the country with rail of these new sections, and rails of light weight and primitive section are still doing duty on light traffic lines as they did 30 years ago. The American Railway Association has been recommending standards for the roadway, track, bridges, buildings, etc., for 15 years, but no railroad officer ever seriously thought of making these standards retroactive and rebuilding their railroads to make them conform thereto.

Is there any more reason for making clearance standards retroactive than standards for locomotives, steel rails, bridges or buildings? Why the necessity of pulling down a bridge with seven-ft. side clearance to replace it with a structure having a side clearance of eight feet, when the present structure has proven by years of service its usefulness and safety?

It is the opinion of your Committee that the clearances recommended in this report should be applied in the same manner as other standard practices recommended by this Association; that there are absolutely no grounds for presupposing that they will become retroactive; that they apply only to new construction, and it is on this basis alone that the recommendations are made.

CLEARANCES UNDER SPECIAL CONDITIONS.

The clearances recommended apply to main tracks, passing tracks, running tracks and yard tracks in general to be constructed in the future. It is clearly recognized, moreover, that there are many special situations in new construction work where these clearances are not practicable—in many of them they are economically impossible. Your Committee therefore submits below a partial list of such situations with the recommendation that they and others similar to them be treated individually and decided each on its own merits.

CONCLUSIONS.

(1) This subject was assigned to your Committee about December 1, 1914, and the latter part of April, 1915, the Committee was requested to hurry its report so as to place it in the hands of the Board of Direction by October 1.

(2) A greater length of time than that allotted to the Committee would have permitted a more exhaustive treatment of the subject.

(3) With the time and the material available the Committee has given the subject careful study. Because of the importance of the subject, however, and the probability of further discussion, it is recommended that the study be continued next year.

(4) The clearances recommended are based on the present general practice as to dimensions of equipment.

(5) Any attempt to establish a clearance diagram will be wholly futile unless there be established at the same time a corresponding maximum width for the size of equipment.

(6) The logical course is to prescribe minimum clearances only and to place no restrictions whatever as to maximum clearances.

RECOMMENDATIONS.

The following minimum clearances are recommended for new construction and reconstruction, subject to the exceptions which are given below:

Objects.	*Minimum Clearance.*
(1) High Switchstands—*for new construction.*	From center of track to nearest point of stand or target—8 ft.
(2) Intermediate Switchstands—*for new construction.*	From center of track to nearest point of stand or target—8 ft.
(3) Low Switchstands—*for new construction.*	From center of track to nearest point of stand, 8 ft., except where, on account of stands being placed between parallel tracks, less clearance is required. In such cases the combined height of the stand and lamp to be not more than 2 ft. above top of the rail.
(4) Signal Stands—*for new construction.*	From center of track to nearest point of stand or target—8 ft. From center of track to center of mast—10 ft.
(5) Low Platforms—*for new construction.*	3 in. to 6 in. high.......5 ft. 6 in. high.......5 ft. 7 in. to 8 in. high.......5 ft. 6 in. 9 in. to 12 in. high.......5 ft. 6 in. 12 in. to 18 in. high.......6 ft.
(6) High Platforms—*for new construction.*	3 ft. to 4 ft. high—8 ft., or to conform to clearance diagram. 4 ft. to 7 ft. high—8 ft.
(7) Platform Shelters—*for new construction.*	8 ft., or to conform to clearance diagram.
(8) Mail Cranes—*for new construction*—Pouch not hung.	8 ft. from center of track to nearest point of crane. (From 3 ft. above to 16 ft. above rail.)
Mail Cranes—*for new construction*—Pouch hung.	6 ft. from center of track to nearest point of pouch. (From 3 ft. above to 16 ft. above rail.)
(9) Water Columns—*for new construction.*	From center of track to nearest point of column—8 ft.
(10) Coal Chutes—*for new construction.*	From center of track to nearest point of apron when not in use—8 ft. From center of track to nearest point of structure—8 ft.

Objects.	*Minimum Clearance.*
(11) Tanks and Tank Spouts—*for new construction.*	From center of track to nearest point of spout when not in use—8 ft. From center of track to nearest point of structure—8 ft.
(12) Bridge Diagrams—*for new construction.*	Horizontal width, 16 ft. from 4 ft. above to 16 ft. above top of rail; top horizontal width—8 ft.
(13) Parallel Tracks—*for new construction.*	Between parallel tracks on tangent—13 ft. On curves a correction per degree of curve should be made for overhang.
(14) General Clearance Diagram—*for new construction.*	Clearance diagram shown on page 435 is recommended.

EXCEPTIONS TO WHICH RECOMMENDED CLEARANCES WILL NOT APPLY.

(1) Grade crossing elimination work in cities.

(2) Separation of grades in new construction work in cities or other restricted situations.

(3) Loading platforms along sidetracks at freight houses, warehouses, piers, etc.

(4) Doors of engine houses and other buildings, the design of which makes the recommended clearances impracticable.

(5) Coach or other yards where the available space is very restricted.

(6) Reconstruction work when the physical conditions make the recommended clearances impracticable.

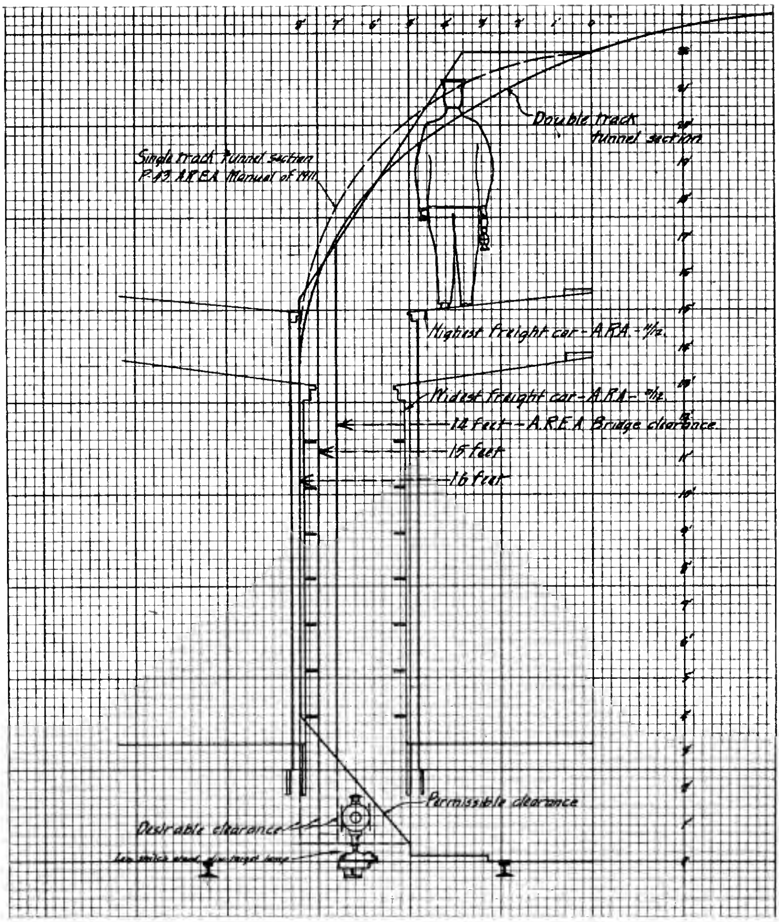
(7) Platforms at coach floor level in subways and other similar situations.

(8) Overhead clearances on tracks used exclusively for passenger service.

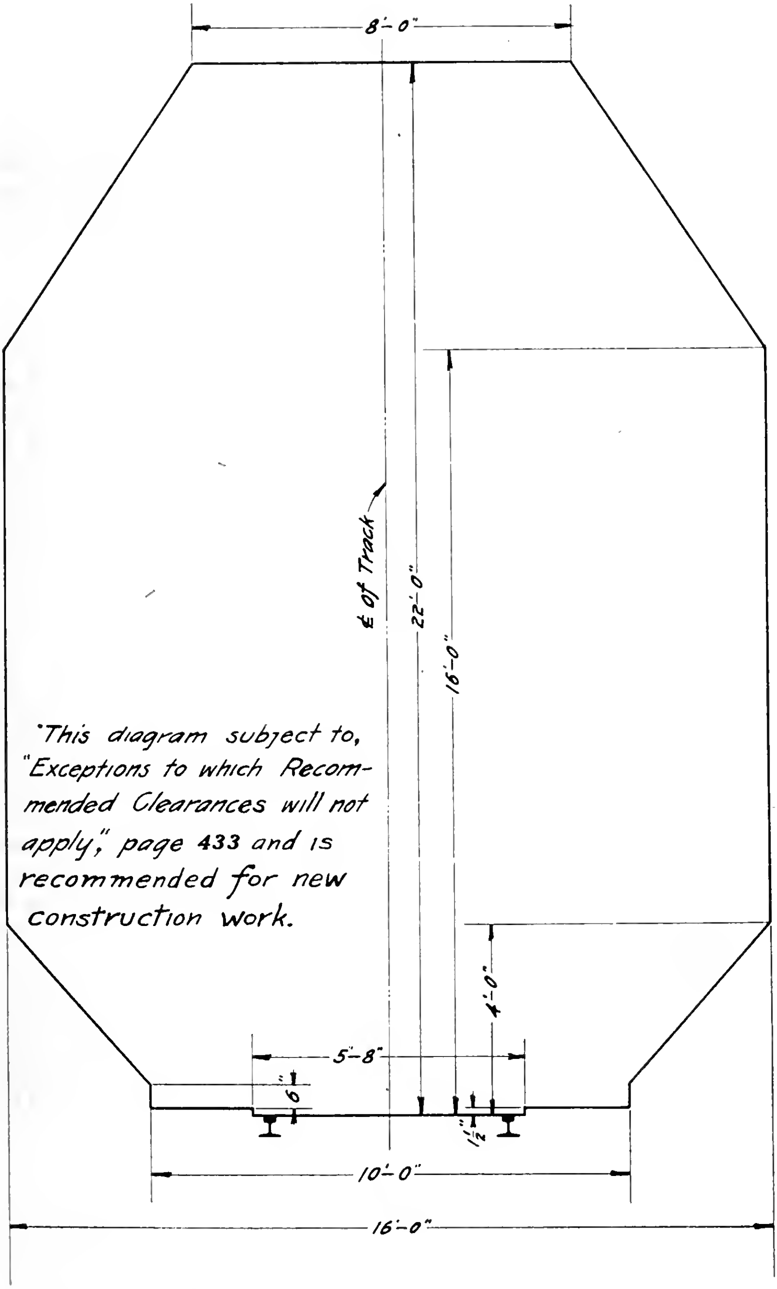
(9) Other special situations requiring special clearances.

Respectfully submitted,

COMMITTEE ON RULES AND ORGANIZATION.



Proposed Standard Clearances.



"This diagram subject to, "Exceptions to which Recommended Clearances will not apply," page 433 and is recommended for new construction work.

Proposed General Clearance Diagram.

TABLE 1.

ACCIDENTS TO EMPLOYES COMING IN CONTACT, WHILE RIDING ON CARS, WITH OVERHEAD BRIDGES, TUNNELS OR ANY SIGNAL APPARATUS, OR ANY FIXED STRUCTURE ABOVE OR AT SIDE OF TRACKS—1904 TO 1914.

Per cent. means per cent. of total casualties from all causes for the year.

	Killed	Per Cent.	Injured	Per Cent.
1914	89	3.5	1490	2.9
1913	94	3.2	1835	3.2
1912	77	2.6	1523	3.1
1911	78	2.4	1523	3.2
1910	96	2.8	1377	2.0
1909	76	3.1	1229	2.4
1908	110	3.3	1353	2.0
1907	134	3.1	1591	2.5
1906	132	3.4	1497	2.7
1905	92	2.8	1185	2.5
1904	116	3.4	1210	2.8

Taken from Interstate Commerce Commission Accident Bulletin.

TABLE 2.

ACCIDENTS TO EMPLOYES YEARS ENDED JUNE 30, 1913 AND 1914, CASUALTIES DUE TO COMING IN CONTACT, WHILE RIDING ON CARS, WITH OVERHEAD BRIDGES, SIGNAL APPARATUS, AND ANY FIXED STRUCTURE ABOVE OR AT SIDE OF TRACK.

Objects Struck	Killed		Per Cent.		Injured		Per Cent.	
	1913	1914	1913	1914	1913	1914	1913	1914
1. Switch Stands	4	6	4.3	6.7	381	334	20.7	22.5
2. Water Columns	3	6	3.2	6.7	147	119	8.0	7.4
3. Mail Cranes	3	0	3.2	0.0	53	55	3.0	3.7
4. Buildings (at side of or inclosing track)	22	13	23.6	14 6	234	191	12.8	12.9
5. Bridges, side	17	17	18.3	19.1	101	94	5.5	6.4
6. Bridges, overhead	31	22	33.3	24.7	278	198	15.1	13.4
7. Tunnels	1	2	1.1	2.3	6	10	0.3	0.7
8. Overhead Wires	2	6	2.2	6.8	140	106	7.6	7.2
9. Poles	2	5	2.2	5.6	222	150	12.1	10.1
10. Miscellaneous	8	12	8.6	13.5	273	233	14.9	15.7
Total	93	89	100.0	100.0	1835	1490	100.0	100.0

Appendix A.

STATEMENT CONCERNING A PROPOSED SPECIFICATION FOR MINIMUM HORIZONTAL CLEARANCE FOR RAILWAY STRUCTURES.

Made before the Meeting of the Committee on Rules and Organization, held at Detroit, July 16, 1915.

By A. J. Himes.

Any opinion as to what the specified minimum clearance shall be should rest on some definite basis, and in order that my vote in favor of 8 feet from the center line of the main track may be properly understood, and by way of contribution to the discussion, I would make the following comments:

1. It seems reasonable to assume that when a body of expert Engineers is requested to make an official recommendation on a matter of engineering, it is expected that that recommendation shall be founded on the experience, observation and judgment acquired in the practice of engineering. It is not expected that the recommendation shall be founded on questions of policy, finance or politics. It is of small moment whether or not the recommendation be finally adopted by those to whom it is made. For those making the recommendation it is enough that the recommendation shall embody the widest and the best professional experience and judgment available. With this in mind there should be eliminated from the discussion all reference to the effect on bodies, political or otherwise, of that recommendation. If those to whom the recommendation is made have reason to believe that its effect in certain quarters might be prejudicial to the interests of the railways, they can be trusted to withhold it from publication.

2. In seeking for a substantial basis for a recommendation, our thoughts turn first to the prominence held in current thought by the subject of safety. We are led to inquire in what manner a limit to the minimum horizontal clearance can result in the saving of life. Statistics available, referring particularly to the August issue of the Railway Age Gazette for 1914, indicate that the number of accidents per annum resulting from contact with objects located near the side of a train is exceedingly small whether viewed from the consideration of the number of accidents per mile of railway operated; per number of train movements; in terms of resulting loss or in the total number of fatalities.

Turning back a moment to a consideration of the probable expense of establishing a minimum clearance that would prevent all such accidents, we find at once that the saving in life per thousand dollars of investment would be so exceedingly small that wise management would immediately turn to some more promising means of conserving life. For instance, it is very certain that a greater number of persons can be saved from contact with lateral obstructions by proper training and discipline of employés than can be prevented by any practicable widening of the clearance diagram. It is also manifestly apparent that the amount of money which would be required to widen all horizontal clearances throughout the country 1 foot or more would, if invested in some efficient method of preventing trespass, effect a very much greater saving of life.

I would, therefore, suggest that the Committee prepare some statistical statement showing the number of lives lost in various ways throughout the year as an indication of the most fruitful field in which to expend our efforts in securing personal safety; also, insofar as may readily be possible, a statement of the probable expenditure per life saved in the several possible fields of effort.

These considerations seem to indicate that the general question of saving life is not the point of view from which it was intended that this Committee should approach the subject. Looking further, we find that the subject relates most intimately to the maintenance of railway structures and to new construction, and here it appears that there has been confusion in the discussion. Arguments are advanced on both sides without a clear understanding of the distinction. Specifications have been formerly written in order that structures might be constructed in accordance therewith. It was from this point of view that the Specifications for Iron and Steel Structures of this Association were written. It happens naturally that maintenance officers consider these specifications with reference to problems of maintenance. However, the two subjects are very distinct and should be considered separately.

As a matter of construction no very great difficulty and no enormous expense would be incurred in providing generally in new structures a minimum lateral clearance of 8 feet from the center line of track.

It is a fact that the present standard clearance of 7 feet was adopted about 30 years ago. It is also a fact that during that period the average width of railway equipment has materially increased. Assuming that a horizontal clearance established 30 years ago was wisely selected, that clearance must be insufficient at the present time. Past records indicate very clearly that 7 feet was sufficient for all purposes, unquestionably prior to any material increase in width of equipment. At the present time the sufficiency of a 7-foot clearance is under discussion. It is a fact that a man swinging from the side of a wide box car can very readily come in contact with objects distant not more than 7 feet from the center line of track. Whether or not the man has any excuse for being in such a position is a question of another sort with which this Committee is not called upon to deal.

In view of these facts it seems that an ordinary display of good sense would require that the clear space between the equipment and the fixed objects along the track should be approximately the same as when the present clearance diagram was first established. A minimum distance of 8 feet from the center line of track will, at the present time, provide that clear space.

Some discussion has been given to the possibility of growth of equipment. That question has been disposed of by the resolution already passed by the Committee and need not be considered here.

Taking up the question of railway maintenance, it appears that current thought is much confused. What is needed for maintenance purposes is not a specification but a dictum that shall determine whether or not a given space is safe. This is commonly treated as a matter of opinion. People differ in their opinions and maintain their differences with great force, but opinions maintained with vehemence are frequently wrong. Whether or not a minimum horizontal clearance of 7 feet is safe is a question of fact, and should be determined by experience and statistics and in no other manner.

When talking about safety one must have in mind that safety has various degrees. Absolute safety does not exist in this world. Comparative safety is quite common. Death is the certain end of all human beings. Yet statistics are so complete that mortuary tables have been compiled on which life insurance companies do a business, which in all human affairs is regarded as exceedingly safe. The safety of railway travel is so great that practically all companies writing accident policies insert a clause whose effect is to double the payments to the injured, where the injury is sustained while riding in a public conveyance. This has been made possible because of the small number of accidents through which injuries are sustained while traveling.

In the same manner it can be stated with certainty that safety with the present standard side clearance is very great, and that the chances that any one individual may suffer injury from contact with objects 7 feet from the center of the track are very small.

It is also a fact that to increase the present existing lateral clearance by another foot throughout the whole country would involve an enormous expenditure entirely out of proportion to the resulting increase of safety.

In the light of these facts it is my conclusion that insofar as maintenance is concerned the only possible duty of this Committee in this matter would be to recommend a rule stating what lateral clearance shall be regarded as safe. I do not say that such a rule should be recommended. Personally, I do not think that any such rule is needed. I believe that there is no occasion for disturbing structures whose present clearance is 7 feet. I do not believe that the public, the trainmen, or the legislative bodies will insist on an increase of present clearances beyond 7 feet unless it be in cases involving only a moderate expenditure. It is probable that numerous instances can be found throughout the country where clearances less than 7 feet exist, and such cases should be given special consideration, treating each individual case according to its merits.

People who are charged with the duty of directing the efforts and safeguarding the lives of multitudes of men must necessarily recognize the fact that all industrial occupations are hazardous to a greater or less degree. Painters are not barred from plying their trade because one of their number occasionally falls from a scaffold and is killed. Structural iron workers are not forbidden to pursue their vocation because of the dangers incident to the driving of rivets and handling of materials at the dizzy heights of tall buildings.

Neither are we barred from operating railways because of the hazards involved in the business. We are under obligations to remove, so far as possible, conditions which render the occupation of railroading hazardous.

Whether or not a given condition is hazardous can be determined with greatest certainty by statistics. If statistics show that a certain number of lives are lost per annum because of an existing condition, we should seek to overcome that condition. If in attempting to do so, we find that the effort or the expenditure is so very great that a similar effort or expenditure, if applied in some other direction, will effect the saving of a very much greater number of lives, we would then be remiss in our duty should we devote that effort and expenditure to a service that would yield the smaller return.

To illustrate the crudity of the thought that any large expenditure for the saving of life should be made unhesitatingly regardless of economic conditions and regardless of the number of lives saved, I have in mind a certain instance where several millions of dollars were expended in the elimination of railroad-highway grade crossings. The loss of life due to these grade crossings for the preceding ten years probably did not average more than one life per year. The year after the work was completed a local guardian of the public peace and safety, a policeman, deserted his accustomed beat and climbed above the street to the railroad tracks and was killed by a passing train.

Another story was told in the newspapers some years ago about how a soldier, returning from a campaign in the Philippines, fell from a chair in his own home and broke his neck.

These two incidents, if interpreted soberly and intelligently, mean simply this, that where the number of accidents is very low these accidents cannot be attributed wholly and primarily to the nominal conditions which appear to have been their cause.

A large number of accidents following one another at comparatively frequent intervals would indicate that certain conditions were responsible and that their elimination would effect a saving in life. Where the accidents occur at rare intervals it may be true that the elimination of some existing condition would occasionally save a life, but it does not mean that all such accidents will be wholly prevented.

In conclusion, therefore, I would emphasize the fact that in voting for a lateral clearance of 8 feet, my vote is intended to apply only to a specification for new construction, and that a clearance of 8 feet is my recommendation to railway officials, and that I am not making, and have no occasion to make any recommendation or express any opinion to the public or Public Utilities Commissions.

Appendix B.

STATEMENT SHOWING MILEAGE OF RAILROADS WITH THE SIDE CLEARANCE FOR BRIDGES, DISTANCE BETWEEN MAIN TRACKS AND OVERHEAD CLEARANCE RECOMMENDED.

RAILROAD.	Side Clearance			Distance Between Main Tracks			Overhead Clearance	
	7 ft. to 7 ft. 3 in.	7 ft. 6 in.	7 ft. 9 in. to 8 ft. or More	Less than 13 ft.	13 ft.	More than 13 ft.	22 ft. or More	Less than 22 ft.
Ann Arbor			292		292			292
Arizona & New Mexico						109		
Atchison, Topeka & Santa Fe (Coast Lines)	2053					2053	2053	
Atchison, Topeka & Santa Fe	5968					5968	5968	
Atlantic Coast Line	4701				4701		4701	
Baltimore & Ohio	4478				4478			4478
Bangor & Aroostook		630			630		630	
Bessemer & Lake Erie	213				213		213	
Boston & Albany		392			392		392	
Boston & Maine		2302			2302			2302
Buffalo & Susquehanna			252		252		252	
Canadian Northern			7018		7018		7018	
Canadian Pacific			11641		11641			11641
Carolina & Northwestern						133	133	
Carolina, Clinchfield & Ohio		277			277		277	
Central New England			304			304		304
Central of Georgia			1924		1924			1924
Central of New Jersey	676				676	676		
Central Vermont			536		536		536	
Charleston & West Carolina	340				340		340	
Chesapeake & Ohio	2371				2371		2371	
Chicago & Alton		1033			1033		1033	
Chicago & Eastern Illinois	1282					1282	1282	
Chicago & Northwestern			8102		8102		8102	
Chicago, Burlington & Quincy			x9376			9376	9376	
Chicago Great Western			1429			1429	1429	
Chicago, Indianapolis & Louisville	578						578	
Chicago, Milwaukee & St. Paul		10667					10667	
Chicago, Peoria & St. Louis	245					245		245
Chicago, Rock Island & Gulf	476					476	476	
Chicago, Rock Island & Pacific	7852					7852	7852	
Chicago, St. Paul, Minneapolis & Omaha			1750			1750		1750
Cincinnati, Hamilton & Dayton			1015		1015		1015	
Cincinnati Northern		236			236		236	
Cleveland, Cincinnati, Chicago & St. Louis		2629			2629		2629	
Coal & Coke			197		197			197
Colorado & Southern			x1089			1089	1089	
Cumberland Valley			164	164				164
Delaware & Hudson			843		843		843	
Delaware, Lackawanna & Western			985		985			985
Denver & Rio Grande			x2585			2585	2585	
Denver & Salt Lake			255			255	255	
Detroit, Toledo & Ironton	422					422	422	
Duluth, South Shore & Atlantic	601					601	601	
Elgin, Joliet & Eastern			478		478		478	
El Paso & Southwestern	1028				1028		1028	
Erie		2257			2257		2257	
Fort Dodge, Des Moines & Southern			125				125	

x—Denotes 7 ft. 9 in.
Railroads having less than 100 miles not shown.
Where no recommendations are made, present practices of the railroads are shown.

Appendix B—Continued.

RAILROAD.	Side Clearance			Distance Between Main Tracks			Overhead Clearance	
	7 ft. to 7 ft. 3 in.	7 ft. 6 in.	7 ft. 9 in. to 8 ft. or More	Less than 13 ft.	13 ft.	More than 13 ft.	22 ft. or More	Less than 22 ft.
Fort Smith & Western		217				217	217	
Fort Worth & Denver City			x454			454	454	
Georgia & Florida	350				350			350
Georgia						307		307
Georgia, Florida & Alabama			195				195	
Georgia Southern & Florida	392				392		392	
Grand Rapids & Indiana			576		576		576	
Grand Trunk Pacific			3170		3170		3170	
Grand Trunk			4785			4785	4785	
Great Northern		8077				8077	8077	
Gulf & Ship Island			307			307	307	
Gulf, Colorado & Santa Fe	1907					1907	1907	
Hocking Valley	351				351			351
Illinois Central			4767			4767	4767	
Indiana Harbor Belt			105			105		105
International & Great Northern	1106					1106	1106	
Kanawha & Michigan	177	177				177	177	
Kansas City, Mexico & Orient		495					495	
Kansas City Southern			826			826	826	
Lake Erie & Western		716				716	716	
Las Vegas & Tonopah		119			119		119	
Lehigh & New England		296			296		296	
Lehigh Valley	1444				1444		1444	
Long Island			399		399			399
Louisiana & Arkansas							279	
Louisiana & Northwestern							121	
Louisiana Railway & Navigation		351			351		351	
Louisville & Nashville		5034			5034		5034	
Louisville, Henderson & St. Louis		188			188		188	
Maine Central		1208			1208			1208
Michigan Central		1800			1800		1800	
Michigan East & West							107	
Minneapolis & St. Louis		1046			1046			1046
Minneapolis, St. Paul & Sault Ste. Marie	4062				4062		4062	
Missouri & North Arkansas	365						365	
Missouri, Kansas & Texas	3065					3065	3065	
Missouri, Oklahoma & Gulf	331					331	331	
Missouri Pacific	7285				7285			7285
Mobile & Ohio	1122				1122		1122	
Nashville, Chattanooga & St. Louis	1231				1231		1231	
National of Mexico		387					387	
New Orleans & Northeastern			196			196	196	
New Orleans Great Northern						277		
New Orleans, Mobile & Chicago	403							403
New Orleans, Texas & Mexico		287				287	287	
New York Central		5032			5032		5032	
New York, Chicago & St. Louis	523				523		523	
New York, New Haven & Hartford			2003		2003		2003	
New York, Ontario & Western		494			494			494
New York, Philadelphia & Norfolk			148	148				148
Norfolk & Western		2043			2043		2043	
Norfolk Southern	907				907		907	
Northern Pacific	6313				6313		6313	
Oregon Short Line		2181			2181		2181	
Oregon-Washington		2027			2027		2027	

x—Denotes 7 ft. 9 in.
x—Denotes 6 ft. 4¼ in.
Railroads having less than 100 miles not shown.
Where no recommendations are made, present practices of the railroads are shown.

Appendix B—Continued.

RAILROAD.	Side Clearance			Distance Between Main Tracks			Overhead Clearance	
	7 ft. to 7 ft. 3 in.	7 ft. 6 in.	7 ft. 9 in. to 8 ft. or More	Less than 13 ft.	13 ft.	More than 13 ft.	22 ft. or More	Less than 22 ft.
Pennsylvania Lines		3103			3103		3103	
Pennsylvania			5379	5379				5379
Pere Marquette		2322			2322		2322	
Peoria & Eastern		338			338		338	
Philadelphia & Reading	1582				1582		1582	
Pittsburgh & Lake Erie		225			225		225	
Pittsburgh, Shawmut & Northern	297				297		297	
Quebec, Montreal & Southern		191			191		191	
Quincy, Omaha & Kansas City	261						261	
Rutland					416			416
St. Joseph & Grand Island		258		258			258	
St. Louis & San Francisco			4748		4748		4748	
St. Louis, Brownsville & Mexico	528					528	528	
St. Louis Southwestern	1658					1658	1658	
San Antonio & Aransas Pass	724					724		724
San Antonio, Uvalde & Gulf	z316						316	
San Pedro, Los Angeles & Salt Lake		1100			1100		1100	
Seaboard Air Line	3098				3098		3098	
Southern Pacific		6517			6517		6517	
Southern Pacific of Mexico		1246			1246		1246	
Southern	7022				7022		7022	
Spokane, Portland & Seattle	556					556	556	
Sunset Central		3534			3534		3534	
Susquehanna & New York	103			103			103	
Temiscouata			113		113		113	
Tennessee Central	293				293			293
Texas & Pacific		1944				1944	1944	
Texas Midland					125		125	
Temiskaming & Northern Ontario					325		325	
Toledo & Ohio Central		431			431		431	
Toledo, Peoria & Western	248				248		248	
Toledo, St. Louis & Western		451					451	
Tonopah & Goldfield			110			110	110	
Toronto, Hamilton & Buffalo			107		107		107	
Trinity & Brazos Valley			303			303	303	
Union Pacific		3617			3617		3617	
Vandalia			910		910		910	
Virginia & Southwestern	240				240		240	
Virginian		503				503	503	
Wabash	2514				2514			2514
Western Maryland			x661		661		661	
Western Pacific			x946				946	
Wheeling & Lake Erie	459				459		459	
Total	89217	78378	56801	6192	154445	70738	198909	45704

x—Denotes 7 ft. 9 in.
z—Denotes 6 ft. 4½ in.
Railroads having less than 100 miles not shown.
Where no recommendations are made, present practices of the railroads are shown.

Appendix E.

ABSTRACT OF STATE LAWS AND COMMISSION ORDERS ON CLEARANCES.

California:

Commission order requires a minimum overhead clearance of 22 feet and minimum lateral clearance of 7 feet 6 inches for trains and bridges, and 8 feet for water stations, fuel stations and other side structures. Minimum distance between centers of yard and industrial tracks, and structures, including platforms, higher than 4 feet, is established at 8 feet 6 inches. Platforms under 4 feet in height and over 1 foot must be 6 feet 6 inches from center of track. Minimum distance between track centers is established at 13 feet, except that house and team tracks may be built on 11-foot 6-inch centers.

Illinois:

Commission ruling requires 22 feet overhead, and 8 feet 6 inches horizontal clearance, with a number of exceptions for platforms, enginehouse doors, etc., 14-foot track centers, 18 feet from center of switch lead to center of adjacent track and 21 feet between adjacent leads. There are a number of other requirements and exceptions set forth in Ruling No. 17 of the State Public Utilities Commission.

Indiana:

Requires 21-foot vertical clearance and 7-foot lateral clearance.

Kentucky:

Requires that no bridge shall be constructed with less than 22-foot vertical clearance.

Massachusetts:

No bridge shall be constructed over a railroad less than 18 feet above track, except by written consent of Railway Commissioners.

Michigan:

Eighteen feet above track is minimum height of bridges, except in cities.

Minnesota:

Forbids bridge construction or repairing of any structure within 8 feet of center of track and less than 21 feet above top of rail, although the Railroad Commission is given authority to suspend these restrictions at any particular place. Minimum distance between tracks is fixed at 14 feet for main tracks and 13 feet for yard tracks.

New Hampshire:

Vertical clearance of 21 feet required on all bridges rebuilt. Prohibits operation of any car over 14 feet in height.

North Dakota:

Forbids operation of locomotives or cars after January 1, 1915, which exceed 10 feet 6 inches in maximum width and 14 feet 2 inches in height. No structure permitted to be erected or maintained on main or sidetracks within 8 feet of center of track, or less than 21 feet above top of rail. These clearance regulations do not apply to any structure on the railroad right-of-way which is owned, leased or used by outside person or corporation. Railroad Commission is given authority to exempt any structure built prior to the passage of the act. Law also specifies that no tracks shall be constructed with less than 13-foot centers.

Ohio:

Specifies minimum lateral clearance line 7 feet from center of track down to 4 feet above top of rail, and extending down from this point to a point 5 feet from the center of track at the elevation of top of rail. Exceptions made for freight and passenger platforms. Additional clearance required on curves.

Oklahoma:

No definite order issued. Recommendation made for 22-foot vertical clearance and 7-foot minimum lateral clearance in some instances.

Oregon:

Railroad Commission has not issued any definite orders, has recommended a lateral clearance of 8 feet and a vertical clearance of 22 feet for main track.

Rhode Island:

Forbids building of any bridge over any railroad track with less than 18 feet clear distance above top of rail, excepting structures rebuilt to replace existing structures.

Vermont:

Requires that all bridges rebuilt must have a minimum clearance between trusses of 15 feet for single track and 27 feet for double track, with vertical clearance of 22 feet.

Dominion of Canada:

Requires vertical clearance of 22 feet 6 inches and a clear headway of 7 feet above top of highest car. In 1910 Board of Railway Commissioners fixed lateral clearance at 6 feet from the gage side of the adjacent rail and 8.35 feet from track center.

REPORT OF COMMITTEE XVII—ON WOOD PRESERVATION.

EARL STIMSON, *Chairman;*	E. H. BOWSER, *Vice-Chairman;*
F. J. ANGIER,	E. A. STERLING,
W. A. FISHER,	LOWRY SMITH,
C. F. FORD,	C. M. TAYLOR,
DR. W. K. HATT,	C. H. TEESDALE,
V. K. HENDRICKS,	T. G. TOWNSEND,
GEORGE E. REX,	DR. HERMANN VON SCHRENK,
	Committee.

To the Members of the American Railway Engineering Association:

Of the subjects assigned by the Board of Direction to your Committee for study, report is submitted on the following:

(1) *Water sampling in creosote oil.*

(2) *The relation of the amount of preservative and the depth of penetration to the resistance of materials against decay.*

(3) *The compilation of service test records.*

Three meetings of your Committee were held—the first at Atlantic City on June 26, 1915, the members present being W. A. Fisher, V. K. Hendricks, George E. Rex, E. A. Sterling, C. M. Taylor, T. G. Townsend, Dr. Hermann von Schrenk and E. H. Bowser, Vice-Chairman, presiding; the second at Chicago on December 16, those present being E. H. Bowser, C. F. Ford, V. K. Hendricks, L. D. Cooper, representing George E. Rex, E. A. Sterling, C. H. Teesdale, T. G. Townsend and Earl Stimson, Chairman; the third at Chicago on January 18, those present being F. J. Angier, W. A. Fisher, C. F. Ford, V. K. Hendricks, George E. Rex, Lowry Smith, C. M. Taylor, C. H. Teesdale, T. G. Townsend, Dr. Hermann von Schrenk and Earl Stimson, Chairman.

(1) WATER SAMPLING IN CREOSOTE OIL.

During the past year the Committee has given further attention to the question of developing a standard method for determining the percentage of water contained in creosote oil when shipped in tank cars.

The sampling of liquids in tank cars is an exceedingly difficult matter; in fact, a Special Committee of the American Society for Testing Materials reported that it had been unable to find any method which could be recommended for obtaining satisfactory samples of liquids when shipped in tank cars. After much consideration, the Committee finally decided to carry on a series of tests with various methods for sampling. These tests were carried on under the auspices of the Committee with the co-operation of similar committees, at the request of the Chairman, of the

American Society for Testing Materials and the American Wood Preservers' Association.

The Committee wishes at this point to express its acknowledgment for the very valuable assistance, in carrying on the tests and in preparing the report, of Mr. S. R. Church, of the Barrett Manufacturing Company, and of Mr. E. B. Fulks, of the American Tar Products Company.

Under the direct supervision of the Sampling Committee, two tank cars were loaded with creosote oil at the Shadyside, N. J., plant of the Barrett Manufacturing Company, December 22, 1915, shipped to Federal Creosoting Company plant at Rome, N. Y., and unloaded at that point on January 3, 1916. Samples were taken by various means and afterwards divided into three sets. One set of samples was tested in the laboratory of von Schrenk and Kammerer, another in the laboratory of the Port Reading Creosoting Plant, and the third in the laboratory of the Barrett Manufacturing Company. This report comprises a description of the manner of loading and unloading the cars and sampling of same.

In accordance with the prearranged plan, one car was loaded with substantially dry oil, and a measured volume of water added to the car from a separate source, and the other car was loaded with oil containing about 7 per cent. of water. The two cars, GATX 4480 and APTX 52, each had a marked capacity of 8,043 gallons, and inside shell diameter of 82 inches. Before loading, the cars were cleaned and the steam coils tested. The procedure was as follows:

GATX 4480:

The oil was pumped from storage tank to car by the plant service pump, and a continuous drip sample taken in accordance with method described in report of Committee D-7, American Society for Testing Materials (Proceedings, 1915, page 625). Four hundred and fifty-two gallons of water were run in by gravity from a measuring drum having an exact capacity of 113 gallons. The flow of water was timed so that it coincided with the flow of oil. The water entered through a 2-inch pipe directed so that the stream of water entered and mingled with the stream of oil. The car was loaded so that the oil level was in the dome. Temperature of oil in car immediately after loading was 126 degrees Fahrenheit. Samples were immediately taken at points one foot from the top, at the center, and one foot from the bottom of the car, as ordinarily practiced at this plant.

The sampling vessel, hereafter referred to as a bottle, consisted of a one-quart metal can, weighted with lead, and stoppered with a cork, to which was attached a cord for withdrawing the stopper at any desired level.

One hour and 40 minutes after loading the car the temperature of the oil was 105 degrees Fahrenheit. A sample was taken at the top of the car by a cross-section sampler, consisting of a glass tube two feet long, closed by a valve at the bottom. (This type of sampler is used to a considerable extent in attempting to estimate the free water on the top of cars.) The tube showed 9 inches of free water, of which 5 inches was in the dome and 4 inches in the car proper.

Zone samples were then taken from levels representing centers of one-foot zones from top to bottom of the car. For this purpose two devices were used, one being the bottle already described, and the other the Braun sampler. The latter consists of a small cylinder of about 200 cc. capacity, attached to a jointed tube having a total length of about nine feet, with an inner tube operating a valve at the bottom of the cylinder, the outer tube acting as an escape pipe, so that when the sampler is opened air is released without disturbing the contents of the car. Owing to the small capacity of this device, it was necessary to take four samples at each level in order to obtain sufficient oil for testing, and it was noticed while transferring the oil from the sampler to the sample can that a considerable amount of water and oil, which adhered to the surface of the rod when the sample was withdrawn, ran down the rod and into the can during the discharge of the sample.

ATPX 52:

The wet oil, which had previously been transferred from a storage tank to a tank car in order to be available when desired, was pumped into Car 52 by means of temporary pump and pipe line connection, and a continuous drip sample taken during the pumping. When the car was loaded the oil level was in the dome. The temperature of the oil immediately after loading was 130 degrees Fahrenheit. Samples were then taken from top, center and bottom by the bottle method, as usual, but no further sampling of this car was done at Shadyside.

The cars arrived at Rome, N. Y., on December 30. They were placed on the unloading track. At this plant the cars discharge by gravity into a tank directly below the track, the oil running from the tank car outlet into a large funnel.

The procedure at Rome was as follows:

No steam was placed in the coils of the cars until 7:30 a. m. on January 3. At this time the oil had solidified in both cars. After three hours' heating, the contents of both cars were perfectly liquid.

GATX 4480:

Temperature of oil in car was 122 degrees Fahrenheit. The oil level in this car was exactly the same as at Shadyside, viz., five inches of oil in the dome. The cross-section sample from top by the two-foot glass tube showed practically no separation between oil and water. One-foot zone samples were taken by a device similar in principle to the Braun sampler used at Shadyside, the latter having been discarded as inadequate. The construction of the sampler used at Rome is roughly indicated in Fig. 1. Samples were taken at top, center and bottom with the bottle sampler. The car was then sampled by the Federal Creosoting Company in the manner ordinarily practiced at that plant, using a thief sampler, consisting of a tin cylinder about two feet long, three inches in diameter, with a one-inch hole in the top. This was lowered quickly to the bottom, and raised slowly in such a way that it was not quite full when removed. The oil was then discharged from the car by gravity, and a dipper sample was taken from the open stream, taking about a pint of oil every five or six minutes. In this way about a two-gallon sample was collected, of which an average sample was finally taken.

ATPX 52:

The procedure in sampling Car 52 was identical with that described for Car 4480. The temperature of oil was 117 degrees Fahrenheit. Oil level was about ½-inch below the dome.

The following is a list of the samples which were marked consecutively as taken at Shadyside and Rome, and the results of water determinations on these samples at the laboratories of von Schrenk and Kammerer, and the Barrett Manufacturing Company. Owing to an unfortunate delay in the delivery of samples to the Port Reading Creosoting Plant, the results of their tests are not available for inclusion in this report.

Samples 1-23, Shadyside; 24-51, Rome.

		Per Cent. Water.	
No.	Description of Sample.	Barrett.	von Schrenk & Kammerer.
1.	Drawn from Storage Tank 45 before loading Car 4480	0.10	0.2
2.	Continuous drip sample taken while loading Car 4480	0.9	0.8
3.	Bottle sample from top of Car 4480	14.0	11.6
4.	Bottle sample from center of Car 4480	5.3	6.0
5.	Bottle sample from bottom of Car 4480	6.5	5.6
6.	Cross-section sample from top 2 ft. Car 4480	54.8	58.5
7.	One-foot zone samples by Braun sampler, Car 4480, sample 7 being the top and sample 13 the bottom	74.5	...
8.	"	8.0	...
9.	"	10.0	...
10.	"	6.5	...
11.	"	6.6	...
12.	"	9.8	...
13.	"	14.1	...
14.	Bottle zone sample Car 4480 (top)	37.1	37.9
15.	" " " " " "	3.5	4.9
16.	" " " " " "	2.0	2.1
17.	" " " " " "	1.9	2.2
18.	" " " " " "	2.5	1.9
19.	" " " " " (bottom)	6.4	7.4
20.	Continuous drip sample from loading Car 52	7.4	7.7
21.	Sample from top Car 52 (bottle sample)	6.1	5.8
22.	Sample from center Car 52 (bottle sample)	5.9	7.7
23.	Sample from bottom Car 52 (bottle sample)	12.0	13.6
24.	19-in. cross-section sample from Car 4480	79.0	...
25.	Cylinder one-foot zone sample, Car 4480	35.0	37.0
26.	" " " " " "	4.0	4.9
27.	" " " " " "	4.0	4.4
28.	" " " " " "	3.0	2.1
29.	" " " " " "	2.0	2.0
30.	" " " " " "	5.6	4.2
31.	" " " " " "	5.0	4.3

Samples 1-23, Shadyside; 24-51, Rome.

		Per Cent. Water.	
No.	Description of Sample.	Barrett.	von Schrenk & Kammerer.
32.	Bottle sample from top of Car 4480	7.3	7.2
33.	Bottle sample from center of Car 4480	4.5	5.0
34.	Bottle sample from bottom of Car 4480	4.0	4.6
35.	Federal Creosoting Co. thief, Car 4480	12.6	15.0
36.	Dipper sample, Car 4480	15.0	19.5
37.	19-in. cross-section sample, Car 52	13.7	...
38.	Cylinder foot zone sample Car 52 (top)	7.5	7.5
39.	“ “ “ “ “ “ “	8.1	8.0
40.	“ “ “ “ “ “ “	8.8	8.0
41.	“ “ “ “ “ “ “	8.0	7.2
42.	“ “ “ “ “ “ “	8.0	8.1
43.	“ “ “ “ “ “ “	9.0	7.4
44.	“ “ “ “ “ “ (bottom)	10.8	10.2
45.	Bottle sample from Car 52, top	8.0	7.7
46.	” “ “ “ “ center	8.0	8.1
47.	” “ “ “ “ bottom	9.5	8.9
48.	Federal Creosoting Co. thief, Car 52	7.9	8.5
49.	“ “ “ “ “ “	9.3	7.4
50.	Dipper sample, Car 52	8.0	8.7
51.	“ “ “ “	8.0	9.7

In order to present the results in graphic form a drawing is appended (Fig. 2), showing vertical cross-sections through each car. On this drawing we have indicated the points at which various samples were taken, the device by which they were taken and the results of the water test. On this drawing the results are those obtained in the Barrett Manufacturing Company's Laboratory.

It will be noted that the figures given for water found for the different zone samples are calculated according to factors found on the drawing appended to this report (Fig. 3). The actual percentage of water found in any zone does not correctly represent the real percentage, because the number of gallons found in the different zones differ because of the shape of the tank car. The percentage of water found in each zone should be multiplied by the figure at the right-hand side of the table representing the relation of this zone to the entire car. In other words, take the diameter of the car, as shown by the figures at the base of the diagram, run up on the vertical line to the zone line, and where this point crosses the horizontal line note the figure at the left-hand side of the table, which will express the percentage relation. The sum of the results obtained for this calculation for the samples from the different zones represents the total percentage of water in the car.

It will be noted that the results obtained by the various methods of sampling from Car 4480, which contained dry oil to which water was deliberately added, varied widely, but on the other hand, the tests on wet oil contained in Car 52 are quite uniform. The Committee observed that the water separated rapidly from the oil in Car 4480, so that indeed there was more free water on the surface of the oil within two hours after loading than there was at the time of unloading. Evidently the

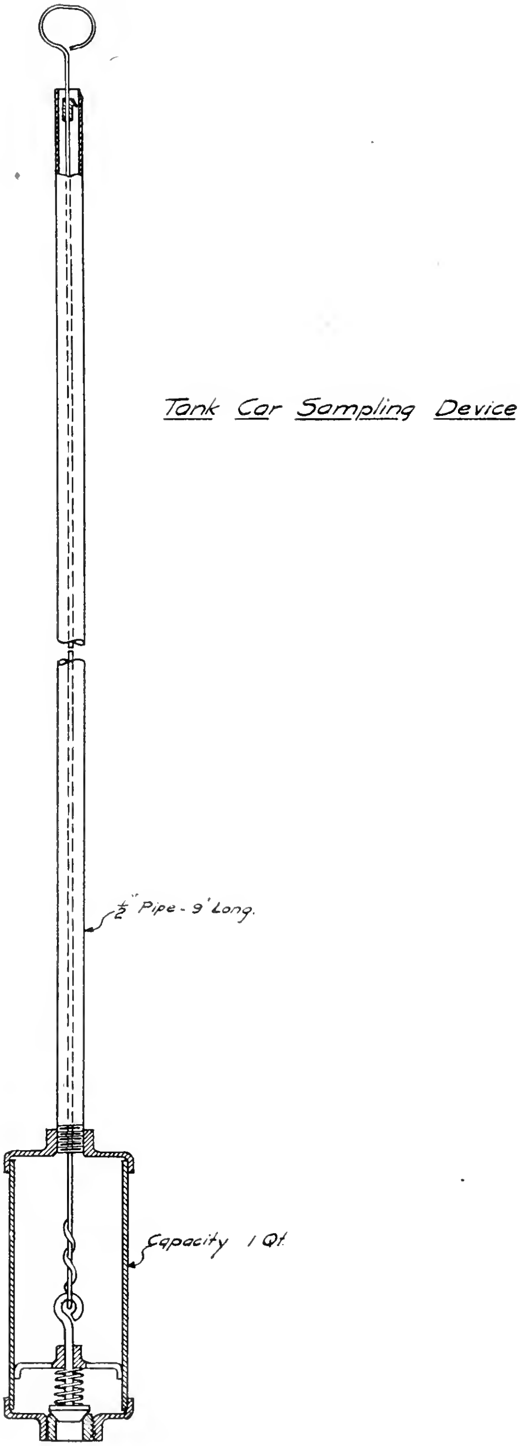


FIG. 1.

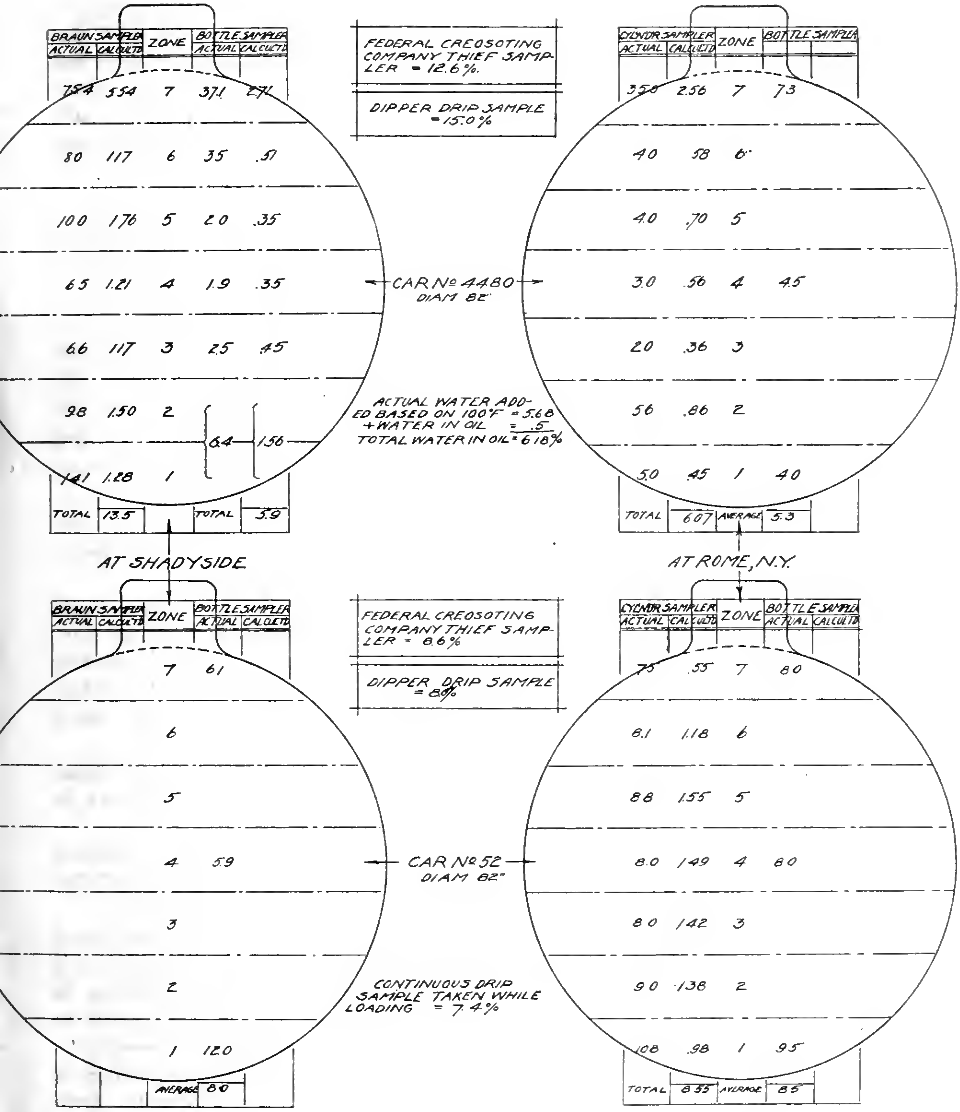


FIG. 2. WATER TESTS ON SAMPLES TAKEN BY COMMITTEE AT SHADYSIDE, DECEMBER 22, 1915, AND AT ROME, N. Y., JANUARY 3, 1916.

NOTE.—Values for zone samples calculated according to factors found on Fig. 3.

water and oil had become mixed during transit and the water did not again separate so rapidly from the oil. With Car 52, on the other hand, there was no apparent separation of water and oil, even though this oil contained more water than the other. It is obvious, of course, that the partial separation of oil and water, such as took place in Car 4480, makes sampling more difficult than when the water is uniformly distributed throughout the oil.

CONCLUSIONS.

The tests described above and the results obtained are presented as a progress report. The following preliminary conclusions have been drawn by the Committee.

1. That for accurate determination of water in a tank car of creosote, a system of sampling from several zones in a car is necessary. These zones must represent definitely calculated areas throughout the entire depth of the car. There must be at least three zones, the top, the middle and the bottom of the car. The indications are that for the most definite determinations zones one foot deep are to be preferred (see Fig. 2).

2. That for calculating any percentage of water found in any zone in relation to the proportion to the entire car, the correction factor indicated on diagram 3 be used.

3. That the cross-section tube frequently used for taking samples from tank cars is of little value. It disregards the fundamental principle of zone sampling, in that it takes no account of the proportionate value of the sample taken with reference to the whole car. It, furthermore, cannot be used in connection with zone sampling without much additional computation.

4. The so-called thief (1915 Proceedings, American Railway Engineering Association, Vol. 16, page 831) has been found incorrect in theory, and the results obtained therewith confirm this.

5. That the taking of a dipper or bucket sample from the running stream of cars while discharging does not give reliable results, and that this method should not be used.

6. That the bottle method, meaning the use of a small stoppered vessel from which the cork can be withdrawn at any desired level, is a convenient apparatus for taking zone samples. Its disadvantage lies in the fact that escaping air, after the withdrawal of the cork, tends to disturb the surrounding oil, and therefore gives an incorrect sample.

7. That for the present an apparatus, the principle of which is shown in Fig. 1, be used for zone sampling in taking samples from cars in which a high percentage of water is suspected. It should be understood that the appended sketch is merely to show the general plan of the sampler.

8. That efforts be made to construct an improved form of the sampler just referred to, provided further tests warrant a definite recommendation for its use.

NGINEERING ASSOCIATION
WOOD PRESERVATION
IT - APPENDIX "A"
TIE SERVICE TEST

soning		Treating								Absorption per Cu. Ft.			Absorption per Tie			Inspec	
Steam		Initial Vacuum		Pressure		Temperature		Final Vacuum								How often Made	Of C
Lbs.	Time	Inches	Time	Lbs	Time	In Tank	In Retort	Inches	Time	Zinc Cl.	Creosote	Miscel.	Zinc Cl.	Creosote	Miscel.		
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																"	
																"	
																"	
																"	
		Initial Air 60#	Pressure 45'	104	1¾ hrs		120				4.56 lb					"	
		"	"	"	"		"				"					"	
		"	"	"	"		"				"					"	
		"	"	"	"		"				"					"	
		65#	50'	"	2¼ "		122				3.93 "					"	
		65	50'	"	"		122				"					"	
		60	45'	"	1¾ "		120				4.56 "					"	
		100	30'	200	2¼ "		186	22	1½ hrs		5.0 "					"	
		100	30'	"			186	23	"		"					"	
		100	30'	"			186	"	"		"					"	
		65	50'	104	2¼ "		122				3.93 "					"	
		100	30'	175	5 "		194	23	2		5.0 "					"	
		85	25'	"	1¾ "		194	22	3		"					"	
		65	25'	"	"		194	23	1		"					"	
																"	
																"	
		Initial Air pressure 75	30'	150	1¾ "		172	22	1¼		5.0 "					"	
		65	50'	104	2¼ "		172				3.92 "					"	
		Initial Vacuum 24"	45'	100	2 "		200			0.58 lb.						"	
		"	"	100	"		"			0.58 "						"	
		"	"	"	"		"			0.58 "						"	
		"	"	"	"		"			0.58 "						"	
one											17.4 "						
"											17.4 "						
"											17.4 "						
"											17.4 "						
		23	1hr. 5Mi.	175	6hr 10min.	153°	152°			0.5 lb.	2.0 "		5.5 Gallons			Annually	Ef M.
											0.675 Gal.			2.5 Gal.		or at	
		23	1hr.	175	4hr 50Mi.	137°	157°			0.5 "	2.0 lb.		5.5 Gallons			Designat.	
		24	1hr. 25m			165°	175°				0.675 gal.			2.5 Gal.		Periods	
				Open Tank	20hrs.	110-208	12hrs.					3.59-11.09#			1.76-5.42 gal.	"	
																"	

AMERICAN RAILWAY ENGINEERING ASSOCIATION
COMMITTEE ON WOOD PRESERVATION
1915 REPORT - APPENDIX "A"
RECORD OF TIE SERVICE TEST

Sheet No 1 of [illegible]

Company or Organization	Official Reporting	Test No.	Locality of Test	Date Placed	Date Reported	Time of Test	Distance of Test	Number of Ties	Description of Conditions: Sub Grade Soil	Kind of Ballast	Drainage	Rail: Wt	Rail: Section	Tie Plate: Size	Tie Plate: Kind of Fastening	Ties per Mi of Track	Cut or Screw Spike	Alinement	Traffic Tonnage Annum	Description of Material: Kind of Wood	Size	Class	Sawed or Hewn	Kind of Treatment	Seasoning: Air	Steam: Lbs	Steam: Time	Treating: Initial Vacuum: Inches	Initial Vacuum: Time	Pressure: Lbs	Pressure: Time	Temperature: In Tank	Temperature: [illegible]	Final Vacuum: Inches	Final Vacuum: Time	Absorption per Cu Ft: Zinc Cl	Creosote	Miscel	Absorption per Tie: Zinc Cl	Creosote	Miscel	Inspection: How often Made	Official in Charge	Number Removed: Acct Decay	Mech Wear	Other Causes	Total	Results: Per Cent of Total Removed: All Causes	Acct Decay	Acct Mech Wear	Average Life	Remarks
ATCHISON	Mgr Treating Plants	1	Beaumont Div	May 02	Dec 14	12 Yrs 7 Mo		196	VARIOUS											White Oak	6x8x8	First		Untreated																		Annually	Manager Treating Plant				196	100			All Ties	All zinc Treated Ties Steam Seasoned
TOPEKA AND	"	2	GC&SF Ry in Texas		"	"		100	"		"										"	"		Burnett Chicago																		"					100	100			9	All Creo Ties Air Seasoned
SANTA FE RY	"	3	"		"	"		101	"	"	"									"	"	"		Wellhouse "																							86	85				
	"	4			"	"		107	"	"	"										"	"		Zinc Creo Bmt																			"				107	100			2	
	"	5		"	"	"		100	"	"	"									"	"	"		Burnett Somrvle																			"				100	100			7	
	"	6	"		"	"		100	"	"	"									"	"	"		Wellhouse "																			"				95	95				
	"	7	"	"	"	"		100	"	"										"	"	"		Allardyce "																			"				91	91				
	"	8	"	"	"	"		196	"	"											"	"		Barschall																		"					196	100			6½	
	"	9	"	March 02	Dec 14	12 Yrs 9 Mo		93												Red Oak	"			Untreated																		"					93	100			3	Ni chanutes Ties Treated - Chicago
	"	10	"	"	"	"		86												"	"	"		Burnett Chicago																			"				85	99				Texas Tie & Lumber Pre. Co Somerville
	"	11	"	"	"	"		20												"	"	"		" Somervle																		"	"				20	100			–	International Cre Co - Beaumont
	"	12	"	"	"	"		20												"	"	"		Wellhouse																		"	"				20	100			7	Hasselman or Berschell by Texas Tie &
	"	13	"	"	"	"		10												"	"	"		Allardyce "																		"	"				10	100			12	Lumber Pre Co Somerville
	"	14	"	"	"	"		19												"	"	"		Barschall "																			"				19	100			4	
	"	15	"	May 02	"	12 Yrs 7 Mo		24												Black Oak	"	"		Untreated																		"	"				24	100			4	
	"	16	"	"	"	"		86												"	"	"		Wellhouse Chicago																		"	"				82	954				
	"	17	"	"	"	"		76												"	"	"		Zinc-Creo Bmt																			"				76	100			1½	Zinc Creosoted Ties Beaumont over
	"	18	"	"	"	"		34												"	"	"		Burnett Somerv le																		"	"				34	100			7	Steamed
	"	19	"	"	"	"		33												"	"	"		Wellhouse "																			"				33	100			8	
	"	20	"	"	"	"		60												"	"	"		Allardyce																			"				60	100			8	
	"	21	"	"	"	"		118													"	"		Barschall																		"	"				118	100			3½	
	"	22	"	April 02	"	12 Yrs 8 Mo		20												Turkey Oak	"	"		Untreated																		"	"				20	100			4	
	"	23		"	"	"		10												"	"	"		Zinc-Creo Bmt																		"	"				10	100			3	
	"	24	"	"	"	"		19												"	"	"		Burnett Somerv le																		"	"				19	100			7	
	"	25	"	"	"	"		20												"		"		Wellhouse "																		"	"				20	100			4½	
	"	26	"	"	"	"		10												"	"	"		Allardyce "																		"	"				10	100			4½	
	"	27	"	"	"	"		19												"	"			Barschall "																		"	"				19	100			3	
	"	28	"	1902	"	12 Years		20												Spanish Oak	"	"		Untreated																		"	"				20	100			4	
	"	29	"	"	"	"		10												"	"	"		Zinc-Creo Bmt																		"	"				10	100			4	
	"	30	"	"	"	"		21												"	"	"		Burnett Somerv lle																		"	"				21	100			7½	
	"	31	"	"	"	"		20												"	"	"		Wellhouse "																		"	"				19	95				
	"	32	"	"	"	"		10												"	"	"		Allardyce "																		"	"				7	70				
	"	33	"	"	"	"		20												"	"	"		Barschall "																		"	"				20	100			4	
	"	33	"	May 02	"	12 Yrs 7 Mo		20	Widely Varying over Twenty Two Sections	"	"									Willow Oak	"	"		Untreated																		"	"				20	100			3½	
	"	34	"	"	"	"		11												"	"	"		Zinc-Creo-Bmt																		"					11	100			3	
	"	35	"	"	"	"		20													"	"		Burnett Somerville																		"					20	100			7	
	"	36	"	"	"	"		20		"	"									"	"	"		Wellhouse "																		"					20	100			7	
	"	37	"	"	"	"		10												"	"	"		Allardyce "																		"	"				10	100			8	
	"	38	"	"	"	"		20												"	"	"		Barschall "																		"	"				20	100			3	
	"	39	"	Feb. 02	"	12 Yrs 10 Mo		100		"	"									Beech	"	"		Untreated																		"	"				100	100			3	
	"	40	"	"	"	"		50													"	"		Zinc-creo-Bmt																		"	"				50	100			5	
	"	41	"	"	"	"		99												"	"	"		Burnett-Chicago																		"	"				99	100			10½	
	"	42	"	"	"	"		100		"	"									"	"	"		Wellhouse																		"	"				100	100			10½	
	"	43	"	"	"	"		50												"	"	"		Allardyce Somvlle																		"	"				50	100			10½	
	"	44	"	"	"	"		98												"	"	"		Barschall "																		"	"				98	100			3	
	"	45	"	Apr 02	"	12 Yrs 8 Mo		101												[illegible]	"	"		Untreated																		"	"				101	100			2	
	"	46	"	"	"	"		49		"	"									"	"	"		Zinc-Creo Bmt																		"	"				49	100			5	
	"	47	"	"	"	"		100												"	"	"		Burnett Chicago																		"	"				100	100			9	
	"	48	"	"	"	"		100												"	"	"		Wellhouse Chicago																		"	"				100	100				
	"	49	"	"	"	"		50		"	"									"	"	"		Allardyce Somvlle																		"	"				50	100			9	
	"	50	"	"	"	"		100												"	"	"		Barschall "																		"	"				100	100			3½	
	"	51	"	May '02	"	12 Yrs 7 Mo		49												[illegible]	"			Untreated																		"	"				49	100			3	
	"	52	"	"	"	"		51												"	"	"		Zinc-Creo-Bmt																		"	"				51	100			8	
	"	53	"	"	"	"		49													"	"		Burnett Chicago																		"	"				49	100			10	
	"	54	"	"	"	"		100												"	"			Wellhouse "																		"	"				100	100			10	
	"	55	"	"	"	"		50												"	"			Allardyce Somvlle																		"	"				50	100			9	
	"	56	"	"	"	"		98												"	"	"		Barschall "																		"	"				98	100			4	
	"	57	"	"	"	"		100												[illegible]	"	"		Untreated																		"	"				100	100			4	
	"	58	"	"	"	"		50												"	"	"		Zinc-Creo Bmt																		"	"				50	100			8	
	"	59	"	"	"	"		100												"	"			Burnett Somvlle																		"	"				98	98				
	"	60	"	"	"	"		100												"	"	"		Wellhouse																		"	"				100	100			4	
	"	61	"	"	"	"		50												"	"	"		Allardyce "																		"	"				46	92				
	"	62	"	"	"	"		98												"	"	"		Barschall "																		"	"				98	100			5	
	"	63	"	"	"	"		100												[illegible]	"	"		Barschall "																		"	"				100	100			5	
	"	64	"	April '02	"	12 Yrs 8 Mo		93												[illegible]	"	"		Untreated																		"	"				93	100			3½	Longleaf and Loblolly Soaked with
	"	65	"	"	"	"		50												"	"	"		Zinc Creo-Bmt																		"	"				50	100			7	Beaumont Oil, absorbed 3lbs Per cu ft
	"	66	"	"	"	"		100												"	"	"		Burnett Somv lle																		"	"				93	93				
	"	67	"	"	"	"		100												"	"	"		Wellhouse "																		"	"				97	97				
	"	68	"	"	"	"		100												"	"	"		Barschall "																		"	"				100	100			6	
	"	69	"	"	"	"		50												"	"	"		Allardyce "																		"	"				41	82				
	"	70	"	"	"	"		100												"	"	"		[illegible] Oil "																		"	"				100	100			5	
	"	71	"	"	"	"		100												"	"	"		[illegible]-oil Zinc Chlo																		"	"				100	100			4	
	"	72	"	"	"	"		100												"	"	"		[illegible]rtine Somvlle																		"	"				100	100			10	
	"	73	"	"	"	"		100												[illegible]	"	"		Untreated																		"	"				100	100			2	

AMERICAN RAILWAY ENGINEERING ASSOCIATION
COMMITTEE ON WOOD PRESERVATION
1915 REPORT - APPENDIX "A"
RECORD OF TIE SERVICE TEST

Sheet No 2 of 7

Company or Organization	Official Reporting	Test No.	Locality of Test	Date		Time of Test	Distance of Test	Number of Ties	Description of Conditions											Description of Material				Kind of Treatment	Seasoning			Treating								Absorption per Cu Ft			Absorption per Tie			Inspection		Number Removed				Results				Remarks
				Placed	Reported				Sub Grade Soil	Kind of Ballast	Drainage	Rail		Tie Plate		Ties per Mi of Track	Cut or Screw Spike	Alinement	Traffic Tonnage per Annum	Kind of Wood	Size	Class	Sawed or Hewn		Air	Steam		Initial Vacuum		Pressure		Temperature		Final Vacuum		Zinc Cl	Creosote	Miscel	Zinc Cl	Creosote	Miscel	How often Made	Official in Charge	Acct Decay	Mech Wear	Other Causes	Total	Per Cent of Total Removed			Average Life	
												Wt	Section	Size	Kind of Bottom											Lbs	Time	Inches	Time	Lbs	Time	In Tank	In Cyl	Inches	Time													All Causes	Acct Decay	Acct Mech Wear		
ATCHISON	Mgr Treating Plants	74	Beaumont Div	April 02	Dec 14	12 Yrs 8 Mo		49												Loblolly Pine	6x8x8	First		Zinc Creo Bmt																		Annually	Manager				49	100			Abt [illegible] yrs	[illegible]
TOPEKA AND	"	75	GC&SF Ry in Texas	"	"	"		99												"	"	"		Burnett Somerville																		"	Treating				99	100			" 9 "	" " 50
SANTA FE RY.	"	76	"	"	"	"		99												"	"	"		Wellhouse "																		"	Plant				99	100			" 8 "	" 100
"	"	77	"	"	"	"		49												"	"	"		Allardice "																		"	"				49	100			9 "	" " 100
	"	78	"	"	"	"		99												"	"	"		Barschall "																		"	"				99	100			" 3½ "	
"	"	79	"	"	"	"		42												"	"	"		Beaumont Oil "																		"	"				42	100			3 "	
"	"	80	"	"	"	"		80												"	"	"		Beaumont Oil-Zinc Chloride																		"	"				80	100			" 9 "	
"	"	81	"	"	"	"		100												"	"	"		Shrifting Somerville																		"	"				100	100			" 3½	
"	"	82	"	"	"	"		84												Pine	"	"		Avenarius Carbolineum																		"	"				84	100			" 5 "	
"	"	83	"	Feb '02	"	12 Yrs 10 Mo		19												"	"	"		Diamond Blue Pryte																		"	"				19	100			" 2 "	
"	"	84	"	"	"	"		[illegible]												"	"	"		Burnett																		"	"				[illegible]	100			" 4 "	
"	"	85	"	"	"	"		8												Cal Redwood	"	"		Burnett-Cal Crude																		"	"				8	100			" 2 "	
"	"	86	"	"	"	"		2												Cal Redwood	"	"		Burnett																		"	"				2	100			" 2 "	
"	"	87	"	"	"	"		4												Loblolly Pine	"	"		"																		"	"				4	100			" 4 "	
"	"	88	"	"	"	"		3												Shortleaf Pine	"	"		"																		"	"				3	100			" 7 "	
"	"	89	"	"	"	"		10												Western Pine	"	"		"																		"	"				10	100			" 11 "	
"	"	90	"	"	"	"		4												Ariz Pine	"	"		"																		"	"				4	100			" 10 "	
"	"	91	"	"	"	"		3												Gum	"	"		"																		"	"				3	100			" 10 "	
"	"	92	"	"	"	"		2												Water Oak	"	"		"																		"	"				2	100			12 "	
"	"	93	"	"	"	"		2												Pin Oak	"	"		"																		"	"				2	100			" 5 "	
"	"	94	"	"	"	"		2												Red Oak	"	"		"																		"	"				2	100			" 9 "	
"	"	95	"	"	"	"		6												Loblolly Pine	"	"		Boiled Zinc Chlo																		"	"				6	100			" 12 "	
"	"	96	"	"	"	"		4												Shortleaf Pine	"	"		" "																		"	"				[illegible]	100			" 10 "	
"	"	97	"	"	"	"		2												Ariz Pine	"	"		" "																		"	"				2	100			" 5 "	
"	"	98	"	"	"	"		1												Gum	"	"		" "																		"	"				1	100			" 7 "	
"	"	99	"	"	"	"		3												Red Oak	"	"		" "																		"	"				3	100			" 7 "	
"	"	100	"	"	"	"		3												Pin Oak	"	"		" "																		"	"				3	100			7 "	
"	"	101	"	"	"	"		1												Water Oak	"	"		" "																		"	"				1	100			7 "	
"	"	102	"	"	"	"		3												Shortleaf Pine	"	"		Bakersfield Oil																		"	"				1	33.3				The three Bakersfield Crude oil Ties
"	"	103	"	"	"	"		4												Loblolly Pine	"	"		"																		"	"				4	100			" 12 "	were removed in 1906 for inspection
"	"	104	"	"	"	"		2												Ariz Pine	"	"		"																		"	"				2	100			" 12 "	and were in a perfect State of Preservation
"	"	105	"	"	"	"		1												Western Pine	"	"		"																		"	"				1	100			" 12 "	
"	"	106	"	"	"	"		1												Gum	"	"		"																		"	"				1	100			" 12 "	
"	"	107	"	"	"	"		2												[illegible] Pine	"	"		Boiled in zinc chlo Oil forced in																		"	"				1	50				
"	"	108	"	"	"	"		7												Western Pine	"	"		Burnett Cal oil																		"	"				7	100			" 12 "	
"	"	109	"	"	"	"		1												Loblolly Pine	"	"		Burnett Cal oil																		"	"				1	100			" 12 "	
"	"	110	Chillicothe Ill	1905	Aug '15	10 Yrs		173		Gravel		85#		6x8			Cut		[illegible]	Pine			Hewn	Rueping	Air			60#	45'	104	1½ hrs		120				4.56 lb					"	"		6	4	10	5.8		3.5		
"	"	111	Marceline Mo	1905	Nov '15	10 "		304		Gravel		85					"		[illegible]	"			"	"	"			"	"	"	"		"				"					"	"	8	12	90	110	36.5	2.6	3.9		
"	"	112	Sutton Kan	1905	"	10 "		44		Slag		85		6x8 7½x9			"		[illegible]	"			"	"	"			"	"	"	"		"				"					"	"		4		4	9.1		9.1		
"	"	113	Ponca City Okla	1904	Aug '15	11 "		190		Rock		90		7½x9			"		[illegible]	"			"	"	"			"	"	"	"		"				"					"	"		6		6	4.2		3.2		
"	"	114	Bliss Okla	1904	"	11 "		275		"		90		"			"			"			Sawed	"	"			65"	50'	"	2¼ "		122				3.93 "					"	"		6		6	2.2		2.2		
"	"	115	Perry Okla	1904	"	11 "		366		"		90		"			"			"				"	"			65	50'	"	"		122				"					"	"									
"	"	116	Perry Okla	1904	"	11 "		27		"		90		"			"			"			Hewn	"	"			60	45'	"	1¾ "		120				4.56 "					"	"									
"	"	117	Hutchinson Kan	1907	Nov '14	7 "		390		"		90		"			"		[illegible]	Gum			Sawed	"	"			100	30'	200	2¼ "		186	22	1½ hrs		5.0 "					"	"									
"	"	118	Hutchinson Kan	1907	Nov '14	7 "		230		Cinders		85		"			"		[illegible]	"			Sawed	"	"			100	30'	"			186	23	"		"					"	"									
"	"	119	Plevna Kan	1907	Nov 14	7 "		432		Rock		90		"			"			"			"	"	"			100	30'	"			186	"	"		"					"	"									
"	"	120	Garnett Kan	1905	Nov '15	10 "		384		"		"		"			"		[illegible]					"	"			65	50	104	2¼ "		122				3.93"					"	"	26			26	7.3	6.8			
"	"	121	Hutchinson Cut off	1910	Nov '15	5 "		14497		"		"		"		3200	Screw		[illegible]	Gum			Hewn	"	"			100	30	175	5 "		194	23	2		5.0 "					"	"									
"	"	122	" "	"	"	5 "		54621		"		"		"		3200	"		"	Pine			"	"	"			85	25'	"	1½ "		154	22	3		"					"	"				75	0.44				
"	"	123	" "	"	"	5 "		9435		"		"		"		"	"		"	"			Sawed	"	"			65	25'	"			194	23	1		"					"	"									
"	"	124	" "	"	"	5 "		108		"		"		"		"	"		"	Oak			"	Untreated	"																	"	"									
"	"	125	" "	"	"	5 "		132		"		"		"		"	"		-				Hewn	"	"																	"	"									
"	"	126	Ottawa Cut off	1906	"	9 "		24238		"		"		6x8 7½x9		3190	Cut		[illegible]	Pine			Hewn	Rueping	"			75	30'	150	1¼	"	172	22	1¼		5.0 "					"	"									
"	"	127	Argonia Kan.	1905	Aug '15	10 "		572		"		"		7½x9			"		[illegible]	"			Sawed	"	"			65	50'	104	2¼ "		172				3.92"					"	"									
"	"	128	Newton Kan.	1905	Nov '15	10 "		9251		"		85		"		3227	"		[illegible]	"			Hewn	Burnettized	"			Initial Vacuum 24"	45'	100	2 "		200			0.58 lb						"	"	2446		601	3047	32.5	26.5			
"	"	129	"	1904	"	11 "		6357		"		85		"		"	"			"			Hewn	"	"			"	"	100	"		"			0.58"						"	"	2257			2257	25.5	35.5			
"	"	130	"	1904	"	11 "		2517		"		85		"		"	"			"			Sawed	"	"			"	"	"	"		"			0.58"						"	"	1054			1054	41.8	41.8			
"	"	131	"	1905	"	10 "		40		"		85		"		"	"			"			Sawed	"	"			"	"	"	"		"			0.58"						"	"									
ALABAMA GREAT	Chief Engineer	1	Birmingham Ala	June '10	Sept '15	5 Yrs 3 Mo.	313	50	Clay	Slag	Good	75#	ASCE	none			Cut			Longleaf Pine	7x9x8½	First	Hewn	Creosote	Unbarked	none											17.4"										0	0				Treated at Plant of Southern Creosote Co Slidell La
SOUTHERN R R	"	2	"	"	"	"	-	50	"	"	"	"					"			Loblolly Pine	"	"	"	"	"	"											17.4"										0	0				
(QUEEN AND	"	3	"	"	"	"	"	50	"	"	"	"					"			Red Oak	"	"	"	"	"	"											17.4"										0	0				
CRESCENT ROUTE)	"	4	"	"	"	"	"	50	"	"	"	"					"			White Oak	"	"	"	"	"	"											17.4"										0	0				
BALTIMORE AND OHIO R R	Engineer M of W	1	East of Windsor, Ohio	Feb 5 '11	Oct '15	4 Yrs 7 Mo	2270	1237	Sandy	Gravel	Good	90#	RB	Tie Plates		2880	Cut		[illegible]	Red Oak	7x9x8½	First	both	Zinc Creosote				23	1 hr 5 m	175	6 hours	153°	152°			0.5 lb	2.0 "		5.5 Gallons			Annually	Eng M of W	0	0	0	0	0	0	0		
	"	2	"	"	"	"	1600	872	Clay	"	"	"	"	"	"	"	"		"		"	"	"	Straight "													0.675 gal			2.5 Gal		or at	"	0	0	0	0	0	0	0		
"	"	3	"	"	"	"	2035	1107	"	"	"	"	"	"	"	"	"		"	Gum & Beech	"	"	"	Zinc "				23	1 hr	175	4 hrs 50 m	137°	157°			0.5 "	2.0 lb		5.5 Gallons			occasional	"	0	0	0	0	0	0	0		
"	"	4	"	"	"	"	460	250	"	"	"	"	"	"	"	"	"		"	"	"	"	"	Straight "				24	[illegible]			165°	175°				0.675 gal			2.5 Gal		periods	"	0	0	0	0	0	0	0		
"	"	5	"	"	"	"	1860	1011	"	"	"	"	"	"	"	"	"		"	Red Oak	"	"	"	Timber Asphalt						Open Tank	20 hrs	[illegible]	[illegible]					[illegible]			[illegible]	"	"	0	0	0	0	0	0	0		
"	"	6	"	"	"	"	1400	760	"	"	"	"	"	"	"	"	"		-	White Oak	"	"	"	Untreated																		"	"	0	0	0	0	0	0	0		

Sheet No2of 7

Number Removed				Results				Remarks
				Per Cent of total Removed			Average Life	
Acct. Decay	Mech Wear	Other Causes	Total	All Causes	Acct. Decay	Acct Mech Wear		
			49	100			Abt 9 Yrs	Original Quantity 50 one out for test
			99	100			" 9 "	" " 50 " " " "
			99	100			" 8 "	" " 100 " " " "
			49	100			" 9 "	" " 100 " " " "
			99	100			" 3½ "	
			42	100			" 3 "	
			80	100			" 9 "	
			100	100			" 3½ "	
			84	100			" 5 "	
			19	100			" 2 "	
			74	100			" 4 "	
			8	100			" 2 "	
			2	100			" 2 "	
			4	100			" 4 "	
			3	100			" 7 "	
			10	100			" 11 "	
			4	100			" 10 "	
			3	100			" 10 "	
			2	100			" 12 "	
			2	100			" 5 "	
			2	100			" 9 "	
			6	100			" 12 "	
			4	100			" 10 "	
			2	100			" 5 "	
			1	100			" 7 "	
			3	100			" 7 "	
			3	100			" 7 "	
			1	100			" 7 "	
			1	333				The three Bakersfield crude oil Ties
			4	100			" 12 "	were removed in 1906 for Inspection
			2	100			" 12 "	and were in a Perfect State of Preservation
			1	100			" 12 "	
			1	100			" 12 "	
			1	50				
			7	100			" 12 "	
			1	100			" 12 "	
	6	4	10	5.8		3.5		
8	12	90	110	36.5	2.6	3.9		
	4		4	9.1		9.1		
	6		6	4.2		3.2		
	6		6	2.2		2.2		
26			26	7.3	6.8			
			75	.044				
2446		601	3047	32.9	26.5			
2257			2257	25.5	35.5			
1054			1054	41.8	41.8			
			0	0				Treated at Plant of Southern Creosote Co. Slidell La
			0	0				
			0	0				
			0	0				
0	0	0	0	0	0	0		
0	0	0	0	0	0	0		
0	0	0	0	0	0	0		
0	0	0	0	0	0	0		
0	0	0	0	0	0	0		
0	0	0	0	0	0	0		

ENGINEERING ASSOCIATION
N WOOD PRESERVATION
RT - APPENDIX "A"
TIE SERVICE TEST

asoning		Treating								Absorption per Cu.Ft.			Absorption per Tie			Inspe
Steam		Initial Vacuum		Pressure		Temperature		Final Vacuum								How often Made
Lbs.	Time	Inches	Time	Lbs	Time	In Tank	In Retort	Inches	Time	Zinc Cl.	Creosote	Miscel.	Zinc Cl.	Creosote	Miscel.	
		26	1 hr.	120	3 to 5 hr.	200°	200°-185°	20	30 Min.	13.3						Annually
		"	"	"	"	"	"	"	"	14.1						"
		"	"	"	"	"	"	"	"	10.2						"
		"	"	"	"	"	"	"	"	11.6						"
		"	"	"	"	"	"	"	"	10.7						"
		"	"	"	"	"	"	"	"	9.4						"
		"	"	"	"	"	"	"	"	8.5						"
		"	"	"	"	"	"	"	"	9.6						"
		"	"	"	"	"	"	"	"	18.2						"
		"	"	"	"	"	"	"	"	15.0						"
		"	"	"	"	"	"	"	"	14.8						"
		"	"	"	"	"	"	"	"	12.9						"
		"	"	"	"	"	"	"	"	10.7						"
		"	"	"	"	"	"	"	"	12.7						"
		"	"	"	"	"	"	"	"	11.0						"
		"	"	"	"	"	"	"	"	10.2						"
		"	"	"	"	"	"	"	"	11.7						"
		"	"	"	"	"	"	"	"	14.1						"
		"	"	"	"	"	"	"	"	10.7						"
		"	"	"	"	"	"	"	"	12.8						"
		"	"	"	"	"	"	"	"	10.7						"
		"	"	"	"	"	"	"	"	11.3						"
		"	"	"	"	"	"	"	"	8.8						"
		"	"	"	"	"	"	"	"	11.2						"
		"	"	"	"	"	"	"	"	18.2						"
		"	"	"	"	"	"	"	"	14.6						"
		"	"	"	"	"	"	"	"	12.8						"
		"	"	"	"	"	"	"	"	11.9						"
		"	"	"	"	"	"	"	"	10.7						"
		"	"	"	"	"	"	"	"	12.7						"
		"	"	"	"	"	"	"	"	10.9						"
		"	"	"	"	"	"	"	"	12.9						"
		"	"	"	"	"	"	"	"	13.9						"
		"	"	"	"	"	"	"	"	11.3						"
		"	"	"	"	"	"	"	"	11.2						"
		"	"	"	"	"	"	"	"	9.7						"
		"	"	"	"	"	"	"	"	9.4						"
		"	"	"	"	"	"	"	"	10.7						"
		26	1 hr.	120	"	"	200°-185°	20	"	9.7						Annually
		"	"	"	"	"	"	"	"	14.1						"
		"	"	"	"	"	"	"	"	12.1						"
		"	"	"	"	"	"	"	"	13.6						"
		"	"	"	"	"	"	"	"	12.5						"
		"	"	"	"	"	"	"	"	10.2						"
		"	"	"	"	"	"	"	"	12.7						"
		"	"	"	"	"	"	"	"	10.9						"
		"	"	"	"	"	"	"	"	8.9						"
		"	"	"	"	"	"	"	"	8.9						"
		"	"	"	"	"	"	"	"	10.9						"
		"	"	"	"	"	"	"	"	7.4						"
		"	"	"	"	"	"	"	"					15#		"
		"	"	"	"	"	"	"	"	10.6						"
		"	"	"	"	"	"	"	"	10.1						"
		"	"	"	"	"	"	"	"	9.4						"
		"	"	"	"	"	"	"	"	7.7						"
														15#		"
																"
																"
																"
																"
																"
										Untreated						"
																"
																"
																"
																"
																"
																"

AMERICAN RAILWAY ENGINEERING ASSOCIATION
COMMITTEE ON WOOD PRESERVATION
1915 REPORT - APPENDIX "A"
RECORD OF TIE SERVICE TEST

Sheet No 3 of 7

Company or Organization	Official Reporting	Test No.	Locality of Test	Date		Time of Test	Distance of Test	Number of Ties	Description of Conditions											Description of Material				Kind of Treatment	Seasoning			Treating								Absorption per Cu Ft			Absorption per Tie			Inspection		Number Removed				Results				Remarks
				Placed	Reported				Sub Grade Soil	Kind of Ballast	Drainage	Rail		Tie Plate		Ties per Mi of Track	Cut or Screw Spike	Alinement	Traffic Tonnage Annum	Kind of Wood	Size	Class	Sawed or Hewn		Air	Steam		Initial Vacuum		Pressure		Temperature		Final Vacuum		Zinc Cl	Creosote	Mixed	Zinc Cl	Creosote	Miscel	How often Made	Official in Charge	Acct Decay	Mech Wear	Other Causes	Total	% of Total Removed			Average Life	
												Wt	Section	Size	Kind of Bottom											Lbs	Time	Inches	Time	Lbs	Time			Inches	Time													All Causes	Acct Decay	Acct Mech Wear		
CHICAGO	Supt of Timber Pres	1	Fort Line	Apr 07	Oct 15	8Yrs 6Mo		58		Gravel		85#		Sellers Tie						Lodge Pole				Creosoted				Treated at Experimental Retort														Annually	Supt of			1	1	1.7		1.7		
BURLINGTON	"	2	Sheridan Wyo	Oct 06	"	9 Yrs		61		-		85		Plates						[illegible]				Various						Sheridan Wyo												"	Timber Pres	12		1	13	21.3	19.7	1.6		
& QUINCY RR	"	3	Sidney Neb to Pecks Colo	Jan 01	Sept 15	15Yrs 9Mo	2 Miles	6354		-		75		None						Pine				Zinc Cl				Treated		at Edgemont S.D.												"	"	448			448	7.1	7.1			
	"	4	Mystic S D	Oct 00	"	15 Yrs		550		Stone		75		Full Tie Plated						Red Oak				Burnettized						"		"										"	"	119		3	122	22.2	21.6	.6		
	"	5	Gillette Wyo	June 04	"	11Yrs 3Mo		1320		Rock										[illegible]				"						Sheridan Wyo												.	"				953	72.2				V Shaped Triangular Ties
		6	Elsberry Mo	Aug 05	Oct 15	10Yrs 2Mo		63												Pine			Hewn	"												0.309[b]											25	40.0				Notes (a) 72 Ties Average
	"	7	" "	"	"	"		25												"			Sawed	Rueping Creosote													4.92										2	8.0				(b) 59
	"	8	" "	"	"	"		39												"			"	Creosote													8.841										3	7.7				(c) Max Temp of oil 287°F
	"	9	" "	"	"	"		77															"	Allardyce												0.384	1.652[a]										5	6.5				(d) 30 Ties Average
	"	10	" "	"	"	"		10												"			"	Untreated																							5	50.0				(e) 70 " "
	"	11	" "	"	"	"		91												[illegible]			"	Burnettized												0.262											7	7.7				
	"	12	" "	"	"	"		40												Fir			"	Rueping Creosote													5.775										0	0.0				
	"	13	" "	"	"	"		74												"			"	Creosote													7.456[a]										2	2.7				
	"	14	" "	"	"	"		41												"			"	Allardyce												0.289	1.766[d]										4	9.5				
	"	15	" "	"	"	"		32												"			"	Treated in Creosote				Immersed in Creosote heated to max 287°F									3.99[c]										3	9.4				
	"	16	" "	"	"	"		89												"			"	Untreated																							43	48.3				
CHICAGO	Tie Agent	1	Bardwell Wis	1911	1915	4 Yrs		107		Gravel	Good	75#		#3			Cut			Hemlock Tamarack	6×8×8		Hewn	Card creo & zinc	8 Mo													Creosote Zinc lbs			Creosote [illegible] lbs							0				
MILWAUKEE	"	2	Braymur Mo	1908	"	7 "		596		Burnt Clay	Fair	85		None			"			Maple	7×9×9		Sawed	"	"													10			2½							0				
& ST PAUL RY	"	3	Madison Wis	1911	"	4 "		176		Gravel	Good	75		"			"			Red Oak	6×8×8		Hewn	Burnettized		Steamed										1½ lbs			½ lb									0				
	"	4	Rio Wis	1899	"	16 "		2100		.		90		"			"			Lt Yellow [illegible]	"		Sawed	Untreated																								87.0				
"	"	5	Minneiska Minn	1911	"	4 "		500			.	90		"			"			Beech	"		"	Burnettized		Steamed										1⅓ lbs			½ lb									1.5				
"	"	6	Cowgill Mo	1911	"	4 "		75		Burnt Clay	"	85		"			"			White Oak	7×9×8		Hewn	Untreated																								0				
"	"	7	Braymur Mo	1911	"	4 "		280			"	85		"			"			"	6×8×8		"	"																								0				
"	"	8	Lake Wis	1912	"	3 "		344		Cinders	"	85		"			"			Beech	"		Sawed	Card	8 Mo													6			2½ lb							0				
	"	9	McLaughlin SD	1906	"	9 "		300		Gravel	"	85		"			"			Red Oak	"		Hewn	Burnettized		Steamed										1½ lbs			½ lb									1.3				
"	"	10	Washington Ia	1903	"	12 "		500			"	85		"			"			White Oak	"		.	Untreated																								44.0				
"	"	11	" "	1903	"	12 "		500			"	85		Tie Plate			"			[illegible]	"		Sawed	Burnettized	Seasoned											1⅓ lbs			½ lb									10.0				
	"	12	Morristown SD	1906	"	9 "		500		Burnt Clay	Fair	85		"			"			Northern Pine	"		"	"	"											1½ lbs			½ lb									11.0				
	"	13	Byron Ill	1913	"	2 "		373		Gravel	Good	100		None			"			Red Oak			Hewn	"	.											1½ lbs			½ lb									0				
	"	14	"	1913	"	2 "		432			.	100		"			"				"		"			Steamed										1½ lbs			½ lb									0				
"	"	15	Groton SD	1912	"	3 "		500		Cinders	Fair	90		Sellers			"			Western Fir	7×8×8		Sawed	Untreated																								0				
"	"	16	Lyndow Wis	1902	"	13 "		500		Gravel	Good	85		Tie Plate			"			Cedar	"		Pole	"																								38.0				
"	"	17	Monroe "	1911	"	4 "		177		Cinders	"	60		None			"			"	6×8×8		Sawed	"																								0				
"	"	18	" "	1913	"	2 "		97		.	"	60		"			"			"	"		"	"																								0				
"	"	19	Milwaukee "	1912	"	3 "		500		Gravel	"	65		Sellers			"			"	"		Hewn	"																								0				
"	"	20	" "	1912	"	3 "		500		.	"	65		"			"			"	"		"	"																								0				
"	"	21	Adeline Ill	1910	"	5 "		1000		.	"	100		Flat Iron Plate			"			Hemlock	8×10×8½		"	Card	Seasoned													11.7			2½ lb							0				
"	"	22	Black Hills Div	1906	"	9 "		496		.	"	65		None			"			Pine	6×8×8		"	Burnettized	"											1½ lbs			½ lb									0				
	.	23	No McGregor Ia	1911	"	4 "		137		Cinders	"	65		"			-			Fir	"		Sawed	Untreated																								0				
CHICAGO	Supervisor Tie	1	Sibley Ia	Nov 00	June 15	14Yrs 8Mo	6 Miles	10856		Gravel & Dirt		60		None			Cut		Light	Hemlock	6×8×8		Hewn	Wellhouse			2 to 3 hrs				3 to 4½ hrs								½ lb			Annually	Supervisor Tie &				3446	31.7				
ROCK ISLAND	& Timber Supply																																										Timber Dept									
& PACIFIC RY																																																				
CHICAGO &	Chief Engineer	1	Tuscola Ill.	Nov '12	Oct 15	2Yrs 11Mo		687	Loam	Gravel	Good	90#	ARA	6½×8¾	⅝ ribs	3200	Cut	2° curve		White Oak	6×8×8	First	Hewn	Untreated																		Annually	Chief Engineer	None			None					
EASTERN	"	2	"	"	"	"		783	"	"		"	"	None		"	"	Tang		"			"	"																		"	"	"			"					
ILLINOIS	"	3	"	"	"	"		1288	-	"		"	"			"	"	"		Elm			"	Lowry	10 Mo	None		None		128	½ hr	180	178	23½	1½ hr		7.56 lbs			2.55 Gal		"	"	"			"					
	"	4	"	"	"	"		68	"	"		"	"			"	"	"		"			Sawed	"	"	"		"		128	"	180	178	"	"		7.56 lbs			"		"	"	"			"					
	"	5	"	"	"	"		775	"	"		"	"			"	"	"		Beech			Hewn	Burnettized	8 Mo	"		22	⅓ hr	100	2 hr			None		510 lbs			1.41 lbs			"	"	"			"					Treated Ties Stacked for Seasoning 26 Days
"	"	6	"	o	"	"		28	"	"		"	"			"	"	"		"			Sawed	"	"	"		22	"	100	"			"		510 lbs			"			"	"	"			"					" " " " " " "
	"	7	"	Oct 12	"	3 Yrs.	43 Miles	345	"	-		"	"	6¼×8¾	⅝ ribs	"	"	"		Gum			Hewn	"	"	"		22	"	100	1⅓ hr			"		592 lbs			1.580 lbs			"	"	"			"					" " " " " 25 "
.	"	8	"	"	"	"		8	"	"		"	"	"	"	"	"	"		"			Sawed	"	"	"		24	"	100	"			"		592 lbs			"			"	"	"			"					" " " " " 25 "
	"	9	"	"	"	"		769	"	"		-	"	None		"	"	"		Red Oak			Hewn	"	12 Mo	"		22	"	100	3 hr			"		539 lbs			1.453 lbs			"	"	"			"					" " " " " 24 "
"	"	10	"	"	"	"		672	"	"		"	"	"		"	"	"		"			Sawed	"	"	"		22	-	100	-			"		539 lbs			"			"	"	"			"					" " " " " 24 "
.	"	11	"	"	"	"		1865	"	"		"	"	"		"	"	"		"			Hewn	Lowry	14 Mo	"		none		175	2¾ hr.	180	176	25	1hr		7.04 lb			2.56 Gal		"	"	"			"					
.	"	12	"	"	"	"		955	"	"		"	"	"		"	"	"		"			Sawed	"	13 Mo.	"		"		175	2 hr.	180	175	26½	1hr		8.79 lb			2.65 Gal		"	"	"			"					
"	"	13	"	"	"	"		621	"	"		"	"	"		"	"	"		"			Hewn	Burnettized	12 Mo	"		22	½ hr	100	"			None		343 lbs			926 lbs			"	"	"			"					Treated Ties Stacked for Seasoning 24 Days
"	"	14	"	"	"	"		724	"	"		"	"	"		"	"	"		"			Sawed	"	"	"		"	⅓ hr	100	2¼ hr			"		347 lbs			916 lbs			"	"	"			"					" " " " " " "
.	.	15	"	"	"	"		1507	"	"		"	"	"		"	"	"		Beech			"	Lowry	6 Mo	"		None		175	1hr.	180	176	24	1hr.		8.44 lb			2.52 Gal		"	"	"			"					
CLEVELAND		1																																																		
CINCINNATI	RECORD		NOT RECEIVED																																																	
CHICAGO &																																																				
ST LOUIS																																																				
(BIG FOUR)																																																				

AMERICAN RAILWAY ENGINEERING ASSOCIATION
COMMITTEE ON WOOD PRESERVATION
1915 REPORT - APPENDIX "A"
RECORD OF TIE SERVICE TEST

Sheet No 4 of 7

Company or Organization	Official Reporting	Test No.	Locality of Test	Date Placed	Date Reported	Time of Test	Distance of Test	Number of Ties	Sub Grade Soil	Kind of Ballast	Drainage	Rail Wt.	Rail Section	Tie Plate Size	Tie Plate Kind of Bottom	Ties per Mi of Track	Cut or Screw Spike	Alinement	Traffic Tonnage Amount	Kind of Wood	Size	Class	Sawed or Hewn	Kind of Treatment	Seasoning Air	Seasoning Steam Lbs	Seasoning Steam Time	Initial Vacuum Inches	Initial Vacuum Time	Pressure Lbs	Pressure Time	Temperature In Tank	Temperature [illegible]	Final Vacuum Inches	Final Vacuum Time	Absorption per Cu Ft Zinc Cl	Absorption per Cu Ft Creosote	Absorption per Cu Ft Mixed	Absorption per Tie Zinc Cl	Absorption per Tie Creosote	Absorption per Tie Mixed	Inspection How often Made	Inspection Official in Charge	Number Removed Acct Decay	Number Removed Mech Wear	Number Removed Other Causes	Number Removed Total	Per Cent of Total Removed All Causes	Per Cent of Total Removed Acct Decay	Per Cent of Total Removed Acct Mech Wear	Average Life	Remarks
C&NW RyCo & US	Asst Genl Mgr	1	Janesville Wis	Dec 07	June 15	7Yrs 1Mo	Total	55	Sandy	Gravel	Good	90#			Flat	3040	Screw		2734000	Hemlock	7"	First	Both	Wellhouse	1Yr			26	1hr	120	3½Hr	200°	200°-10°	20	30Min	13.3						Annually	Asst					3.6				
DEPARTMENT OF	C&NW RY	2	"	"	"	"	Test	40	Loam	"	"	"			Steel	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	14.1						"	Gen'l				0	0				
AGRICULTURE	"	3	"	"	"	"	5280'	41	& Clay	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	10.2						"	Mgr &				0	0				
"	"	4	"	"	"	"		40	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	11.6						"	Forest				0	0				
"	"	5	"	"	"	"		40	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	10.7						"	Rep				0	0				
"	"	6	"	"	"	"		37	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	9.4						"	"				0	0				
"	"	7	"	"	"	"		41	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	8.5						"	"					9.8				
"	"	8	"	"	"	"		40	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	9.6						"	"				0	0				
"	"	9	"	"	"	"		24	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	18.2						"	"				0	0				
"	"	10	"	"	"	"		25	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	15.0						"	"					0				
"	"	11	"	"	"	"		40	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	14.8						"	"					2.5				
"	"	12	"	"	"	"		47	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	12.9						"	"					2.1				
"	"	13	"	"	"	"		125	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	10.7						"	"				0	0				
"	"	14	"	"	"	"		125	"	"	"	"			"	"	"		"	Tamarack	"	"	"	Burnettized				"	"	"	"	"	"	"	"	12.7						"	"				0	0				
"	"	15	"	"	"	"		50	"	"	"	"			"	"	"		"	"	"	"	"	Wellhouse				"	"	"	"	"	"	"	"	11.0						"	"					0				
"	"	16	"	"	"	"		38	"	"	"	"			Wood	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	10.2						"	"					2.5				
"	"	17	"	"	"	"		40	"	"	"	"			(Flat	"	Cut		"	Hemlock	"	"	"	"				"	"	"	"	"	"	"	"	11.7						"	"					2.0				
"	"	18	"	"	"	"		40	"	"	"	"			(Steel	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	14.1						"	"					2.5				
"	"	19	"	"	"	"		40	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	10.7						"	"				0	0				
"	"	20	"	"	"	"		40	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	12.8						"	"				0	0				
"	"	21	"	"	"	"		40	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	10.7						"	"				0	0				
"	"	22	"	"	"	"		40	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	11.3						"	"					2.5				
"	"	23	"	"	"	"		40	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	8.8						"	"					5.0				
"	"	24	"	"	"	"		39	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	11.2						"	"				0	0				
"	"	25	"	"	"	"		25	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	18.2						"	"				0	0				
"	"	26	"	"	"	"		25	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	14.6						"	"				0	0				
"	"	27	"	"	"	"		40	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	12.8						"	"				0	0				
"	"	28	"	"	"	"		44	"	"	"	"			"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	11.9						"	"					2.3				
"	"	29	"	"	"	"		125	"	"	"	"			"	"	"		"	Tamarack	"	"	"	"				"	"	"	"	"	"	"	"	10.7						"	"				0	0				
"	"	30	"	"	"	"		125	"	"	"	"			"	"	"		"	"	"	"	"	Burnettized				"	"	"	"	"	"	"	"	12.7						"	"				0	0				
"	"	31	"	"	"	"		50	"	"	"	"			"	"	"		"	"	"	"	"	Wellhouse				"	"	"	"	"	"	"	"	10.9						"	"				0	0				
"	"	32	"	"	"	"		39	"	"	"	"		C Strip-Plate		"	"		"	Hemlock	"	"	"	"				"	"	"	"	"	"	"	"	12.9						"	"				0	0				
"	"	33	"	"	"	"		41	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	13.9						"	"				0	0				
"	"	34	"	"	"	"		43	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	11.3						"	"				0	0				
"	"	35	"	"	"	"		39	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	11.2						"	"				0	0				
"	"	36	"	"	"	"		40	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	9.7						"	"				0	0				
"	"	37	"	"	"	"		40	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	9.4						"	"					2.5				
"	"	38	"	"	"	"		40	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	10.7						"	"				0	2.5				
"	"	39	"	"	"	"		40	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	9.7						"	"				0	0				
"	"	40	"	"	"	"		25	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	14.1						"	"				0	0				
"	"	41	"	"	"	"		21	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	12.1						"	"				0	0				
"	"	42	"	"	"	"		40	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	13.6						"	"				0	0				
"	"	43	"	"	"	"		49	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	12.5						"	"				0	0				
"	"	44	"	"	"	"		128	"	"	"	"		"	"	"	"		"	Tamarack	"	"	"	"				"	"	"	"	"	"	"	"	10.2						"	"					0.8				
"	"	45	"	"	"	"		125	"	"	"	"		"	"	"	"		"	"	"	"	"	Burnettized				"	"	"	"	"	"	"	"	12.7						"	"				0	0				
"	"	46	"	"	"	"		50	"	"	"	"		"	"	"	"		"	"	"	"	"	Wellhouse				"	"	"	"	"	"	"	"	10.9						"	"				0	0				
"	"	47	"	"	"	"		53	"	"	"	"		"	"	"	"		"	Hemlock	"	"	"	"				"	"	"	"	"	"	"	"	8.9						"	"					7.5				
"	"	48	"	"	"	"		51	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	8.9						"	"					3.9				
"	"	49	"	"	"	"		51	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	10.9						"	"					3.9				
"	"	50	"	"	"	"		25	"	"	"	"		"	"	"	"		"	"	"	"	"	Burnettized				"	"	"	"	"	"	"	"	7.4						"	"					16.0				
"	"	51	"	"	"	"		33	"	"	"	"		"	"	"	"		"	"	"	"	"	Open Tank				"	"	"	"	"	"	"	"					15#		"	"				0					
"	"	52	"	"	"	"		59	"	"	"	"		"	"	"	"		"	Tamarack	"	"	"	Wellhouse				"	"	"	"	"	"	"	"	10.6						"	"				0					
"	"	53	"	"	"	"		55	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	10.1						"	"					1.8				
"	"	54	"	"	"	"		58	"	"	"	"		"	"	"	"		"	"	"	"	"	"				"	"	"	"	"	"	"	"	9.4						"	"					1.7				
"	"	55	"	"	"	"		13	"	"	"	"		"	"	"	"		"	"	"	"	"	Burnettized				"	"	"	"	"	"	"	"	7.7						"	"				0					
"	"	56	"	"	"	"		19	"	"	"	"		"	"	"	"		"	"	"	"	"	Open Tank																15#		"	"				0					
"	"	57	"	"	"	"		20	"	"	"	"		No Plates		"	"		"	Hemlock	"	"	"	Untreated																		"	"				20	100	945	5.5		
"	"	58	"	"	"	"		20	"	"	"	"		"	"	"	"		"	"	"	"	"	"																		"	"				14	100	633	6.7		
"	"	59	"	"	"	"		20	"	"	"	"		"	"	"	"		"	"	"	"	"	"																		"	"				17	100	186	64		
"	"	60	"	"	"	"		20	"	"	"	"		"	"	"	"		"	"	"	"	"	"																		"	"				14	100	635	6.0		
"	"	61	"	"	"	"		20	Sandy	"	"	"		"	"	"	"		"	"	"	"	"	"																		"	"				16	100	80		6Years	
"	"	62	"	"	"	"		20	Loam	"	"	"		"	"	"	"		"	"	"	"	"	"																		"	"				16	100	80		5Yrs 5Mo.	
"	"	63	"	"	"	"		50	& Clay	"	"	"		"	"	"	"		"	"	"	"	"	"																		"	"				31	80	62		7Years	
"	"	64	"	"	"	"		25	"	"	"	"		"	"	"	"		"	Tamarack	"	"	"	"												Untreated						"	"				16	72	64		6Yrs 4Mo.	
"	"	65	"	"	"	"		25	"	"	"	"		"	"	"	"		"	"	"	"	"	"																		"	"				24	100	96		6Yrs 3Mo.	
"	"	66	"	"	"	"		20	"	"	"	"		"	"	"	"		"	"	"	"	"	"																		"	"				17	95	85		7Years	
"	"	67	"	"	"	"		62	"	"	"	"		"	"	"	"		"	"	"	"	"	"																		"	"				57	95²	92		7 "	
"	"	68	"	"	"	"		50	"	"	"	"		"	"	"	"		"	Red Oak	"	"	"	"																		"	"				0	36.0				

Sheet No. 4 of 7

tion fficial in charge	Number Removed				Results				Remarks
					Per Cent of Total Removed			Average Life	
	Acc't. Decay	Mech. Wear	Other Causes	Total	All Causes	Acct Decay	Acct. Mech Wear		
sst					3.6				
				0	0				
				0	0				
rest				0	0				
ep				0	0				
"				0	0				
"					9.8				
"				0	0				
"				0	0				
"					0				
"					2.5				
"					2.1				
"				0	0				
"				0	0				
"					0				
"					2.5				
"					2.0				
"					2.5				
"				0	0				
"				0	0				
"				0	0				
"					2.5				
"					5.0				
"				0	0				
"				0	0				
"				0	0				
"				0	0				
"					2.3				
"				0	0				
"				0	0				
"				0	0				
"				0	0				
"				0	0				
"				0	0				
"				0	0				
"				0	0				
"					2.5				
"				0	2.5				
"				0	0				
"				0	0				
"				0	0				
"				0	0				
"				0	0				
"					0.8				
"				0	0				
"				0	0				
"					7.5				
"					3.9				
"					3.9				
"					16.0				
"				0					
"				0					
"					1.8				
"					1.7				
"				0					
"				0					
"				20	100	94.5	5.5		
"				14	100	63.3	6.7		
"				17	100	18.6	6.4		
"				14	100	63.5	6.0		
"				16	100	80		6 Years	
"				16	100	80		5 Yrs. 5 Mo.	
"				31	80	62		7 Years	
"				16	72	64		6 Yrs. 4 Mo.	
"				24	100	96		6 Yrs. 3 Mo.	
"				17	95	85		7 Years	
"				57	95.2	92		7 "	
				0	36.0				

ENGINEERING ASSOCIATION
ON WOOD PRESERVATION
ORT - APPENDIX "A"
F TIE SERVICE TEST

Seasoning			Treating								Absorption per Cu.Ft			Absorption per Tie			In
	Steam		Initial Vacuum		Pressure		Temperature		Final Vacuum								How Oft Made
Air	Lbs.	Time	Inches	Time	Lbs.	Time	In Tank	In Retort	Inches	Time	Zinc Cl.	Creosote	Miscel.	Zinc Cl.	Creosote	Miscel.	
Air																	
easoned																	
tolzHo	None				175	5¾ hrs			24	1 hr.					2.48 gal.		
"	"				"	1½ "			24½	"					2.76 "		
"	"				"	3¾ "			23½	"					3.38 "		
"	"				"	5¼ "			25	"					2.61 "		
"	"				"	3 "			24½	"					2.53 "		
-Mo.																	Annually
"	25	4 hrs.	22	5 hrs.	20 hrs.	½ hr.						10 lbs.					"
"																	"
"																	"
"											Absorpti	on 101.65	%of Weight	Strength	of Zinc So	lution 32%	"
"											"	69.61	"	"	"	" 32%	"
"																	"
"																	"
"											Absorptio	n 85.75%	of Weight	Strength	of Zinc So	lution 32%	"
"											"	35.00%	"	"	"	" 32%	"
-Mo.																	"
																	Annuall
																	"
																	"
																	"
																	"
reen																	Annuall
ir																	"
"																	"
reen																	"
"																	"
r																	"
"																	"
reen																	"
"																	"
ir																	"
"																	"
reen																	"
"																	"
ir																	"
"																	"
een																	"
"																	"
ir																	"
"																	"
een																	"
"																	"
r																	"
											0.786 lbs						"
											0.786 "						"
ir																	"
zen																	"
											0.786 "						"
											0.786 "						"
r																	"
"																	"
zen																	"
r																	"
												6.17 lbs.					"
zen																	"
"																	"

AMERICAN RAILWAY ENGINEERING ASSOCIATION
COMMITTEE ON WOOD PRESERVATION
1915 REPORT - APPENDIX "A"
RECORD OF TIE SERVICE TEST

Sheet No 5 of 7

Company or Organization	Official Reporting	Test No	Locality of Test	Date		Time of Test	Distance of Test	Number of Ties	Description of Conditions											Description of Material				Kind of Treatment	Seasoning			Treating								Absorption per Cu Ft			Absorption per Tie			Inspection		Number Removed				Results				Remarks
				Placed	Reported				Sub Grade Soil	Kind of Ballast	Drainage	Rail Wt	Rail Section	Tie Plate Size	Tie Plate Kind of Bottom	Ties per M of Track	Cut or Screw Spike	Alinement	Traffic Tonnage Annual	Kind of Wood	Size	Class	Sawed or Hewn		Air	Steam Lbs	Steam Time	Initial Vacuum Inches	Initial Vacuum Time	Pressure Lbs	Pressure Time	Temperature In Tank	Temperature In Cyl	Final Vacuum Inches	Final Vacuum Time	Zinc Cl	Creosote	Miscel	Zinc Cl	Creosote	Miscel	How often Made	Official in Charge	Acct Decay	Mech Wear	Other Causes	Total	% of Total Removed All Causes	Acct Decay	Acct Mech Wear	Average Life	
GALVESTON	ENGINEER M W	1	Bay View to San Leon Texas	Oct 05	July 15	9 Yrs 9 Mo	9803	1001				80#	ASCE	Part Tie	Fulled		Both		Normal	Pine	7x9x8		Hewn	Burnettized		25	4hrs			25	4hrs					0.4122 lbs			1.44 lbs				Eng MW				999	99.8				
HARRISBURG	"	2	"	"	"	"	6370	1000				"	-	and Part	not		"		"	"			Sawed	Untreated																			"				999	99.9				
& SAN ANTONIO RY	-	3	"	Mar 05		10 Yrs 4 Mo	5539	1003				"	"	-			"		"	"	7x8x8		Hewn	Zinc Creosoted		25	4hrs									0.27 lbs	6.78		.835 "	21.22 lbs			"				326	32.5				
	–	4	"	"	"	"	2800	1000				"	"	-			"		"	Cypress	7x9x8		"	Untreated																			"				354	35.4				
	"	5	"	"	"	"	1800	129				"	"				"		"	Red Gum	6x8x8		Sawed	Burnettized		25	4 hrs									0.2138 lbs			.729				"				121	93.8				
	"	6	"	"	"	"	1625	113				"	"				"		"	Tupelo "			"	-		-	-									0.2239 "			.555 "				"				107	94.7				
	"	7	"	"	"	"	1419	113				"	"				"		"	Red "	"		"	"		None										0.3347 "			.811 "				"				106	93.2				
	"	8	"	"	"	"	1204	85				"	"				"		"	Tupelo "	"		"	"		2	4hrs									0.234 "			.622 "				"				79	92.9				
	"	9	"	"	"	"	1047	112				"	"				"		"	Red "	"		"	Creosoted		25	4hrs										12.52 lb			33.3 lbs			"				49	43.7				
	"	10	"	"	"	"	838	113				"	"				"		"	Tupelo "	"		"	"		"	"										11.31 "			29.82			"				40	35.4				
	"	11	"	"	"	"	678	88				"	"				"		"	Red "	"		"	"		None											14.45 "			38.45 "			"				15	17.0				
	"	12	"	"	"	"	477	88				"	"				"		"	Tupelo "	"		"	"		"											13.21 "			35.15 "			"				21	23.9				
	"	13	"	"	"	"	314	45				"	"				"		"	Red "	"		"	Zinc Creosoted												0.2734 lbs	0.7785		2.3 lbs	6.14			"				23	51.1				
	"	14	"	"	"	"	231	42				"	"				"		"	Tupelo "	"		"													0.2239 "	0.9935		2.02 "	3.38 "			"				37	88.1				
	"	15	"	"	"	"	151	41				"	"				"		"	Red "	"		"	Untreated																			"				41	100			?	
	"	16	"	"	"	"	79	42				"	"				"		"	Tupelo "	"		"	"																		Once a Year	"				42	100				
	"	17	"	Dec '09	"	5 Yrs 7 Mo	4198	2290		Gravel		"	"	8x8¼	Flat		Screw		"	Cypress	7x9x8		"	"																			"				0	0				
	"	18	"	Nov '09	"	5 Yrs 8 Mo	6690	3637		"		"	"	8x8¼	"		"		"	"	"		"	"																			"				0	0				
	"	19	Fort Hancock Texas	Oct '94	"	20 Yrs 9 Mo		200				"	"	5x8	Servis				"	Pine			"	Zinc Creosoted																			"	87			157	78.5	64			Dry Rot
	"	20	Ft Hancock to Isler, Texas	Jan '07	"	8 Yrs 6 Mo	804	500		Slag		"	"	5x8	Glendon		Cut		"	Red Oak	7x9x8		Hewn	Diamond Wood Preserver							1½ Min							0.18			0.52 gal		"				15	3.0				Treatment directed by
	"	21	"	"	"	"	814	500		"		"	"	"	"		"		"	" Gum	"		"	"														0.21			0.73 "		"				4	0.8				Percival Wood Preserving Co
	"	22	"	"	"	"	816	500		"		"	"	"	"		"		"	Sap Pine	"		"	-														0.114			0.40 "		"				158	31.6				
	"	23	Witherow to Solis, Louisiana	Feb 07	"	8 Yrs 5 Mo		433		Good		90#	C S	8x8½	Flat		"		"	Pine	7x9x9		"	Zinc Creosoted													3½-6 lbs						"				27	6.2				7% Slightly decayed 5% badly decayed
	"	24	"	"	"	"		205		"		"	"	"	"		"		"	"	"		"	Creosoted													12 lbs						"				0	0				No evidence of decay
	"	25	"	Apr '07	"	8 Yrs 3 Mo		95		"		-	"	"	"		"		"	"	7x8x8		"	Rueping																			"				0	0				" " "
	"	26	Lafayette to Scott Louisiana	Jan '07	"	8 Yrs 6 Mo		100		"		80#	ASCE	8x8¼	-		"		"	"	"		"	"																			"				2	2.0				Slight decay
	"	27	"	Aug '06	"	8 Yrs 11 Mo		250				"	"	"	"		"		"	Red Oak	"		"	Zinc Creosoted												4%	12%		4%	12%			"				92	36.8				15 " 6 badly decayed
	"	28	"	Dec 06	"	8 Yrs 7 Mo		599		"		"	"	"	"		"		"	Pine	7x9x9		"	"													5½-6 lbs						"				109	18.2				52 Removed to put in Switch [illegible]
	"	29	"	"	"	"		285		"		"	"	"	"		"		"	"	"		"	Creosoted													12 "						"				10	3.5				21 [illegible] decayed 8 Slightly
	"	30	"	Mar '07	"	8 Yrs 4 Mo		100		"		"	"	"	"		"		"	"	"		"	Untreated																			"				100	100			2 Yrs 8 Mo	
"	"	31	Bay View to San Leon, Texas	Oct '09	"	5 Yrs 9 Mo		868		"		"	"	"	"		Screw		"	"	6x10x8		"	Creosoted													1.326 gal			4.42			"				0	0				
GEORGIA R R	Roadmaster	1	Barnett to Union Pt Ga	Sept 07	Feb 15	7 Yrs 3 Mo	570	1000	Clay	Cinder	Open	63#	ASCE	None		3000	Cut	Tang.	[illegible]	[illegible]	7x9x8		Hewn	Creosoted	6 Mos												10 lbs			35 lbs		Annually	Roadmaster	12			12	1.2%				Ties in good [illegible]
"	"	2	Barnett, Ga	"	"	" "	570	1000	"		Good Surface	"	"	"		"	–		[illegible]	Sap Pine	"		"	Creosoted	1 Yr												10 lbs						"	8			8	0.8 "				" " " "
ILLINOIS	Supt Timber Dept	1	Bloomington Ill	Oct '10	Sept 10 '15	5 Yrs	502	274	Loam	Gravel	Good	75#	ASCE	50%			Cut			Red Oak	6x8x8		Both	Burnettized				26	1 hr	100	1 hr 30 Min					.05#			.4 gal				Supt Tim Dpt									Showing signs of Mechanical Wear and Decay
CENTRAL RR	"	2	"	"	"		503	274	"	"	"	"	"	"			"			Beech Gum	"		"	"				"	"	"	"					.05#			"				"									
"	"	3	"	"	"		502	274	"	"	"	"	"	"			"			Pine	"		"	"				"	"	"	"					.05#			"				"									
"	"	4	"	"	"		499	274	"	"	"	"	"	"			"			"	"		"	Rueping				75#	30 Min	175	2 hrs						5 lbs			1.7 gal			"									
"	"	5	"	"	"		502	274	"	"	"	"	"	"			"			Red Oak	"		"	"				"	"	"	"						5 "			"			"									
"	"	6	"	"	"		506	274	"	"	"	"	"	"			"			Beech Gum	"		"	"				"	"	"	"						5 "			"			"									
"	"	7	"	"	"		503	274	"	"	"	"	"	"			"			Northern Red Oak	"		"	Untreated																			"				1					
"	"	8	"	"	"		502	274	"	"	"	"	"	"			"			Southern Red Oak	"		"	"																			"				1					
"	"	9	Kankakee, Ill	Nov '09	Sept 10 15	6 Yrs	Total	Total	"	Stone	"	90#	AREA	"			"			Red Oak	"		"	Burnettized				26	1 hr	100	1 hr 30 Min					.05#			.4 gal				"			[illegible] wear	2					
"	"	10	"	"	"	"	Length	Ties	"	"	"	"	"	"			"			Beech Gum	"		"	"				"	"	"	"					.05#			"				"			"	2					
"	"	11	"	"	"	"	3839	2122	"	"	"	"	"	"			"			Pine	"		"	"				"	"	"	"					.05#			"				"			"	2					
"	"	12	"	"	"	"			"	"	"	"	"	"			"			"	"		"	Rueping				75#	30 Min	175	2 hrs						5 lbs			1.7 gal			"									
"	"	13	"	"	"	"			"	"	"	"	"	"			"			Red Oak	"		"	"				"	"	"	"						5 "			"			"									
"	"	14	"	"	"	"			"	"	"	"	"	"			"			Beech Gum	"		"	"				"	"	"	"						5 "			"			"			[illegible] wear	1					
"	"	15	"	"	"	"			"	"	"	"	"	"			"			Northern Red Oak	"		"	Untreated																			"	2		"	3					
"	"	16	"	"	"	"			"	"	"	"	"	"			"			Southern Red Oak	"		"	"																			"									
"	"	17	Fulton, Ky	Dec '09	Sept 11 15	"	Total	Total	"	Gravel	"	75#	ASCE	"			"			Red Oak	"		"	Burnettized	Air Seasoned			26	1 hr	100	1 hr 30 Min					.05#			.4 gal				"			53	53					Removed 8-1-15 [illegible] these ties
"	"	18	"	"	"	"	Length	Ties	"	"	"	"	"	"			"			Beech Gum	"		"	"				"	"	"	"					.05#			"				"									were removed Acct being rotten and
"	"	19	"	"	"	"	4094	2192	"	"	"	"	"	"			"			Pine	"		"	"				"	"	"	"					.05#			"				"				1					worn out by badly creeping track
"	"	20	"	"	"	"			"	"	"	"	"	"			"			"	"		"	Rueping				75#	30 Min	175	2 hrs						5 lbs			1.7 gal			"									
"	"	21	"	"	"	"			"	"	"	"	"	"			"			Red Oak	"		"	"				"	"	"	"						5 lbs			"			"									
"	"	22	"	"	"	"			"	"	"	"	"	"			"			Beech Gum	"		"	"				"	"	"	"						5 lbs			"			"				1					Broken by [illegible]
"	"	23	"	"	"	"			"	"	"	"	"	"			"			Northern Red Oak	"		"	Untreated																			"				15					
"	"	24	"	"	"	"			"	"	"	"	"	"			"			Southern Red Oak	"		"	"																			"				98					Lula track abandoned on account
"	"	25	Lula Miss	Oct '10	–	5 Yrs	Total	Total	"	"	"	"	"	"			"			Red Oak	"		"	Burnettized				26	1 hr	100	1 hr 30 Min					.05#			.4 gal				"									of bad derailments for full length of track
"	"	26	"	"	"	"	Length	Ties	"	"	"	"	"	"			"			Beech Gum	"		"	"				"	"	"	"					.05#			"				"									
"	"	27		"	"	"	4119'	2167	"	"	"	"	"	"			"			Pine	"		"	"				"	"	"	"					.05#			"				"									
"	"	28	"	"	"	"			"	"	"	"	"	"			"			"	"		"	Rueping				75#	30 Min	175	2 hrs						5 lbs			1.7 gal			"									
"	"	29	"	"	"	"			"	"	"	"	"	"			"			Red Oak	"		"	"				"	"	"	"						5 lbs			"			"									
"	"	30	"	"	"	"			"	"	"	"	"	"			"			Beech Gum	"		"	"				"	"	"	"						5 lbs			"			"									
"	"	31	"	"	"	"			"	"	"	"	"	"			"			Northern Red Oak	"		"	Untreated																			"									
"	"	32		"	"	"			"	"	"	"	"	"			"			Southern Red Oak	"		"	"																			"									
"	"	33	Greenville Miss	Nov '10	"	"	Total	Total	"	"	"	"	"	"			"			Red Oak	"		"	Burnettized				24	1 hr	100	1 hr 30 Min					.05#			.4 gal				"				1					
"	"	34	"	"	"	"	Length	Ties	"	"	"	"	"	"			"			Beech Gum	"		"	"				"	"	"	"					.05#			"				"	2			2					
"	"	35	"	"	"	"	6980	2475	"	"	"	"	"	"			"			Pine	"		"	"				"	"	"	"					.05#			"				"				2					
"	"	36	"	"	"	"			"	"	"	"	"	"			"			"	"		"	Rueping				75#	30 Min	175	2 hrs						5 lbs			1.7 gal			"			15	15					15 removed 1915 Acct Crushed & Spike Worn
"	"	37	"	"	"	"			"	"	"	"	"	"			"			Red Oak	"		"	"				"	"	"	"						5 lbs			"			"			2	2					2 removed 1915 Acct Split
"	"	38	"	"	"	"			"	"	"	"	"	"			"			Beech Gum	"		"	"				"	"	"	"						5 lbs			"			"									

AMERICAN RAILWAY ENGINEERING ASSOCIATION
COMMITTEE ON WOOD PRESERVATION
1915 REPORT - APPENDIX "A"
RECORD OF TIE SERVICE TEST

Sheet No 6 of 7

Company or Organization	Official Reporting	Test No.	Locality of Test	Date		Time of Test	Distance of Test	Number of Ties	Description of Conditions											Description of Material				Kind of Treatment	Seasoning			Treating								Absorption per Cu Ft			Absorption per Tie			Inspection		Number Removed				Results				Remarks
				Placed	Reported				Sub-grade Soil	Kind of Ballast	Drainage	Rail Wt	Rail Sect	Tie Plates Size	Tie Plates Kind of Bottom	Ties per Mile of Track	Cut or Screw Spike	Alinement	Traffic Tons per Annum	Kind of Wood	Size	Class	Sawed or Hewn		Air	Steam Lbs	Steam Time	Initial Vacuum Inches	Initial Vacuum Time	Pressure Lbs	Pressure Time	Temperature In Tank	Temperature [illegible]	Final Vacuum Inches	Final Vacuum Time	Zinc Cl	Creosote	Miscel.	Zinc Cl.	Creosote	Miscel	How Often Made	Official in Charge	Account Decay	Mechanical Wear	Other Causes	Total	Per Cent of Total Removed All Causes	Account Decay	Account Mechanical Wear	Average Life	
ILLINOIS	Supt Timber Dept	39	Greenville Miss.	Nov '10	Sept 1 '15	5 Yrs	Total Length	Total Ties	Loam	Gravel	Good	75#	ASCE	50#			Cut			[illegible]	6x8x9		Both	Untreated	Air																											
CENTRAL R R	"	40	"	"	"	"	4360	2475	"	"	"	"	"												Seasoned																											
			"																																																	
LAKE SHORE AND	Consulting Timber Eng	1	Cleveland Short line	Oct '11	Oct '14	3 Yrs			Rock & Clay	Stone	Good	80#	ASCE				Cut		Heavy	German Beech	6x8x8		Both	Lowry Creosote Process	[illegible]	None				175	5¾ hrs			24	1 hr					2.48 gal							0	0				
MICHIGAN	"	2	"	"	"	"			"	"	"	"	"				"		"	Southern Beech	"		"	"	"	"				"	1½ "			24½	"					2.76 "							0	0				
SOUTHERN RY	"	3	"	"	"	"		5000 in all	"	"	"	"	"				"		"	Hard Maple	"		"	"	"	"				"	3¾ "			23½	"					3.38 "							0	0				
"	"	4	"	"	"	"			"	"	"	"	"				"		"	[illegible]	"		"	"	"	"				"	5¼ "			25	"					2.61 "							0	0				
"	"	5	"	"	"	"			"	"	"	"	"				"		"	Red Oak	"		"	"	"	"				"	3 "			24½	"					2.53 "							0	0				
MEXICAN CENTRAL	Mex Tie & Timber Dept.	1	Tampico Branch	June '05	July '11	6 Yrs 1 Mo.		146											Br. Line	Pine				Rueping																			Mx T & T Co				0	0				
"	"	2	"	"	"	"		29											"	"				Guissani Creosote																			"				0	0				
"	"	3	"	"	"	"		19											"	"				" Zinc "																			"				0	0				
"	"	4	"	"	"	"		17											"	"				Creosoted																			"				0	0				
"	"	5	"	"	"	"		11											"	"				"																			"				0	0				No report since July 1 1911
"	"	6	"	"	"	"		7											"	Red Oak				Guissani Creosote																			"				0	0				
"	"	7	"	"	"	"		43											"	Pine				Burnettized																			"				0	0				
"	"	8	"	"	"	"		10											"	Red Oak				"																			"	4			4	40	40			
"	"	9	"	"	"	"		10											"	Pine				Carbolineum																			"	9			9	90	90		4.15 Yrs	
"	"	10	"	June '07	"	"		198											"					Bakersfield Crude Oil																			"				0	0				
NORFOLK	Chief Engineer	1	Norfolk Division	May '97	Oct '15	18 Yrs 5 Mo.		1095	Loam & Clay	Gravel & Sand	Good	70#	P R			2816	Cut		Main Line	Juniper	7x9x8		Hewn	Untreated	14 Mo.																	Annually	Chief Eng				885	80.8				
SOUTHERN R R	"	2	"	"	"	"		100	"	"	"	"	"			"	"		"	"	"		"	Creosoted	10 "	25	4 hrs	22	5 hrs	20 lbs	½ hr						10 lbs					"					16	16				
"	"	3	"	"	"	"		125	"	"	"	"	"			–	"		"	Pine	"		"	Vulcanized	6 "																	"					all	100			2.23 Yrs	
"	"	4	"	"	"	"		125	"	"	"	"	"			"	"		"	"	"		Sawed	"	"																	"					all	100			2.91 "	
"	"	5	"	"	"	"		125	"	"	"	"	"			"	"		"	"	"		Hewn	Wellhouse	"											Absorption	10.65	% of Weight	Strength	of Zinc Solution	3.2%	"					84	67.2				
"	"	6	"	"	"	"		125	"	"	"	"	"			"	"		"	"	"		Sawed	"	"											"	69.61	"	"	"	" 3.2%	"					92	73.6				
"	"	7	"	"	"	"		125	"	"	"	"	"			"	"		"	Gum	"		"	Vulcanized	"																	"					all	100			5.61 Yrs	
"	"	8	"	"	"	"		125	"	"	"	"	"			"	"		"	"	"		Hewn	"	"																	"					all	100			2.92 "	
"	"	9	"	"	"	"		125	"	"	"	"	"			"	"		"	"	"		"	Wellhouse	"											Absorption	85.75%	of weight	Strength	of Zinc Solution	3.2%	"					74	59.2				
"	"	10	"	"	"	"		125	"	"	"	"	"			"	"		"	"	"		Sawed	"	"											"	35.00%	"	"	"	" 3.2%	"					102	80.6				
"	"	11	"	"	"	"		300	"	"	"	"	"			"	"		"	White Oak	"		Hewn	Untreated	14 Mo.																	"					all	100			8.63 "	
NEW YORK	Eng M. of W	1	Fair Haven Tunnel Conn.	June '94	Oct '15	20 Yrs 5 Mo.	1 Mile	6000	Rock	Stone	Ditches	100#		none			Cut		Main Line	Pine	7x9x8	First	Hewn	Creosoted																		Annually	Div Eng				597	9.95			16 Yrs	Dead Oil of Coal Tar Creosote
NEW HAVEN	"	2	[illegible] Tanks, Conn	Oct '01	"	14 Yrs.	600'	300	Gravel	"	"	"		5"			"		"	L.L. Pine	6x8x8		Sawed	Burnettized																		"	"					59.6				
& HARTFORD R.R.	"	3	Wallingford Conn.	June '81	Jan '14	32 Yrs 7 Mo.	About 2 m.	1006	Sand	"	Good	74-100		none			"		"	White Pine	7x9		"	Tillhomy																		"	"				all	100			14 "	Last tie removed 1896
"	"	4	Medway Mass	" 80	Dec 13	33 Yrs 6 Mo.		400	Gravel	Gravel	"	56#		"			"		"	Hemlock	6x8	[illegible]	Hewn	Creosoted																		"	Track Foreman				"	100			20 "	Last one removed Apr '12 not rotten but c
"	"	5	Somerset Mass	" 88	"	15 Yrs 6 Mo.														"				"																		"	[illegible]				"	100			20 "	
NORTHERN	Eng M. of W.	1	Plains Mont.	Mar. '07	Apr '15	8 Yrs.	Total	95		Gravel	Good	72-85		Wooden & Sellers			Both	Tangent	Main Line	[illegible]	7x9x8		Hewn	Untreated	Green																	Annually	Div M of W				95	100		7.56		Originally laid with Sellers Tie Plates
PACIFIC RY	"	2	"	"	"	"	Length	32		"	"	"		"			"	"	"	"	"		"	"	Air																	"	"				31	97		7.39		and cut spikes at rail Joints Wooden
"	"	3	"	"	"	"	4800'	27		"	"	"		"			"	"	"	[illegible]	"		"	"	"																	"	"				27	100		6.89		plates and screw spikes on intermediate
"	"	4	"	"	"	"		96		"	"	"		"			"	"	"	"	"		"	"	Green																	"	"				96	100		6.92		ties. 72 lb rail. Joints opposite the
"	"	5	"	"	"	"		94		"	"	85#	ASCE	5x8	Wolhaupter		Cut	"	"	[illegible]	"		"	"	"																	"	"				94	100		7.34		Wooden Plates were made of White
"	"	6	"	"	"	"		90		"	"	"	"	"	"		"	"	"	"	"		"	"	Air																	"	"				90	100		7.59		Oak, Treated with ½ lb creosote each
"	"	7	"	"	"	"		90		"	"	"	"	"	"		"	"	"	[illegible]	"		"	"	"																	"	"				90	100		7.08		7" wide and ½ thick
"	"	8	"	"	"	"		91		"	"	"	"	"	"		"	"	"	"	"		"	"	Green																	"	"				91	100		7.15		In Aug 1910 owing to failure of wooden
"	"	9	"	"	"	"		91		"	"	"	"	6x9	Sellers		"	"	"	[illegible]	"		"	"	"																	"	"				91	100		7.39		Plates 1 to 4 were relaid. 72 lb rail
"	"	10	"	"	"	"		90		"	"	"	"	"	"		"	"	"	"	"		"	"	Air																	"	"				90	100		7.54		Changed to 85# rail ties 1 to 72
"	"	11	"	"	"	"		90		"	"	"	"	"	"		"	"	"	[illegible]	"		"	"	"																	"	"				90	100		7.52		equipped with Sellers Plates, 2 Screw
"	"	12	"	"	"	"		90		"	"	"	"	"	"		"	"	"	"	"		"	"	Green																	"	"				90	100		7.21		Spikes and 1 cut spike to each end
"	"	13	"	"	"	"		92		"	"	"	"	"			Both	"	"	[illegible]	"		"	"	"																	"	"				92	100		7.50		Ties 72 to 250 have Wolhaupter Plates
"	"	14	"	"	"	"		90		"	"	"	"	"			"	"	"	"	"		"	"	Air																	"	"				90	100		7.94		and Single Spiked with Cut Spikes
"	"	15	"	"	"	"		90		"	"	"	"	"			"	"	"	[illegible]	"		"	"	"																	"	"				90	100		7.34		Sellers tie plates, Screw Spikes at
"	"	16	"	"	"	"		91		"	"	"	"	"			"	"	"	"	"		"	"	Green																	"	"				91	100		7.36		Joints, centers & quarters Cut spikes in
"	"	17	"	"	"	"		108		"	"	"	"	"			"	"	"	[illegible] Fir	"		"	"	"																	"	"				108	100		7.66		other ties 120 ties Screw Spikes 245 ties Cu
"	"	18	"	"	"	"		90		"	"	"	"	"			"	"	"	"	"		"	"	Air																	"	"				90	100		7.61		Spikes Sellers tie plates. Screw spikes
"	"	19	"	"	"	"		90		"	"	"	"	"			"	"	"	[illegible]	"		"	"	"																	"	"				90	100		7.41		at Joints and alternate Intermediate ties
"	"	20	"	"	"	"		91		"	"	"	"	"			"	"	"	"	"		"	"	Green																	"	"				91	100		7.42		208 ties with Screw Spikes. 171 ties
"	"	21	"	"	"	"		90		"	"	"	"	"			[illegible]	"	"	[illegible] Fir	"		"	"	"																	"	"				90			7.50		with Cut Spikes
"	"	22	"	"	"	"		90		"	"	"	"	"			"	"	"	"	"		"	"	Air																	"	"				90			7.70		
"	"	23	"	"	"	"		90		"	"	"	"	none			"	"	"	"	"		"	Burnettized												0.786 lbs						"	"				1	1.1				Sellers tie plates and screw spikes
"	"	24	"	"	"	"		101		"	"	"	"	"			"	"	"	[illegible]	"		"	"												0.786 "						"	"				0	0				all ties
"	"	25	"	"	"	"		90		"	"	"	"	"			"	"	"	"	"		"	Untreated	Air																	"	"				90	100		7.67		
"	"	26	"	"	"	"		92		"	"	"	"	"			"	"	"	"	"		"	"	Green																	"	"				92	100		7.63		
"	"	27	"	"	"	"		107		"	"	"	"	"			Both	"	"	[illegible]	"		"	Burnettized												0.786 "						"	"				4	37				Sellers tie Plates, screw Spikes at
"	"	28	"	"	"	"		92		"	"	"	"	"			"	"	"	[illegible]	"		"	"												0.786 "						"	"				8	87				Joints and alternate ties
"	"	29	"	"	"	"		89		"	"	"	"	6x8¼	[illegible]		Cut	"	"	[illegible]	–		"	Untreated	Air																	"	"				89	100		7.47		
"	"	30	"	"	"	"		91		"	"	"	"	"	"		"	"	"	[illegible]	"		"	"	"																	"	"				91	100		7.36		
"	"	31	Marwood Wash.	[illegible]	Apr '15	8 Yrs	Total	264		"	"	"	"	6x9	Sellers		"		"	[illegible]	7x9x8		Sawed	"	Green																	"	"				178	67.4				
"	"	32	"	"	"	"	Length	350		"	"	"	"	"	"		"		"	"	"		"	"	Air																	"	"				257	73.4				
"	"	33	"	"	"	"	[illegible]	173		"	"	"	"	"	"		"		"	[illegible]	"		"	Creosoted													6.17 lbs					"	"				37	21.3				Tie Plates, screw spikes at rail
"	"	34	"	"	"	"		100		"	"	"	"	"	"		"		"	[illegible]	"		"	Untreated	Green																	"	"				100	100		7.28		Joints, and cut spikes in intermediate ties
"	"	35	"	"	"	"		100		"	"	"	"	"	"		Both		"	"	"		"	"	"																	"	"				70	70				No tie plates

pection	Number Removed				Results				Remarks
					Per Cent of Total Removed			Average Life	
Official In Charge	Account Decay	Mechanical Wear	Other Causes	Total	All Causes	Account Decay	Account Mech Wear		
				0	0				
				0	0				
				0	0				
				0	0				
				0	0				
MgrT&T Dep				0	0				
"				0	0				
"				0	0				
"				0	0				
"				0	0				No report since July 1-1911
"				0	0				
"				0	0				
"	4			4	40	40			
"	9			9	90	90		Abt 5 Yrs	
"				0	0				
"									
Chief Eng.				885	80.8				
				16	16				
				all	100			223 Yrs	
				all	100			3.91 "	
				84	67.2				
				92	73.6				
				all	100			5.61 Yrs	
				all	100			2.92 "	
				74	59.2				
				102	80.6				
				all	100			8 63 "	
Div. Eng.				5976	99.7			16 Yrs.	Dead Oil of Coal Tar Creosote
"					59.6				
"				all	100			14 "	Last tie removed 1896
Track Foreman				"	100			20 "	Last one removed Apr. '12 not rotten but cut
Eng. of Tests				"	100			20 "	
Eng M. of W.				95	100		7.56		Originally laid with Sellers Tie Plates
"				31	97		7.39		and cut spikes at rail Joints Wooden
"				27	100		6.89		plates and screw spikes on Intermediate
"				96	100		6.92		ties. 72 lb rail. Joints opposite the
"				94	100		7.34		Wooden Plates were made of White
"				90	100		7.59		Oak, Treated with $\frac{1}{12}$ lb creosote each
"				90	100		7.08		7" wide and $\frac{1}{2}$" thick.
"				91	100		7.15		In Aug. 1910 owing to failure of wooden
"				91	100		7.39		Plates, 1 to 4 were relaid, 72 lb rail
"				90	100		7.54		Changed to 85# rail. ties 1 to 72
"				90	100		7.52		equipped with Sellers Plates, 2 Screw
"				90	100		7.21		Spikes and 1 cut spike to each end.
"				92	100		7.50		Ties 72 to 250 have Walhaupter Plates
"				90	100		7.94		and Single Spiked with cut spikes.
"				90	100		7.34		Sellers tie plates, Screw spikes at
"				91	100		7.36		Joints, centers & quarters Cut spikes in
"				108	100		7.66		other ties 120 ties Screw Spikes 245 ties cut
"				90	100		7.61		Spikes. Sellers tie plates, Screw spikes
"				90	100		7.41		at Joints and alternate Intermediate ties.
"				91	100		7.42		208 ties with Screw spikes. 171 ties
"				90			7.50		with cut Spikes.
"				90			7.70		
"				1	1.1				Sellers tie plates and screw spikes
"				0	0				all ties.
"				90	100		7.67		
"				92	100		7.63		
"				4	3.7				Sellers tie Plates, screw spikes at
"				8	8.7				Joints and alternate ties.
"				89	100		7.47		
"				91	100		7.36		
"				178	67.4				
"				257	73.4				
"				37	21.3				
"				100	100		7.28		Tie Plates, screw spikes at rail
				70	70				Joints, and cut spikes in intermediate ties
									No tie plates

RECORD OF TIE SERVICE TEST.

AMERICAN RAILWAY ENGINEERING ASSOCIATION
COMMITTEE ON WOOD PRESERVATION
1915 REPORT - APPENDIX "A"
RECORD OF TIE SERVICE TEST

Sheet No 7 of 7

Company or Organization	Official Reporting	Test No	Locality of Test	Date Placed	Date Reported	Time of Test	Distance of Test	Number of Ties	Description of Conditions: Sub Grade Soil	Kind of Ballast	Drainage	Rail Wt	Rail Section	Tie Plate Size	Tie Plate Kind of Bottom	Ties per M of Track	Cut or Screw Spike	Alinement	Traffic Tonnage per Annum	Description of Material: Kind of Wood	Size	Class	Sawed or Hewn	Kind of Treatment	Seasoning Air	Seasoning Steam Lbs	Seasoning Steam Time	Treating: Initial Vacuum Inches	Initial Vacuum Time	Pressure Lbs	Pressure Time	Temperature in Tank	Temperature [illegible]	Final Vacuum Inches	Final Vacuum Time	Absorption per Cu Ft Zinc Cl	Absorption per Cu Ft Creosote	Absorption per Cu Ft Mixed	Absorption per Tie Zinc Cl	Absorption per Tie Creosote	Absorption per Tie Mixed	Inspection How often Made	Inspection Official in Charge	Number Removed Acct Decay	Number Removed Mech Wear	Number Removed Other Causes	Number Removed Total	Results Per Cent of Total Removed All Causes	Per Cent of Total Removed Acct Decay	Per Cent of Total Removed Acct Mech Wear	Average Life	Remarks
NORTHERN	Chief Engineer	36	Maywood-Wash	Feb '06 Feb '07	Apr 15	8 Yrs	Total	100		Gravel	Good	85#	ASCE	6x9	Sellers		Both		Main Line	Douglas Fir	7x9x8		Sawed	Untreated	Air																	Annually	Engr M of W				74	74				
PACIFIC RY CO		37	"	"	"	"	Length	52				"	"				"		"	"	"		"	Creosoted													6 17lbs					"	"				0	0				
		38	"	"	"	"	4055'	58			"	"	"	None			Screw		"	"	"		"	Untreated	"																	"	"				55	95				
	"	39	"	"	"	"		96			"	"	"	6x9	Sellers		"			"	"		"	"	"																	"	"				87	69 8				
	"	40	"	"	"	"		100		"	"	"			"		"		"	"	"			Creosoted													6 17lbs					"	"				8	8				
	"	41	"	"	"	"		46		"	"		"		"		"		"	"	"		"	Untreated	Green																	"	"				41	90 1				
	"	42	"	"	"	"		47		"	"	"	"	"	"		Both		"	"	"		"	"	"																	"	"				40	85 1				Tie Plates Screw Spikes in alternate
	"	43	"	"	"	"		91		"	"	"		"	"		"		"	"	"		"	"	Air																	"	"				61	67				Ties and both ties at Joints
	"	44	"	"	"	"		46			"	"	"	"	"		"		"	"	"		"	Creosoted													6 17lbs					"	"				7	15 3				Cut Spikes in other ties
	"	45	"	"	"	"		99			"	"	"	None			Cut		"	"	"		"	Untreated	Air																	"	"				92	93				
	"	46	"	"	"	"		100			"		"	"			"		"	"	"		"	"	Green																	"	"				99	99				
	"	47	"	"	"	"		71			"	"		"			"		"	"	"		"	Creosoted													6 17lbs					"	"				5	7 0				
	"	48	"	"	"	"		103		"	"						"		"	Hemlock	"		"	Untreated	Green																	"	"				103	100			6 98 Yrs	
	"	49	"	"	"	"		284		"	"	"		6x9	Sellers		"		"	Douglas Fir	"		"	"	Air																	"	"				204	71 8				
OREGON	Ass't Sup't	1	Dodsons Oregon	Aug 08	Oct 14		1749	1000	Loam	Gravel	Good	75#	C S	8x8½			Cut		6000000	Oregon Fir	7x9x8	F	Sawed	Creosoted	Sun dried					100	12 hrs						8										2	0 2				Good Condition
WASHINGTON R R	"	2	"	"	"		1885	1006	"	"		"	"	"			"		"	"	"	D	"	Untreated	30 days																						156	15 5				30% Show Surface decay on Sides +
& NAV CO	"	3	"	"	"		1826	977	"				"	"			"		"	"	"	A	"	Burnettized	"	40	2½ hrs	25	1¼ hrs	100	2½ hrs					0 25											0	0				Generally Sound Condition
UNION PACIFIC SYS	"	4	"	"	"		1958	1007	"	"	"	"	"	"			"		"	"	"	C	"	Untreated	None																						87	8 6				Fair Condition
"	"	5	"	"	-		1845	975	"	"	"	"	"	"			"		"	"	"	B	"	Burnettized	"			25	1¼ hrs		2¾ hrs					0 25											1	0 1				Exceptionally good Condition
"	"	6	"	"	"		3718	1969	"		"	"	"	"			"		"	"	"	G	Hewn	"	Sun dried 6 mos			25	1¼ hrs		2¾ hrs					0 25											17	0 8				Good Condition
"	"	7	"	"	"		545	300	"		"	"	"	"			"		"	"	"	H	Sawed	Carbolineum	None					Open	Tank	150°						1 2									5	1 7				Very good Condition
PENN LINES WEST	Chief Eng M of W	1	Wooster Ohio	[illegible]	Sep 15	5 Yrs	1200	2743	Clay	Stone	Gravel	100#	P S	7x9x½	Flat B	2880	Screw	Curve	2000000	Loblolly Pine	7x9x8½	First	Both	Straight Creosote				22	15-35 Min	40	25-45 Min	170°		25	45 Min		8-11 lbs					Weekly	Chief Eng M of W	7	19	547	573	20 9	0 3	0 7		547 removed in July and October 1911
NORTHWEST SYSTEM	"	2	" "	"	"	"		3850	"			100#		7x13½	Goldie	"	"	"	"	Oak Mixed	"	"	"	" "		15	0-2 hrs	23	30-45 Min	170	[illegible]	170°		25	"		7-9 "					"	"									account wreck relaid by Similar ties
SOUTHERN PACIFIC Co	Ass't Chief Eng	1	Various locations	1895	9.15	13 Yrs		217	[illegible]	[illegible]		[illegible]			[illegible]		[illegible]		Heavy	Douglas Fir	7x9x8		Sawed	Burnettized	Partly Seasoned			24	30 Min			165°				0243						Annually	Chief Eng M of W					100			11 34	Ties 18 to 33 rail 16 to 30' rail
"	"	2	"	1896	"	13 "		4043		[illegible]		"			"		"		"	"	"		"	"	"											"												100			10 97	
	"	3	"	1897	"	13 "		1941				"			"		"		"	"	"		"	"	"											"												100			10 74	
"	"	4	"	1898	"	14 "		20536				"			"		"		"	"	"		"	"	"											"												100			11.21	
"	"	5	"	1899	"	14		2551				"			"		"		"	"	"		"	"	"											"												100			10 46	
"	"	6	"	1900	"	13 "		76146				"			"		"		"	"	"		"	"	"											"												100			9 31	
"	"	7	"	1901	"	13 "		41611				"			"		"		"	"	"		"	"	"											"												96 41				
"	"	8	"	1902	"	12 "		52204				"			"		"		"	"	"		"	"	"											"												Records not Complete				
"	"	9	"	1903	"	11 "		44856							"		"		"	"	"		"	"	"											"												89 08				
"	"	10	"	1904	"	10 "		42541				"			"		"		"	"	"		"	"	"											"												66 50				
	"	11	"	1905	"	9 "		58983							"		"		"	"	"		"	"	"											"												88 18				
"	"	12	"	1906	"	8 "		48478				"			"		"		"	"	"		"	"	"											"												69 56				
	"	13	"	1907	"	7 "		[illegible]8673				"			"		"		"	"	"			"	"											"												Records not Complete				
	"	14	"	1908	"	6 "		44685				"			"		"		"	"	"		"	"	"											"												42 0				
"	"	15	"	1909	"	5 "		22146				"			"		"		"	"	"		"	"	"											"												25 34				
	"	16	"	1910	"	4 "		34774				"			"		"		"	"	"		"	"	"											"												2 98				
"	"	17	"	1911	"	3 "		44449				"			"		"		"	"	"		"	"	"											"												0 58				
"	"	18	"	1912	"	2 "		142111				"			"		"		"	"	"		"	"	"											"												0 29				
"	"	19	"	1913	"	1 "		54273							"		"		"	"	"		"	"	"											"												0 02				
"	"	20	"	1914	"	0 "		112155				"			"		"		"	"	"		"	"	"											"																
ST LOUIS AND	Chief Engineer	1	St Clair Mo	Oct 06	Oct 15	9 Yrs	1300	752	[illegible]	[illegible]	[illegible]	85#	ASCE	[illegible]	[illegible]	3200	Cut	[illegible]	[illegible]	[illegible]	6x8x8	First	Hewn	Rueping Process	[illegible] Yrs	None		Air Pressure 80 lbs	30 Min	180	2 hrs	175		23½	1 hr 40 min		4 53			12 03lbs		Semi Annually	Ass't Chief Eng			1	1	0 1				[illegible]# replaced by 85# rail in 1909 Chats Ballast
SAN FRANCISCO R R	"	2	"		"			321	"		"	85#	"	"	"	"	"	"	"	Redwood	"	"	Sawed	[illegible] in Creosote Oil	"	"			"	"	"	175		24	1 hr 30 min		3 66			9 70 "		"	"			1	1	0 3				Put in on Gravel in 1913 - Tie Plates Applied
	"	3	Pacific Mo	Oct 05	"	10 Yrs		43	"	Gravel	Fair	90#	"	[illegible]x9	"	"	"	Curve	[illegible]	[illegible]	"	"	Both	[illegible]	Seasoned	"		*	*	*	*	*	*	*	*				75 lb	10-15 "		"	"	14	4		18	41 8	32 6	9 2		In 1913 1914 Gravel Ballast Put in on Cinder
	"	4	"		"	"		83	"		"	"	"	"	"	"	"	"	"	"	"	"	"	Creosoted	"	"		0-27	[illegible] hrs	75-175	35 Min to 4 hrs			16-29	15 Min 2 hr					11-30 "		"	"	"	2		11	13 2	10 8	2 4		In 1914 Tie Plates Applied 85# replaced
	"	5	"					40	"		"	"	"	"	"	"	"	"	"	"	"	"	"	Rueping	"	"		[illegible]	[illegible]	125 250	3 hrs			23 27	½-2 hrs					7-21 5 "		"	"	3	1		4	10 0	7 5	2 5		with 90# St L & S F Test No 3 - Ties were
	"	6		"				1	"		"	"	"	"	"	"	"	"	"	"	"	"	Hewn	[illegible]ersed in Oil	Fully	"				125	1 hr						7 18lbs			2 7 "		"	"				0					Put in hot creosote bath from 2 to 3½ hrs
		7		"	"			76	"		"	"	"	"	"	"	"	"	"	"	"	"	Both	Bethell	Varied	20-65	1-4 hrs	4 28	1 hr	[illegible]-175	2-4 hrs			25-27	1 hr					6-42 "		"	"	2	6		8	10 5	2 6	7 9		in cold bath 2 to 5 Minutes in 2½ % Zinc
		8		"	"	"		24	"		"	"	"	"	"	"	"	"	"	"	"	"	"	Creosoted	"	None		0-26	[illegible] 3 hrs	[illegible]5-125	1-2 hrs			24-26	½-1 hr					6-42 "		"	"	1	1		2	8 3	4 2	4 1		chloride solution 2 hrs

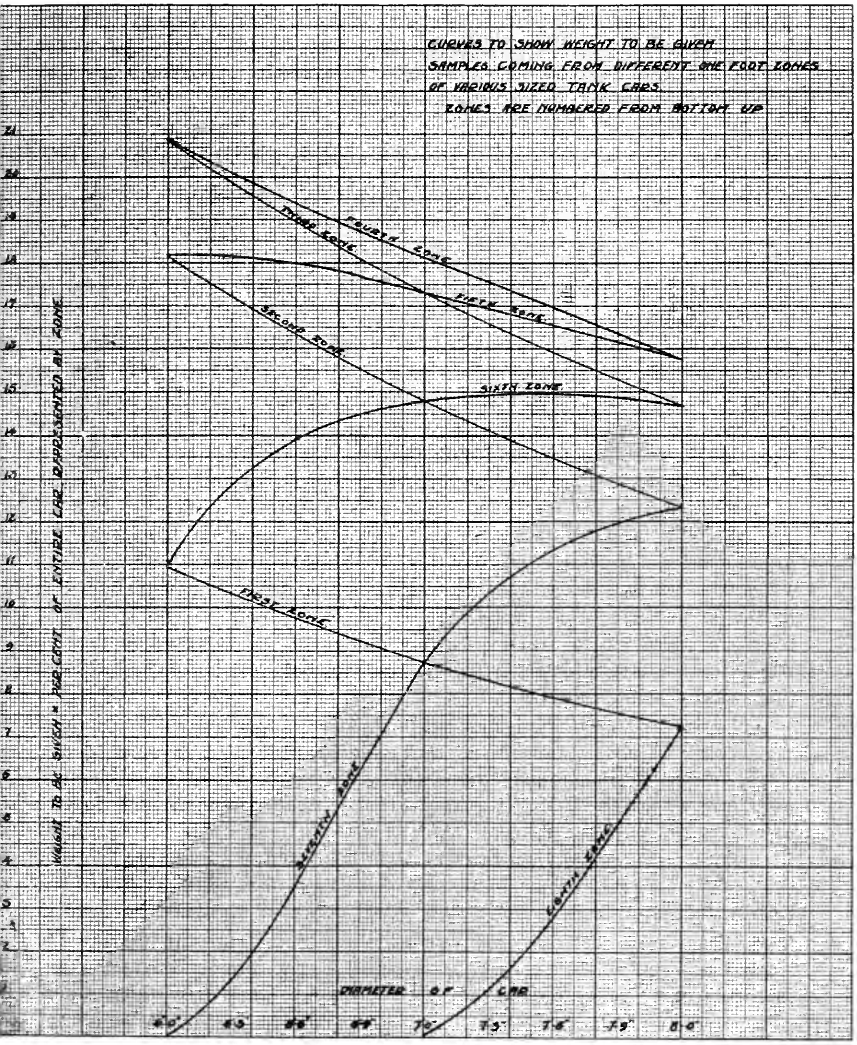
CURVES TO SHOW WEIGHT TO BE GIVEN
SAMPLES COMING FROM DIFFERENT ONE FOOT ZONES
OF VARIOUS SIZED TANK CARS.
ZONES ARE NUMBERED FROM BOTTOM UP
WEIGHT TO BE GIVEN = PER CENT OF ENTIRE CAR REPRESENTED BY ZONE
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
FOURTH ZONE
THIRD ZONE
FIFTH ZONE
SECOND ZONE
SIXTH ZONE
FIRST ZONE
SEVENTH ZONE
EIGHTH ZONE
DIAMETER OF CAR
6'0"
6'3"
6'6"
6'9"
7'0"
7'3"
7'6"
7'9"
8'0"

FIG. 3.

9. That for ordinary purposes the taking of three zone samples, that is, from the top, the middle and the bottom of a car, by means of the apparatus just referred to or by means of a bottle device, is recommended.

10. That the tests described this year be considered preliminary and that similar tests be made at various treating plants and tar plants during the coming year. Care should be taken to make such tests to include both summer and winter shipments.

(2) THE RELATION OF THE AMOUNT OF PRESERVATIVE AND THE DEPTH OF PENETRATION TO THE RESISTANCE OF THE MATERIAL AGAINST DECAY.

This subject is new as regards its investigation by your Committee, and, in fact, as far as known has not been systematically investigated by any organization.

The value and importance of an established relation between the amount and depth of preservatives to the resistance of the timber against decay is readily apparent, and it is equally obvious that this determination must be based on the results of service tests. In examining the data available it was immediately found that service records include only one of the factors, namely, the amount of preservative, and that the depth of penetration is not recorded. There is a further difficulty; that of the widely recognized variation in penetrability, even of woods of the same species. In other words, ties or timbers treated with a given amount of oil will show wide variations in the depth of penetration, due to the percentage of sapwood, the moisture contents of the stick, and other variables which are less readily explained. It is assumed that all good treatments completely penetrate the sapwood, the heartwood absorption usually being superficial.

The factor of mechanical abrasion is most important in determining the depth of penetration necessary to give protection against decay. The records of timbers and piling that were not exposed to mechanical wear and in which the impregnated wood extends from one-half to two inches on the outside, indicate that complete penetration is not necessary if the outer protective ring remains unbroken, and the ends are likewise protected. On the other hand, we have a very definite record of (creosoted) ties placed in the tracks of the Norfolk Southern Railroad in 1896, which resisted decay until abrasion under the rail cut through the treated portion. As soon as this happened decay commenced at the unprotected point, and necessitated the removal of many ties which otherwise were in good condition. This simply indicates that penetration of creosote should be of sufficient depth to always give protection to the untreated center, and that as soon as this protective area is broken decay commences.

The extent to which the amount of preservative is a coincident influence with the depth is a matter which requires a more extended study than your Committee has been able to give. The records definitely show that comparatively heavy injections of creosote are an absolute protection, and the point remaining to be determined is to what extent these injections can be reduced and still give protection which is at least in reasonable proportion to the reduced cost.

The consideration of this subject will be continued the coming year, and it is expected that the analysis and study of the service test records will furnish a basis for definite conclusions.

(3) RECORD OF SERVICE TESTS.

The record of service tests is presented as Appendix A to this report. It consists of the usual tabulated statement of the results of the latest inspection of the test sections of track maintained by the various railroads, and in addition a detailed description of several of the test tracks upon which records of the service have been kept for eight years or more. The following tests are reported on in this manner:

Chicago & Northwestern Railway, near Janesville, Wis.
Northern Pacific Railway, near Plains, Mont., and near Maywood, Wash.
Chicago, Milwaukee & St. Paul Railway, Tracks Nos. 4. 9, 10, 11 and 12.
Chicago, Indianapolis & Louisville Railway, between Chicago and Louisville.
Central Railroad Company of New Jersey, near Boundbrook, N. J.

From these reports much valuable information may be had as to the service of ties which have been treated by the different processes and subjected to different service and climatic conditions.

REVISION OF THE MANUAL.

Your Committee recommends no changes in the Manual.

CONCLUSIONS.

Your Committee presents this report to the Association as information. In doing so it desires to especially call attention to the subject matter under "Water Sampling in Creosote Oil," wherein certain preliminary conclusions are offered for the information and guidance of the Association in dealing with this important matter. Your Committee desires to give this subject further study before presenting conclusions for adoption and insertion in the Manual.

OUTLINE OF WORK FOR NEXT YEAR.

Your Committee recommends:

(1) Continue the study of water sampling in creosote oil.

(2) Continue the study of the relation of the amount of preservative and depth of penetration to the resistance of the material against decay.

(3) Derive conclusions from the results of exposure tests of material treated with water gas tar.

(4) Report on the economics of treated timber.

(5) Compilation of service test records, extending same to include structural timbers.

Respectfully submitted,

COMMITTEE ON WOOD PRESERVATION.

SUMMARY OF TREATED TIE SERVICE TESTS WHICH HAVE BEEN CARRIED ON SIX YEARS OR LONGER

As given in Appendix A, 1915 Report of Committee on Wood Preservation, American Railway Engineering Association.

CLASSIFIED AS TO DIFFERENT PROCESSES OF TREATMENT.

REF. NO. TO 1915 SERVICE RECORD Name of Road	Test No.	No. of Ties	Kind	Time of Test		Locality	Failures to date		Average Life
				Yrs.	Mos.		Total	Per Cent.	
			BURNETT-IZED						
Atchison, Topeka & Santa Fe	128	9,251	Pine	10		Newton, Kan	3,047	32.9	
	129	6,357	"	11		"	2,257	25.5	
	130	2,517	"	11		"	1,054	41.8	
	131	40	"	10		"			
Chicago, Burlington & Quincy	3	6,354	"	15	9	Sidney, Neb	448	7.1	
	6	63	"	10	2	Elsberry, Mo	25	40.0	
Chicago, Milwaukee & St. Paul	11	500	"	12		Washington, Iowa		10.0	
	22	496	"	9		Black Hills Div			
	12	500	"	9		Morristown, S. D		11.0	
Galveston, Harrisburg & San Antonio	1	1,001	"	9		Bay View, Tex	999	99.8	
New York, New Haven & Hartford	2	300	"	14		Connecticut		59.6	
Chicago, Burlington & Quincy	4	550	Red Oak	15		Mystic, S. D	122	22.2	
Chicago, Milwaukee & St. Paul	9	300	"	9		McLaughlin, S. D		1.3	
Chicago, Burlington & Quincy	5	1,320	Tamarack	11	3	Gillette, Wyo	953	72.2	
Chicago & Northwestern	14	125	"	7	1	Janesville, Wis			
	30	125	"	7	1	"			
	45	125	"	7	1	"			
	55	13	"	7	1	"			
Northern Pacific	24	101	"	8		Plains, Mont			
	28	92	"	8		"	8	8.7	
Chicago & Northwestern	50	25	Hemlock	7	1	Janesville, Wis		16.0	
Calveston, Harrisburg & San Antonio	5 and 7	244	Red Gum	10	4	Bayview, Tex	227	93.0	
	6 and 8	198	Tupelo Gum	10	4	"	186	93.9	
Northern Pacific	23	90	Douglas Fir	8		Plains, Mont	1	1.1	
	27	107	"	8		"	4	3.7	
Chicago, Burlington & Quincy	11	91	"	10	2	Elsberry, Mo	7	7.7	
Oregon-Washington Railroad & Navigation	3	977	Oregon Fir	6	2	Dodsons, Ore			
	5	975	"	6	2	"	1	0.1	
	6	1,969	"	6	2	"	17	0.8	
Southern Pacific	1	1,179,097	Fir	1 to 19		Various Locations	311,235	26.4	10 years

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As given in Appendix A, 1915 Report of Committee on Wood Preservation, American Railway Engineering Association

CLASSIFIED AS TO DIFFERENT PROCESSES OF TREATMENT.

REF. NO. TO 1915 SERVICE RECORD				Time of Test			Failures to date		
Name of Road	Test No.	No. of Ties	Kind	Yrs.	Mos.	Locality	Total	Per Cent.	Average Life
			WELLHOUSE						
Norfolk Southern	5	125	Pine	18	5	Norfolk Div.	84	67.2	
	6	125	"	18	5	"	92	73.6	
	9	125	Gum	18	5	"	74	59.2	
	10	125	"	18	5	"	102	80.6	
Chicago, Rock Island & Pacific	1	10,856	Hemlock	14	8	Sibley, Ia.	3,446	31.7	
Chicago & Northwestern	1 to 12, inc.	470	"	7	1	Janesville, Wis.	8	1.7	
	13	125	"	7	1	"	....	....	
	17 to 28, inc.	453	"	7	1	"	6	1.3	
	32 to 43, inc.	457	"	7	1	"	2	0.5	
	47 to 49, inc.	155	"	7	1	"	8	5.2	
	15 and 16	88	Tamarack	7	1	"	1	1.2	
	29, 31, 44, 46	353	"	7	1	"	1	0.3	
	52 to 54, inc.	172	"	7	1	"	2	1.2	
			THILMANY						
New York, New Haven & Hartford	3	1,006	White Pine	22	7	Wallington, Conn.	All	100.0	14 years
			VULCANIZED						
Norfolk Southern	3	125	Pine	18	5	Norfolk Div.	All	100.0	2.23 years
	4	125	"	18	5	"	"	100.0	3.91 years
	7	125	Gum	18	5	"	"	100.0	5.61 years
	8	125	"	18	5	"	"	100.0	2.92 years
			CARBO-LINEUM						
Oregon-Washington Railroad & Navigation	7	545	Oregon Fir	6	2	Dodsons, Ore.	5	1.0	
			CREOSOTED						
Chicago, Burlington & Quincy	1	58	Lodge Pole Pine	8	6	Fort Line	1	1.7	
	8	39	Pine	10	2	Elsberry, Mo.	3	7.7	
Galveston, Harrisburg & San Antonio	24	205	"	8	5	Salix, La.	....	....	
	29	285	"	8	7	Scott, La.	10	3.5	
Georgia	1	1,000	"	7	5	Barnett, La.	12	1.2	
	2	1,000	"	7	5	"	8	0.8	
New York, New Haven & Hartford	1	6,000	"	20	5	Fair Haven	5,976	99.7	16 years

SUMMARY OF TREATED TIE SERVICE TESTS WHICH HAVE BEEN CARRIED ON SIX YEARS OR LONGER

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CLASSIFIED AS TO DIFFERENT PROCESSES OF TREATMENT.

REF. NO. TO 1915 SERVICE RECORD Name of Road	Test No.	No. of Ties	Kind	Time of Test		Locality	Failures to date		Average Life
				Yrs.	Mos.		Total	Per Cent.	
			CREOSOTED—Continued						
Chicago, Burlington & Quincy	13	74	Douglas Fir	10	2	Elsberry, Mo.	2	2.7	
Northern Pacific	37	52	"	8.7		Maywood, Wash.			
	40	100	"	8.7		"	8	8.0	
	44	46	"	8.7		"	7	15.3	
	47	71	"	8.7		"	5	7.0	
Oregon-Washington Railroad & Navigation	1	1,000	Oregon Fir	6	2	Dodsons, Ore.	2	0.2	
New York, New Haven & Hartford	4	400	Hemlock	23	6	Midway, Mass.	All	100.0	20 years
Northern Pacific	33	173	"	8.7		Maywood, Wash.	37	21.3	
Norfolk Southern	2	100	Juniper	18	5	Norfolk Div.	16	16.0	
Galveston, Harrisburg & San Antonio	10 and 12	201	Tupelo Gum	10	4	Bay View, Tex.	61	30.3	
	9 and 11	200	Red Gum	10	4	"	64	32.0	
St. Louis & San Francisco		83	Red Oak & Gum	10		Pacific, Mo.	11	13.2	
	4	24	"	10		"	2	8.3	
	8	76	"	10		"	8	10.5	
	7		RUEPING CREOSOTE						
Atchison, Topeka & Santa Fe	110	173	Pine	10		Chillicothe, Mo.	10	5.8	
	111	304	"	10		Marceline, Mo.	110	36.5	
	112	44	"	10		Sutton, Kan.	4	9.1	
	113	190	"	11		Ponca City, Okla.	6	4.2	
	114	275	"	11		Bliss, Okla.	6	2.2	
	115	275	"	11		Perry, Okla.			
	116	366	"	11		"			
	126	24,238	"	9		Ottawa Cut Off, Kan.			
	127	572	"	10		Argonia, Kan.			
Chicago, Burlington & Quincy	7	25	"	10	2	Elsberry, Mo.	2	8.0	
Galveston, Harrisburg & San Antonio	25	95	"	8	3	Salix, La.			
	26	100	"	8	6	Scott, La.	2	2.0	
Chicago, Burlington & Quincy	12	40	Douglas Fir	10	2	Elsberry, Mo.			
Atchison, Topeka & Santa Fe	117	390	Gum	7		Hutchinson, Kan.			
	118	230	"	7		"			
	119	432	"	7		Plevna, Kan.			

SUMMARY OF TREATED TIE SERVICE TESTS WHICH HAVE BEEN CARRIED ON SIX YEARS OR LONGER

As given in Appendix A, 1915 Report of Committee on Wood Preservation. American Railway Engineering Association

CLASSIFIED AS TO DIFFERENT PROCESSES OF TREATMENT.

REF. NO. TO 1915 SERVICE RECORD Name of Road	Test No.	No. of Ties	Kind	Time of Test		Locality	Failures to date		Average Life
				Yrs.	Mos.		Total	Per Cent.	
			RUEPING CREOSOTED—Contd						
St. Louis & San Francisco	2	321	Red Gum	9		St. Clair, Mo	1	0.3	
	1	752	Red Oak	9		"	1	0.1	
	5	40	Red Oak & Gum	10		Pacific, Mo	4	10.0	
			ALLARDYCE TREATED						
Chicago, Burlington & Quincy	9	77	Pine	10	2	Elsberry, Mo	5	6.5	
	14	41	Douglas Fir	10	2	"	4	9.5	
			CARD TREATED						
Chicago, Milwaukee & St. Paul	2	596	Maple	7		Braymore, Mo	....	....	
			ZINC CREOSOTED						
Galveston, Harrisburg & San Antonio	3	1,003	Pine	10	4	Bay View, Tex	326	32.5	
	19	200	"	20	9	Ft. Hancock, Tex	157	78.5	
	23	433	"	8	5	Salix, La	27	6.2	
	28	599	"	8	7	Scott, La	109	18.2	
	13	45	Red Gum	10	4	Bay View, Tex	23	51.1	
	14	42	Tupelo Gum	10	4	"	37	88.1	
	27	250	Red Oak	8	11	Scott, La	92	36.8	
	TIES TREATED BY DIAMOND WOOD PRESERVING CO. PROCESS								
Galveston, Harrisburg & San Antonio	20	500	Red Oak	8	6	Ft. Hancock, Tex	15	3.0	
	21	500	Red Gum	8	6	"	4	0 8	
	22	500	Sap Pine	8	6	"	188	37.6	
		GUISSANI ZINC CREOSOTED							
St. Louis & San Francisco	3	43	Red Oak & Gum	10		Pacific, Mo	18	41.8	

Appendix A.

SERVICE TEST OF TIES ON THE CHICAGO & NORTHWESTERN RAILWAY NEAR JANESVILLE, WIS.

In 1905 and 1906 the Forest Service co-operated with the Chicago & Northwestern Railway Company in experiments with the seasoning and treating of Eastern hemlock and Eastern tamarack cross-ties, the experiments being conducted at the company's treating plant at Escanaba, Mich. The results secured from these experiments are described in Forest Service Circular 132, entitled "The Seasoning and Preservative Treatment of Hemlock and Tamarack Cross-ties."

With a view to securing additional information regarding the comparative durability of the ties, 3040 were selected for further experiments. This number included some untreated hemlock and tamarack and some of each species treated respectively by the Burnett, Wellhouse and Open-Tank Creosote processes. In addition to the 3040 experimental hemlock and tamarack ties selected for the test, 50 untreated white oak ties were included.

The section of track selected for the experiment lies about four miles south of the Chicago & Northwestern station at Janesville, Wis. Briefly, the ties were laid in gravel ballast, in a fairly well-drained roadbed, with sandy clay subsoil. Ninety-pound rail was used, but only passenger traffic in one direction passes over this section of the track, amounting to about 27,314,000 tons annually. All of the treated ties were equipped with tie plates, the following different kinds being used:

Sellers shoulder plates with flat bottoms used with screw spikes;
Sellers shoulder plates with flat bottoms used with cut spikes;
Wolhaupter plates used with cut spikes;
Creosoted wood plates used with screw spikes.

The wood plates were of hard maple of dimensions 5 inches by 8 inches by ¼-inch and were thoroughly treated with creosote by the open-tank process. Ordinary cut spikes and no tie plates were used with the untreated ties.

Ties were divided into 67 lots, according to the species, method of seasoning, treatment and the absorption secured.

The general arrangement of the ties and characteristic points of each lot is shown in Table 1. The fifty white oak ties are not included in any of the above lots, and were marked only with copper tags bearing no number. They were placed at the south end of the experimental track, being laid with cut spikes and no tie plates.

Treatment.

The Burnett and Wellhouse processes were used in the treatments. About 12 lbs. of 4 per cent. solution was injected per cubic foot. The ties treated with creosote were given an open-tank treatment and about 15 lbs. were absorbed per tie.

Inspection.

Inspections of the track have been made in 1909, 1911, 1913, 1914 and 1915. The results of the 1915 inspection (made on June 19) after 7½ years' service are given in Table 1.

Untreated Ties (see Table 2).

One hundred and seventy untreated hemlock ties were included in this track and of this number 152, or 89.4 per cent., had been removed, the remainder being partly decayed. Of the 132 untreated tamarack ties, 123, or 93.2 per cent., have been removed, 2.3 per cent. partly decayed, and 4.5 per cent. sound. If it is assumed that all untreated ties will have been removed at the time of the inspection in 1916, the average life for untreated hemlock in this test will be 6.70 years, while that of the tamarack will be 6.58 years.

The 50 untreated white oak ties (see Table 4) had begun to fail at this inspection. Eighteen were so badly decayed as to warrant removal, and the remainder were partly decayed. If we assume that these 32 ties will be removed within the next two years, the average life in service will be about 8⅓ years.

Effect of Season of Cutting.

The condition of the untreated hemlock and tamarack ties with regard to the season of cutting and the seasoning period is given in Table 2. The date of removal and average life estimates are given in Table 3. A comparison of the condition of the hemlock ties cut in the summer, fall and winter is shown as follows:

	Per Cent. Removed, 1915.	Average Life, Years.
Summer cut	95	6.65
Fall cut	100	6.53
Winter cut	88⅓	6.94

These figures would indicate that the winter cut ties are yielding the best results. When it is considered, however, that Lot 63, which contained over half of the winter cut ties, was seasoned but 11 months in an unpeeled condition, while the remainder were seasoned 23 and 35 months peeled, it is hardly fair to include them in the comparison with the summer and fall cut ties which were seasoned about 26 to 29 months peeled. Neglecting Lot 63, it is found that the averages become:

	Per Cent. Removed, 1915.	Average Life, Years.
Summer cut	95	6.65
Fall cut	100	6.53
Winter cut	97½	6.45

Too much significance cannot be placed on these figures, for the number of ties involved is too small in each case.

Effect of Peeling and Time of Seasoning.

The effect of peeling can best be indicated by lots 64 and 65 (see Table 3) on winter cut tamarack ties seasoned 23 months. In 1915, 72 per cent. of the peeled ties were removed, compared with 100 per cent. of the unpeeled ones. The estimated average lives were 6.94 and 6.50 years, respectively. This indicates somewhat better results from peeling the ties while seasoning.

Comparing winter cut hemlock, group 62, peeled and seasoned 35 months, with winter cut hemlock, group 63, unpeeled and seasoned 11 months, the average lives are 6.3 years and 7.14 years, respectively. This indicates a longer life for a shorter seasoning period, especially as the ties in group 63 were unpeeled.

In general, the data indicate that the ties that are laid untreated will give better service if peeled before being seasoned, and that a short seasoning period is more desirable than a long one.

Treated Ties.

A comparison of the condition of the Burnettized, Wellhouse and creosote open-tank treated ties (Table 4) is scarcely possible on account of the wide difference in the number of ties in each class. On the whole, the condition of these ties is very satisfactory.

It was observed that most of the decay on the Burnettized and Wellhouse treated ties took place on the top of the tie and those portions which were exposed to the weather. The sides and bottoms of these ties when inspected were found to be quite sound and clean.

Plate Wear.

Plate wear and rail cutting were not excessive, since the traffic over this line is not heavy. It was observed, however, that the ties protected by flat plates with smooth bases were in better condition than those protected by plates with ribbed bases. The ribbed plates cut into the surface of the ties, causing splitting and wear to a greater extent than the smooth plates, which also naturally increased the liability to decay. Creosoted wood plates were split, broomed and practically worthless as a protection to the tie by 1911 after 3½ years.

Table 5 was prepared to show the effect of tie plates and spikes on the condition of the treated ties. No evident advantage from using screw spikes compared with cut spikes has been indicated to date, when the present condition of the ties is considered, but not considering the greater ease of maintaining the track. However, the treated ties have not been in service long enough to draw definite conclusions on this point.

Ties on which Wolhaupter plates were used are in noticeably worse condition than those on which flat plates were used.

Creosoted wood tie plates were not a success. The ties on which these plates were used have practically had no plate protection since 1911.

TABLE 1. CONDITION OF TIES LAID IN JANESVILLE TEST TRACK (CHICAGO & NORTHWESTERN RAILWAY) AFTER 7½ YEARS' SERVICE.

Lot No.	Tie Nos.	Species	Cut		Months seasoned	Conditions while seasoning	Preservative	Process	Absorption of Solution Lbs. per Cu. Ft.	Tie Plates	Spikes	Total No. Set	Good		Partly Decayed		Removed		Partly Split	
			Season	Mo.									No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent
1	1- 55	Hemlock	Summer	June	17	Peeled	Zinc Chloride	Wellhouse	13.3	Sellers	Screw	55	47	85.4	6	11.1	2	3.6	0	0.0
2	56- 95	"	"	July	16½	"	Glue & Tannin	"	14.1	"	"	40	37	92.5	3	7.5	0	0.0	0	0.0
3	96-136	"	"	Aug.	16	"	"	"	10.2	"	"	41	37	90.2	4	9.8	0	0.0	0	0.0
4	137-176	"	Fall	Sept.	15	"	"	"	11.6	"	"	40	37	92.5	3	7.5	0	0.0	0	0.0
5	177-216	"	"	Oct.	14	"	"	"	10.7	"	"	40	37	92.5	3	7.5	0	0.0	0	0.0
6	217-253	"	"	Nov.	12	"	"	"	9.4	"	"	37	30	81.1	7	19.9	0	0.0	0	0.0
7	254-294	"	Winter	Dec.	11	"	"	"	8.5	"	"	41	28	68.3	9	21.9	4	9.8	0	0.0
8	295-334	"	"	"	11	"	"	"	9.6	"	"	40	36	90.0	4	10.0	0	0.0	0	0.0
9	335-358	"	Summer	June	17	Unpeeled	"	"	18.2	"	"	24	22	91.7	2	8.3	0	0.0	0	0.0
10	359-383	"	"	Aug.	16	"	"	"	15.0	"	"	25	24	96.0	1	4.0	0	0.0	0	0.0
11	384-423	"	Fall	Nov.	12	"	"	"	14.8	"	"	40	37	92.5	2	5.0	1	2.5	0	0.0
12	424-470	"	Summer	June	17	Soaked	"	"	12.9	"	"	47	41	87.2	6	12.8	0	0.0	0	0.0
1-12 inc.	1-470	"	....	......	11-17	....	"	"	......	"	"	470	413	87.9	50	10.6	7	1.5	0	0.0
13	471-595	Tamarack	Winter	......	11	Peeled	"	"	10.7	"	"	125	107	85.6	18	14.4	0	0.0	0	0.0
15	721-761	"	"	......	11	Unpeeled	"	"	11.0	"	"	41	41	100.0	0	0.0	0	0.0	0	0.0
	762-770	"	"	......	11	"	"	"	11.0	Creo. Wood	"	9	7	77.8	1	11.1	1	11.1	0	0.0
14	....	"	"	......	11	"	"	"	......	....	"	175	155	88.4	19	11.0	1	0.6	0	0.0
14	596-720	"	"	......	10	3 mo. Un. 7 mo. Pe.	Zinc Chloride	Burnett	12.7	Sellers	"	125	115	92.0	10	8.0	0	0.0	0	0.0
....	....	"	"	......	10	....	"	"	......	"	"	125	115	92.0	10	8.0	0	0.0	0	0.0
16	771-801	"	"	......	11	Unpeeled	"	Wellhouse	10.2	Creo. Wood	"	31	28	90.2	3	19.8	0	0.0	0	0.0
	802-808	"	"	......	11	Peeled	Glue & Tannin	"	10.2	Sellers	Cut	7	7	100.0	0	0.0	0	0.0	0	0.0
	771-808 Except 801	"	"	......	11	....	"	"	......	....	......	38	35	92.1	3	7.9	0	0.0	0	0.0
17	809-848	Hemlock	Summer	June	17	Peeled	"	"	11.7	Sellers	Cut	40	33	82.5	5	12.5	1	2.5	1	2.5
18	849-888	"	"	July	16½	"	"	"	14.1	"	"	40	34	85.0	6	15.0	0	0.0	0	0.0
19	889-928	"	"	Aug.	16	"	"	"	10.7	"	"	40	37	92.5	3	7.5	0	0.0	0	0.0
20	929-968	"	Fall	Sept.	15	"	"	"	12.8	"	"	40	38	95.0	2	5.0	0	0.0	0	0.0
21	969-1008	"	"	Oct.	14	"	"	"	10.7	"	"	40	36	90.0	4	10.0	0	0.0	0	0.0
22	1009-1048	"	"	Nov.	12	"	"	"	11.3	"	"	40	37	92.5	2	5.0	1	0.0	0	0.0
23	1049-1088	"	Winter	Dec.	11	"	"	"	8.8	"	"	40	33	87.5	4	10.0	2	5.0	1	2.5
24	1089-1127	"	"	"	11	"	"	"	11.2	"	"	39	38	97.5	1	2.5	0	0.0	0	0.0
25	1128-1152	"	Summer	June	17	Unpeeled	"	"	18.2	"	"	25	24	96.0	1	4.0	0	0.0	0	0.0
26	1153-1177	"	Fall	Sept.	14	"	"	"	14.6	"	"	25	25	100.0	0	0.0	0	0.0	0	0.0
27	1178-1217	"	Winter	......	10	"	"	"	12.8	"	"	40	37	92.5	3	7.5	0	0.0	0	0.0
28	1218-1261	"	Summer	Aug.	16	Soaked	"	"	11.9	"	"	44	36	81.8	7	15.9	1	2.3	0	0.0
17-28	809-1261	"	....	......	10-17	....	"	"	......	"	"	453	408	90.1	38	8.4	5	1.1	2	0.4
29	1262-1386	Tamarack	Winter	......	11	Peeled	"	"	10.7	"	"	125	106	84.8	19	15.2	0	0.0	0	0.0
31	1512-1561	"	"	......	11	Unpeeled	"	"	10.9	"	"	50	47	94.0	3	6.0	0	0.0	0	0.0
	....	"	"	......	11	....	"	"	......	"	"	175	153	87.4	22	12.6	0	0.0	0	0.0
30	1387-1511	"	"	......	10	Peeled	Zinc Chloride	Burnett	12.7	"	"	125	123	98.4	2	1.6	0	0.0	0	0.0
32	1562-1600	Hemlock	Summer	June	17	"	" and Glue & Tannin	Wellhouse	12.9	Wolhaupter	"	39	32	82.1	7	17.9	0	0.0	0	0.0
33	1601-1641	"	"	July	16	"	"	"	13.9	"	"	41	39	95.1	2	4.9	0	0.0	0	0.0
34	1642-1684	"	"	Aug.	15	"	"	"	11.3	"	"	43	43	100.0	0	0.0	0	0.0	0	0.0

TABLE I—Continued. CONDITION OF TIES LAID IN JANESVILLE TEST TRACK (CHICAGO & NORTHWESTERN RAILWAY) AFTER 7½ YEARS' SERVICE.

Lot No.	Tie Nos.	Species	Cut		Months seasoned	Conditions while seasoning	Preservative	Process	Absorption of Solution Lbs. per Cu. Ft.	Tie Plates	Spikes	Total No. Set	Good		Partly Decayed		Removed		Partly Split	
			Season	Mo.									No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.
35	1685-1723	Hemlock	Fall	Sept.	14	Peeled	Glue & Tannin	Wellhouse	11.2	Wolhaupter	Cut	39	38	97.4	1	2.6	0	0.0	0	0.0
36	1724-1763	"	"	Oct.	13	"	"	"	9.7	"	"	40	38	95.0	2	5.0	0	0.0	0	0.0
37	1764-1803	"	"	Nov.	12	"	"	"	9.4	"	"	40	32	80.0	7	17.5	1	2.5	0	0.0
38	1804-1843	"	Winter	Dec.	11	"	"	"	10.7	"	"	40	38	95.0	1	2.5	1	2.5	0	0.0
39	1844-1883	"	"	......	10	"	"	"	9.7	"	"	40	33	82.5	7	17.5	0	0.0	0	0.0
40	1884-1908	"	Summer	July	16	Unpeeled	"	"	14.1	"	"	25	17	68.0	8	32.0	0	0.0	0	0.0
41	1909-1929	"	Fall	Oct.	13	"	"	"	12.1	"	"	21	20	95.2	1	4.8	0	0.0	0	0.0
42	1930-1969	"	Winter	......	10	"	"	"	13.6	"	"	40	37	92.5	3	7.5	0	0.0	0	0.0
43	1970-2018	"	Fall	Sept.	15	Soaked	"	"	12.5	"	"	49	45	91.8	4	8.2	0	0.0	0	0.0
44	2019-2146	Tamarack	Winter	......	11	Peeled	"	"	10.2	"	"	128	119	93.0	8	6.2	1	0.8	0	0.0
46	2272-2321	"	"	......	11	Unpeeled	"	"	10.9	"	"	50	49	98.0	1	2.0	0	0.0	0	0.0
32-46 Except 45	1562-2319 Except 2147-2271	......	......	......	10-17	......	Zinc Chloride and Glue & Tannin	"	......	"	"	635	580	91.3	52	8.2	3	0.5	0	0.0
45	2147-2271	Tamarack	Winter	......	10	3 mo. Un. 7 mo. Pe.	Zinc Chloride	Burnett	12.7	"	"	125	111	88.8	14	11.2	0	0.0	0	0.0
47	2322-2374	Hemlock	"	......	10	Peeled & Unpeeled	Zinc Chloride and Glue & Tannin	Wellhouse	8.9	"	"	53	35	66.0	14	26.5	4	7.5	0	0.0
48	2375-2425	"	"	......	10	"	"	"	8.9		"	51	28	54.9	20	39.2	2	3.9	1	2.0
49	2426-2476	"	"	......	10	"	"	"	10.9		"	51	40	78.5	9	17.6	2	3.9	0	0.0
52	2535-2593	Tamarack	"	......	10	"	"	"	10.6	"	"	59	33	55.9	26	44.1	0	0.0	0	0.0
53	2594-2648	"	"	......	10	"	"	"	10.1	"	"	55	46	83.7	8	14.5	1	1.8	0	0.0
54	2649-2706	"	"	......	10	"	"	"	9.4	"	"	58	45	77.6	12	20.7	1	1.7	0	0.0
47-54 Except 50 & 51	2322-2706 Except 2477-2534	......	"	......	10	"	"	"	......	"	"	327	227	69.4	89	27.2	10	3.1	1	0.3
50	2477-2501	Hemlock	"	......	10	Peeled	Zinc Chloride	Burnett	6.5	"	"	25	15	60.0	6	24.0	4	16.0	0	0.0
55	2707-2719	Tamarack	"	......	10	"	"	"	7.7	"	"	13	8	61.5	5	38.5	0	0.0	0	0.0
												38	23	60.5	11	29.0	4	10.5	0	0.0
51	2502-2534	Hemlock	Mixed	......	......	Both	Creosote	OpenTank	14.3	"	"	33	22	66.7	11	33.3	0	0.0	0	0.0
56	2720-2738	Tamarack	"	......	......	"	"	"	15.5	"	"	19	19	100.0	0	0.0	0	0.0	0	0.0
												52	41	78.8	11	21.2	0	0.0	0	0.0
57	2739-2758	Hemlock	Summer	July	29	Soaked	Untreated	Untreated	......	None	"	20	0	0.0	2	10.0	18	90.0	0	0.0
58	2759-2778	"	"	Aug.	28	Peeled	"	"	......	"	"	20	0	0.0	0	0.0	20	100.0	0	0.0
59	2779-2798	"	Fall	Oct.	26	"	"	"	......	"	"	20	0	0.0	0	0.0	20	100.0	0	0.0
60	2799-2818	"	Winter	......	23	"	"	"	......	"	"	20	0	0.0	0	0.0	20	100.0	0	0.0
61	2819-2838	"	Fall	Oct.	26	"	"	"	......	"	"	20	0	0.0	0	0.0	20	100.0	0	0.0
62	2839-2858	"	Winter	......	35	"	"	"	......	"	"	20	0	0.0	1	5.0	19	95.0	0	0.0
63	2859-2908	"	"	......	11	Unpeeled	"	"	......	"	"	50	0	0.0	15	30.0	35	70.0	0	0.0
64	2909-2933	Tamarack	"	......	23	Peeled	"	"	......	"	"	25	6	24.0	1	4.0	18	72.0	0	0.0
65	2934-2958	"	"	......	23	Unpeeled	"	"	......	"	"	25	0	0.0	0	0.0	25	100.0	0	0.0
66	2959-2978	"	"	......	35	Peeled	"	"	......	"	"	20	0	0.0	1	5.0	19	95.0	0	0.0
67	2979-3040	"	"	......	11	Unpeeled	"	"	......	"	"	62	0	0.0	1	1.6	61	98.4	0	0.0
57-67 inc.	2742-3040	......	......	......	11-35	......	......	......	......	......	......	302	6	2.0	21	7.0	275	91.0	0	0.0

TABLE 2. COMPARISON OF CONDITIONS OF UNTREATED TIES CUT AT DIFFERENT SEASONS AND SEASONED FOR DIFFERENT PERIODS. CONDITION AS FOUND IN JUNE, 1915, INSPECTION, 7½ YEARS' SERVICE.

Lot No.	Species	Time Seasoned	Season cut	Condition while Seasoning	No. of Ties	Good	Per cent. Good	Removed*	Per cent. Removed*	Partly decayed	Per cent. Partly decayed
		Months									
57	Hemlock	29	Summer	Peeled and soaked for few days prior to seasoning	20	......	......	18	90	2	10
58	"	28	"	Peeled	20	......	......	20	100	......	......
59	"	26	Fall	Peeled	20	......	......	20	100	......	......
60	"	23	Winter	Peeled	20	......	......	20	100	......	......
61	"	26	Fall	Peeled	20	......	......	20	100	......	......
62	"	35	Winter	Peeled	20	......	......	19	95	1	5
	"	11	"	Unpeeled on two sides	50	......	......	35	70	15	30
				Total	170	......	......	152	89.4	18	10.6
64	Tamarack	23	Winter	Peeled	25	6	24	18	72	1	4
65	"	23	"	Unpeeled on two sides	25	......	......	25	100	......	......
66	"	35	"	Peeled	20	......	......	19	95	1	5
67	"	11	"	Unpeeled on two sides	62	......	......	61	98.4	1	1.6
				Total	132	6	4.5	123	93.2	3	2.3

*Includes some ties which were in the track at time of inspection but which were decayed sufficiently to warrant removal and were to be removed in a few days.

TABLE 3. UNTREATED TIES REMOVED FROM JANESVILLE TRACK, AT VARIOUS INSPECTIONS.

Lot No.	Species	Months Seasoned	Season cut	Condition while Seasoning	Number of ties	Per cent. Removed			Average Life Years
						1913 Per cent.	1914 Per cent.	1915 Per cent.	
57	Hemlock	29	Summer	Soaked	20	20	90*	90	6.5
58	"	28	"	Peeled	20	0	70	100	6.8
59	"	26	Fall	"	20	5	85	100	6.6
60	"	23	Winter	"	20	10	80	100	6.6
61	"	26	Fall	"	20	25	80	100	6.45
62	"	35	Winter	"	20	45	80	95	6.3
63	"	11	"	Unpeeled	50	4	62	70	7.14
				Total	170	14.7	75.3	89.4	6.7
64	Tamarack	23	Winter	Peeled	25	20	64	72	6.94
65	"	23	"	Unpeeled	25	4	96	100	6.5
66	"	35	"	Peeled	20	10	85	95	6.6
67	"	11	"	Unpeeled	62	13	91.9	98.4	6.47
				Total	132	12.9	86.4	93.2	6.58

*Reported as 100 per cent. removed in 1914

Lot No.	Species	Preservative	Treatment	Number Set	1911	1913	1914	1915	1915	
					Good Per cent.	Good Per cent.	Good Per cent.	Good Per cent.	Removed	
									No.	Per cent.
50..............	Hemlock	Zinc Chloride.........	Burnett............	25	100	88.0	84.0	60.0	4	16.0
1 to 12, inc., 17 to 28, inc., 32 to 43, inc., 47 to 49, inc.........	"	Zinc Chloride, Glue and Tannia..............	Wellhouse...........	1535	100	99.1	94.6	87.0	23	1.5
51..............	"	Creosote..............	Open Tank..........	33	100	100	90.9	66.6	0	0.0
57 to 63, inc......	"	Untreated............	Untreated...........	170	37.6	23.5	0.0	0.0	①15.2	①89.4
....	White Oak	Untreated............	Unterated...........	50	Not Examined	74	0.0	0.0	④18	36.0
14, 30, 45, 55.....	Tamarack	Zinc Chloride.........	Burnett............	388	③99.5	③99.75	96.6	92.3	0	0.0
56..............	"	Creosote..............	Open Tank..........	19	100.0	④89.5	④89.5	④100.0	0	0.0
13, 15, 16, 29, 31, 44, 46, 52, 53, 54	"	Zinc Chloride, Glue and Tannin..............	Wellhouse...........	738	100.0	99.1	96.3	86.1	4	0.05
64 to 67, inc......	"	Untreated............	Untreated...........	132	19.7	9.1	②3.8	②4.5	①123	①93.2

①Includes some ties now in track which were to be removed within a few days.
②One tie which was classed as partly decayed in 1914 was classed as good in 1915 owing to difference in inspection.
③One tie classed as partly decayed in 1911 was classed as good in 1913.
④Two ties which were very slightly decayed in 1913–1914 were classed as good in 1915.

TABLE 5. EFFECT OF TIE PLATES ON DURABILITY OF TIES IN JANESVILLE TRACK.

Lot No.	Species	Treatment	Plate	Spike	Number of Ties	Condition in 1915			
						Good Per cent.	Partly decayed Per cent.	Removed Per cent.	Partly split Per cent.
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	Hemlock..........	Wellhouse.........	Sellers.................	Screw.....	470	87.2	10.6	1.5	0.0
17, 18, 19, 20, 21, 22, 23, 24, 24, 25, 26, 27, 28........	"	"	"	Cut.......	453	90.1	8.4	1.1	0.4
32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49.............	"	"	Wolhaupter...........	"	612	84.1	14.1	1.6	0.2
50......................	"	Burnett...........	"	"	25	60.0	24.0	16.0	0.0
13, 15 (721-761)...........	Tamarack.........	Wellhouse.........	Sellers.................	Screw.....	166	89.2	10.8	0.0	0.0
29, 31, 16 (802-808).......	"	"	"	Cut.......	182	87.9	12.1	0.0	0.0
16 (771-801), 15 (762-770).	"	"	Wood-Creosoted.......	Screw.....	40	87.5	10.0	2.5	0.0
44, 46, 52, 53, 54..........	"	"	Wolhaupter...........	Cut.......	350	83.4	15.7	0.9	0.0
45, 55.....................	"	Burnett...........	"	"	138	86.2	13.8	0.0	0.0
14.........................	"	"	Sellers.................	Screw.....	125	92.0	8.0	0.0	0.0
30.........................	"	"	"	Cut.......	125	98.4	1.6	0.0	0.0

SERVICE TESTS OF CROSS-TIES ON NORTHERN PACIFIC RAILWAY NEAR PLAINS, MONT.

NATURE OF TRACK.

The ties for this test were placed early in the year 1907 on the main line of the Northern Pacific Railway, beginning about two miles west of Plains, Mont. The ties were all laid on a tangent in a continous stretch, extending from 3461 feet west of milepost 203 (Helena-Hope) to 3203 feet west of milepost 204, covering approximately 4800 feet of track, exclusive of space omitted for crossings, switches and bridges. There is a uniform grade of 0.0167 per cent. over the entire test track.

FLAT, FLANGED AND WOODEN PLATES—SCREW SPIKES.

The material used for this test was as follows:

Ties.

Western larch—Green, 570; seasoned, 571; treated, 197.
Douglas fir—Green, 551; seasoned, 568; treated, 193.
Total, 2650.

Tie Plates.

Flanged plates	794
Flat plates with ordinary spikes	1726
Flat plates with screw spikes	1984
Combination (flat and flanged)	360
Wooden plates	436
Total	5300

The wooden plates were made of white oak, treated with one-twelfth of a pound of creosote each, with the following dimensions: Length, 7 inches; thickness, ¼-inch, and width a little greater than the base of the rail.

The ties were generally spaced 22 inches from center to center, which allowed 18 ties per rail length of 33 feet. In a few cases it was necessary to insert extra ties when the ties averaged less than 7 inches in width; also in filling in part of a rail length near the crossing, bridge and switch. More than half of the roadbed is filled, which fact, together with the quality of the gravel, gives excellent drainage.

The test was arranged primarily to determine the durability of green, seasoned and treated timbers which were cut at different seasons of the year.

The screw spikes, 5276 in number, and flat plates used in this test are similar to those used in the Maywood track, and were placed in the track as in the former instance. The Western larch and Douglas fir ties used in the Plains track were hewn pole ties from Montana and Idaho and varied much in size and shape.

Treatment.

The ties were treated at the plant of the Great Northern Railway at Somers, Mont. Both species were seasoned and were treated in the same charge. The gage readings showed an average injection of 0.786 lb. zinc chloride per cubic foot. The larch ties absorbed more preservative than the Douglas fir.

INSPECTION.

Inspections of this track have been made annually since 1909, excluding the year 1912. Acknowledgments are due Mr. J. D. Korem, Division Engineer of the Northern Pacific Railway at Spokane, Wash., and Mr. B. L. Crosby, Division Engineer of the Northern Pacific Railway at Tacoma, Wash., for assistance in the inspection of this test track. The results of the last inspection are given in Table on Sheet 6, Appendix A.

Untreated Ties.

Practically all of the untreated ties have been removed because of decay. Table 6 shows the number removed each year and the average life obtained. Practically no difference in life was obtained from ties placed green or seasoned. It was also noted that rail wear and spike holding qualities were the same. A slight difference in life was noted between Douglas fir and Western larch. It was noted in the earlier inspections that the Western larch checked worse and showed more rail wear than the fir and evidently caused their shorter life.

Effect of Tie Plates.

Two years after the track was laid it was found that the white oak wooden tie plates were not a success. They had a tendency to work out from under the rail, allowing the tie to become badly rail worn. They also split badly. The wooden plates were removed in 1910 and replaced with Sellers plates and cut spikes.

It was found that the flat Sellers plate and the Northern Pacific tie plate gave better protection to the ties than the flanged Wolhaupter plates. The latter seemed to dig into the ties, especially on the outer side of the rail. They also cause the ties to spread and broom more at the ends.

Screw spikes seemed to offer better protection than cut spikes. They held the rail firmly, whereas the cut spikes were loose, allowing play in the rail and rail wear on the ties. Trouble was experienced from the screw spikes bending away from the rail at the head. The test shows that the tie plates should be provided with a shoulder to support the heads of the screw spikes.

Where screw spikes were used at the rail joint with cut spikes on the intermediate ties, some improvement was noted over the use of all cut spikes.

The results obtained with the various forms of fastenings are shown in Table 7. The table does not indicate any marked increase in the life obtained from Sellers plates compared with the Wolhaupter, though the ties equipped with the former were in better condition throughout their life. Screw spikes with Sellers plates seemed to give a slight increase in the average life obtained compared with cut spikes and Sellers plates.

Treated Ties.

The effectiveness of the zinc chloride treatment of Douglas fir and Western larch ties is clearly evident in Table 6. Practically all of the untreated ties are out, whereas only 2.5 per cent. of the fir and 4.1 per cent. of the larch ties have been removed after 8 years' service.

All of the treated ties were equipped with Sellers plates with screw spikes or with screw spikes in joint ties and cut spikes on intermediate ties.

It was noted in the earlier inspections that the treated ties had a tendency to rail cut, split and broom at the ends to a greater extent than the untreated ties. Most of the untreated ties were removed because of decay. The treated ties, however, were removed because of mechanical wear, which indicates very strongly that treated fir and larch should be protected with tie plates.

Quite a number of the treated ties would have been removed in 1915 for spike killing and rail wear had they not been turned over. It is expected that turning the badly worn ties a year or two before they would have to be removed will give them several years more of service in the track.

It is interesting to note that the untreated Douglas fir ties in the Maywood track are failing less rapidly than those in the Plains track. The Maywood ties are sawn ties, while those at Plains are pole ties. Maywood is subject to the heavy precipitation of the west slope of the Cascades, while Plains lies in the comparatively dry region of Western Montana. There is greater tonnage carried on the Plains track, but Maywood lies on a mountain grade with several curves. The difference in climatic conditions is believed to cause the variation in durability. Although pole ties at Plains contain more sap, their failure is due principally to checking and subsequent center decay.

It is also interesting to note that 12.9 per cent. of the creosoted Douglas fir ties at Maywood, compared with only 2.5 per cent. of the zinc treated ties at Plains, have been removed. All failures of treated ties were due to crushing, and it is probable that the creosoted ties have been subjected to harder wear because of the grades and curves.

SERVICE TESTS OF CROSS-TIES ON NORTHERN PACIFIC RAILWAY AT MAYWOOD, WASH.

NATURE OF TRACK.

The ties for this test were placed late in 1906 in the main line of the Northern Pacific Railway, about 6 miles west of Hot Springs, Wash., near the station at Maywood. They were laid in a continuous stretch, extending from 2410 feet west of milepost 197 (Pasco-Tacoma) to about 1185 feet west of milepost 198, covering approximately 4055 feet of track or about three-quarters of a mile. Two curves, one of 2 degrees and the other of 5 degrees, are included in this section. The

TABLE 6. REMOVALS OF TIES PLACED IN PLAINS TRACK (NORTHERN PACIFIC RAILWAY) EARLY IN YEAR 1907. TOTALS IRRESPECTIVE OF TRACK EQUIPMENT.

Kind of Timber	Condition when placed	Number originally placed	Removals (Per cent.)*				Average Life Years
			1911 4⅓ yrs.	1913 6⅓ yrs.	1914 7⅓ yrs.	1915 8⅓ yrs.	
Douglas fir	Green	570	0	6.1	66.3	99.0†	7.6
" "	Seasoned	571	0	1.9	62.5	97.3†	7.7
" "	Treated with zinc chloride	197	0	0	2.5	2.5	....
Western larch	Green	551	0.4	13.8	85.3	99.9†	7.3
" "	Seasoned	568	0	9.8	83.8	99.6†	7.4
" "	Treated with zinc chloride	193	0	0	4.1	4.1*	....

*Assumed as being removed in June each year.
†Remainder assumed to be removed in June, 1916.

TABLE 7. EFFECT OF TIE PLATES ON DURABILITY OF UNTREATED TIES PLACED IN THE PLAINS TRACK, EARLY IN YEAR 1907.

Group Nos.	Species	Kind of Plate	Kind of Spike	Number of Ties	Removals (Per Cent.)*				Average Life Years†
					1911 4.3 yrs.	1913 6.3 yrs.	1914 7.3 yrs.	1915 8.3 yrs.	
1- 2	Douglas fir	Wooden—'07-'10 Sellers —'10-'15	Screw—'07-'10 Cut —'10-'15	127	0	12.6	56.6	97.6	7.63
3- 4	Western larch	"	"	123	1.6	41.5	95.9	100.0	6.89
5- 6	Douglas fir	Wolhaupter	Cut	184	0	9.2	65.8	97.3	7.58
7- 8	Western larch	"	"	181	0	26.0	89.5	100.0	7.15
9-10 13-14	Douglas fir	Sellers	"	363	0	3.6	71.1	98.9	7.56
11-12 15-16	Western larch	"	"	361	0	9.4	90.3	100.0	7.30
21-22	Douglas fir	"	Screw	180	0	0	59.4	99.4	7.71
25-26	Western larch	"	"	182	0	0	52.7	98.9	7.78
17-18	Douglas fir	"	Alternate cut and screw	198	0	0	54.0	98.0	7.78
19-20	Western larch	"	"	181	0	0	86.7	99.4	7.44
29	Douglas fir	N. P. No. 21	Cut	89	0	0	78.7	95.5	7.56
30	Western larch	N. P. No. 21	"	91	0	0	95.6	100.0	7.34

*Removals assumed to have been made in June of each year.
†Ties still in track assumed to be removed in June, 1916.

grade varies from 0.46 to 0.96 per cent. The following material was used:

Green Western hemlock ties	203
Green Douglas fir ties	557
Seasoned Douglas fir ties	1078
Seasoned and creosoted Douglas fir ties	442
Total ties	2280
Screw spikes	1500
Flat tie plates	3700

FLAT PLATES, SCREW SPIKES AND CUT SPIKES.

The flat pieces, used exclusively in this test, measures 6-3/16 by 8⅞ inches, giving a bearing surface on the tie of 54.9 square inches. Wherever tie plates were used with screw spikes it was necessary to enlarge the holes in the tie plates to a diameter of 15/16-inch. The screw spikes were imported from France, and are similar to those used by the French Eastern Railway. The spikes have the following dimensions: Total length, 6.39 inches; length, exclusive of head, 5 inches; diameter, 0.92-inch; diameter of core, 0.66-inch. There are 9 spirals with a pitch of thread of 0.49-inch and a height of thread of 0.13-inch. The spikes weighed 1.16 pounds each. The common track spikes used are 5.5 inches long, exclusive of the head, and measure 9/16 by 9/16-inch in cross-section.

It is the general practice to double spike all ties on the mountain curves, that is, to insert eight spikes per tie, four at each end. This was adhered to throughout the test wherever common spikes were employed. In the case of screw spikes, four were inserted per tie, on both tangents and curves. An 11/16 auger was used in boring the holes for inserting the screw spikes. The holes were filled with creosote before the spikes were screwed into place.

The roadbed, for the most part, is earth embankment, well drained. Gravel is used exclusively for ballast. The valley, at the point where the track has been placed, is very narrow, with standing timber on both sides of the right-of-way, so that the track receives the sun only a few hours of the day.

Sawn Douglas fir ties were used and were obtained at Tacoma, Wash. The wood showed from 4 to 36 rings per inch and were made from trees 3 to 6 feet in diameter.

Treatment.

The Douglas fir ties were treated with creosote after air seasoning. An increase in weight of 8.6 lbs. per cubic foot was obtained during treatment, but when placed in the track four months later they had lost 2.4 lbs. per cubic foot, leaving the net increase 6.2 lbs. per cubic foot.

Inspection of Ties.

Inspections of this track have been made annually since 1909, excluding the year 1912. Acknowledgments are due Mr. J. D. Korem, Division Engineer of the Northern Pacific Railway at Spokane, Wash., and Mr.

TABLE 8. REMOVALS OF TIES PLACED IN MAYWOOD TRACK, LATE IN 1906. TOTALS IRRESPECTIVE OF TRACK EQUIPMENT.

Kind of Timber	Condition when placed	Number originally placed	Removals (Per Cent.)*				Average Life Years†
			1911 4.7 yrs.	1913 6.7 yrs.	1914 7.7 yrs.	1915 8.7 yrs.	
Douglas fir	Green	557	1.0	12.6	62.2	76.3	8.2
" "	Seasoned	1078	0.3	4.4	59.7	76.0	8.3
" "	Creosote	442	0.2	0.2	7.7	12.9	....
Western hemlock	Green	203	2.0	33.0	99.5	100.0	7.3

*Assumed as being removed in June of each year.
†Assuming that remainder of ties will be removed in 1916.

B. L. Crosby, Division Engineer of the Northern Pacific Railway at Tacoma, Wash., for assistance in the inspection of this test track. The results of the last inspection are given in Table on Sheets 6 and 7, Appendix A.

Untreated Ties.

A large number of the untreated ties have been removed for decay. Table 8 is given to show the number removed each year. The data indicate that there was practically no difference in durability between green and seasoned untreated Douglas fir ties and that the untreated Douglas fir ties were more durable than the untreated Western hemlock ties. The average life of the latter in this track was 7.3 years, while it can be estimated that the green and seasoned Douglas fir ties will last at least 8.2 and 8.3 years, respectively.

Effect of Tie Plates.

The effectiveness of tie plates on untreated Douglas fir ties is shown in Table 9, where from 71 to 75 per cent. of ties with tie plates were removed after 8 years' service, compared with 95 per cent. removals without tie plates. At the various inspections it was noted that where screw spikes were placed at joints, with cut spikes on the intermediate ties, rail wear was not diminished on the joint ties. Also that screw spikes held the rail more securely to the tie than the cut spikes. No difference in rail wear was noted between the ties fastened with cut and with screw spikes.

TABLE 9. EFFECT OF TIE PLATES ON DURABILITY OF UNTREATED DOUGLAS FIR TIES IN MAYWOOD, WASHINGTON. (AFTER 8.7 YEARS OF SERVICE.)

Group Nos.	Kind of Plate	Kind of Spike	Number of Ties	Removed 1915 Per Cent.
1, 2, 5, 6	Sellers	Cut	814	71
9, 14	Sellers	Screw	142	75
11, 12	Sellers	Alternate cut and screw	138	72
8	None	Screw	58	95
15, 17	None	Cut	199	96

Treated Ties.

The lower percentage of removals of creosoted Douglas fir ties demonstrates the protection from decay afforded by a preservative treatment with creosote.

Effect of Tie Plates.

The advantage to be derived from tie plates on the creosoted ties is clearly shown by Table 10. The creosoted ties not tie plated were badly broomed and shattered on the upper side. It was evident at the 1913

TABLE 10. EFFECT OF TIE PLATES ON DURABILITY OF CREOSOTED DOUGLAS FIR TIES IN THE MAYWOOD TEST TRACK. FROM 1915 INSPECTION.

Group No.	Kind of Tie Plate	Kind of Spike	Number of Ties	Good Per Cent.	Removed Per Cent.
3 and 7....	Sellers.........	Cut......................	225	79.6	16.4
10.........	Sellers.........	Screw.....................	100	86.0	8.0
13.........	Sellers.........	Alternate cut and screw....	46	78.2	15.3
18.........	None..........	Cut......................	71*	0	7.0

*Ties all turned over in 1913.

inspection that these ties would wear out before they would decay, and hence they were turned over and plated with the standard tie plate used by the Northern Pacific Railway. The 1915 inspection showed that the expense of turning these ties was fully justified by their excellent condition. However, the ties originally tie plated did not rail cut as badly as those not plated and did not need to be turned over.

The creosoted Douglas fir ties seemed to be softer and wore more rapidly at first than the untreated ones, which indicates a greater need for tie plates on the treated ties. It is doubtful whether the increased life obtained by tie plating the untreated ties would warrant the expense. There is little doubt, however, that the expense is justified in the case of the treated ties.

As to the relative advantage of cut versus screw spikes little can be said from the results of the test. The screw spike held the rail more firmly and the per cent. of removals is somewhat lower than with cut spikes. More time must elapse before conclusions can be drawn.

SERVICE TESTS OF CROSS-TIES ON CHICAGO, MILWAUKEE & ST. PAUL RAILWAY.

Between 1911 and 1913 several sections of track on the Chicago, Milwaukee & St. Paul Railway were set aside as test tracks, and records kept of all removals. Since no records were maintained previous to the time the tracks were established, the dates of removal of a few of the ties could not be determined. No records of treatment are available except the purchase requirements. The following are the records of those ties that have been in service long enough to give data of interest. The data were furnished by Mr. F. S. Pooler, Tie Agent, Chicago, Milwaukee & St. Paul Railway, Chicago, Ill. (See Sheet 3, Appendix A.)

TRACK NO. 4.

(Longleaf Pine, Untreated. Laid 1899 and 1900.)

This test is located on the La Crosse Division and its purpose is to test longleaf yellow pine ties. It is located from 1 mile to 1000 feet east of Rio, Wis., to 2980 feet east of Rio. Twenty-one hundred longleaf yellow pine sawed ties (90 per cent. heart), 6 by 8 inches by 8 feet are used without treatment. Seven hundred and thirty-two of the ties are placed on a curve and 1368 are on a tangent. Common spikes without tie plates are used. The ballast is gravel and drainage is good. The ties were laid in 1899 and 1900, 85-lb. rail being used, but later changed to 90 lbs. The traffic is as heavy as any on the lines of this road.

Removals to date are as follows:

1911—529 because of decay.
330 broken off because of rail cutting.
538 decayed and split.
1912—103 because of decay.
1913—72 because of decay.
1914—118 because of decay.
1915—130 because of decay.

Two hundred and eighty ties still remained in the track in 1915.

The average life of these ties was between 12 and 13 years.

TRACK NO. 9.

(Red Oak, Zinc Treatment, Laid 1906.)

This test is located on the Trans-Missouri Division, Puget Sound Line, and its purpose is to test red oak zinc-treated ties. It is located at McLaughlin, S. D., beginning at the tool house east of that place and extending eastward, being marked by stone monuments placed about 25 feet from the rail on the north side of the track and opposite each end. Three hundred hewn red oak ties, 6 by 8 inches by 8 feet, treated by the Burnett process at the Carbondale, Ill., plant of Ayer & Lord Tie Company, were laid in 1906. Records of treatment are not available, except that a 4 per cent. solution of zinc chloride was used and 0.5-lb. per cubic foot was injected. The ties were steam seasoned. No tie plates were used. American Society of Civil Engineers section of rail was used in this track, the weight of the rail being 85 lbs. Common spikes without tie plates were used. The ties are on a level tangent with good drainage. Density of traffic is about average.

Removals to date are as follows:

None previous to 1913.
1913—1 because of decay.
1914—3 because of decay.
1915—Data not received.

TRACK NO. 10.

(Untreated White Oak Ties, Laid 1906.)

This test is located on the Kansas City Division, Rutledge Line, and its purpose is to test untreated white oak cross-ties. It is located one and one-half miles east of Washington, Iowa, where the white oak cross-ties (see Track No. 11) join the zinc-treated pine cross-ties. Five hundred hewn white oak ties, 6 by 8 inches by 8 feet, were laid in May, 1903, all on a tangent. Common spikes without tie plates are used.

The ballast is gravel. American Society of Civil Engineers section of rail was used in this track, the weight of the rail being 85 lbs. The traffic is heavy.

Removals to date are as follows:

*1913—202 because of decay (40.4 per cent.).
1914— 18 because of decay (3.6 per cent.).
1915— 87 because of decay (17.4 per cent.).

One hundreds and ninety-three ties, or 38.6 per cent., still remain in the track after twelve years' service. The average life of these ties, assuming that one-half of those remaining will come out in 1916 and the remainder in 1917, would be about 11 to 12 years.

TRACK NO. 11.

(Zinc-Treated Shortleaf Pine Ties, Laid 1903.)

This test is located on the Kansas City Division, Rutledge Line, and its purpose is to test zinc-treated pine cross-ties. It is located on a tangent one and one-half miles east of Washington, Iowa, where white oak cross-ties join the zinc-treated pine cross-ties (see Track No. 10). Five hundred sawed shortleaf yellow pine ties, 6 by 8 inches by 8 feet, treated by the Burnett process, after air-seasoning, with one-half lb. of chloride of zinc per cubic foot, were laid in May, 1903. Tie plates were put on these ties in 1911. These are malleable iron flanged (¾-inch) plates, Chicago, Milwaukee & St. Paul, type "M." The ballast is gravel and drainage good. American Society of Civil Engineers section of rail was used in this track, the weight of the rail being 85 lbs. Traffic is heavy.

Removals to date are as follows:

1913—21 because of decay.
1914— 8 because joint ties with new steel were put in.
11 because of decay.
1915—10 because of decay.

Four hundred and fifty-nine ties, or 90 per cent., still remain in the track after twelve years of service. This track has special interest, as a direct comparison with Track No. 10 is obtained where untreated white oak ties are used.

TRACK NO. 12.

(Zinc-Treated Shortleaf Pine Ties, Laid 1906.)

This test is located on the Puget Sound Line, Trans-Missouri Division, and its purpose is to test zinc-treated shortleaf Southern pine ties. It is located on a tangent one-quarter mile west of Morristown, S. D., stakes being placed at each end of the track. Five hundred sawed ties, 6 by 8 inches by 8 feet, air-seasoned and treated by the Burnett process with one-half lb. of zinc per cubic foot, were treated and laid in 1906. Malleable iron tie plates with ¾-inch flanges, Chicago, Milwaukee & St. Paul, type "M," are used. The ballast is sand and

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*Some may have been removed before 1913, but no record is available.

60 per cent. burnt clay. Drainage is fair. American Society of Civil Engineers section of rail was used in this track, the weight of the rail being 85 lbs. Traffic is average for the road.

Removals to date are as follows:

None previous to 1914.

To Sept. 23, 1914—53 because of decay.

Data on 1915 removals are not yet available.

TIE SERVICE TESTS ON THE CHICAGO, INDIANAPOLIS & LOUISVILLE RAILWAY.

During August, 1915, Mr. T. G. Stull, Chief Tie Inspector of the Chicago, Indianapolis & Louisville Railway Company, made an inspection of ties placed in the track during the year 1908, between milepost 120 and milepost 240 on a line between Chicago and Louisville; that is, he walked and inspected in detail ties in 120 miles in the main line. He made actual notes of 52,252 creosoted ties. All of the creosoted ties reported as laid in this track were not found, due to some removals and largely due to washouts which had taken place in this particular section several years before. Of the ties found separate records were kept for creosoted and untreated white oak. Referring to the creosoted ties, he made the following notes:

Good condition—Not rail cut more than ¼ inch—61.88 per cent....	On tangent	21,053
	On curve	11,273
	Total	32,326
Slightly rail cut, ¼ to ¾ inches—31.42 per cent..................	On tangent	10,180
	On curve	6,235
	Total	16,415
Badly rail cut, ¾ to 1½ inches—6.41 per cent..................	On tangent	1,795
	On curve	1,554
	Total	3,349
Ties that should be removed—0.29 per cent......................		152

Mr. Stull reports:

"These figures, of course, do not include ties on road and street crossings, as these could not be examined. It is also probable that not all of the 1908 treated ties had dating nails put in them, as great difficulty was experienced in getting the section men to use the dating nails properly, and, as the dating nails are the only means of identifying these ties now, any which were not dated and are still in track could not be included in the inspector's count.

"There were 1764 white oak ties found containing 1908 dating nails; condition as follows:

Good	157	Ties	9.00	per cent.
Fair	892	"	50.57	" "
Bad	715	"	40.43	" "
Total	1764	"	100.00	" "

"If we assume, as is reasonable, that these white oak ties were put in the track in 1908, it is interesting to note that over 40 per cent. of them were in bad condition as compared with only about 6 per cent. of the treated ties. We have no means of telling how many of the 1908 white oak ties have been removed.

"The white oak ties appear to be living up well to reputation of lasting from seven to nine years, but the treated red oak tie of the same size is outlasting them considerably under similar conditions. A white oak tie with sapwood on corners and face begins to show decay in a few years, and, after four or five years, the sapwood sloughs off, leaving the inner harder wood, which will usually last three or four years. The sapwood on the treated red oak tie remains intact, giving a full-sized tie for a much longer period.

"Treated ties placed in the track in 1908 included nearly all kinds of timber produced along our lines—red oak, hickory, ash, beech, sugar elm, black gum, sweet gum, chestnut, white walnut, pine and soft maple—all being used. Very few show any external evidence of decay and only 19 ties show fungus growths. The principal apparent defect, rail cutting, may, in some measure, be due to the interior decay not evident on the surface, which is more thoroughly impregnated with the preservative oil.

"Red oak ties show less rail wear than any of the others, hickory, ash, beech and sugar elm following in the order named. The other treated woods are cut more severely, nearly three-fourths of the badly cut ties being of these softer woods. The hickory and ash ties season check and split.

"Where the harder ties are distributed sparingly among the softer woods, the former, having to bear more than their share of service, are cutting badly with the latter and noticeably worse than where hard ties are laid in entire panels. The same condition applies where new ties are distributed sparingly among old, badly worn ones.

"Ties are cutting worse on curves than on tangent, worse on grades than on level track and much worse on curved grade. Where tie plates are used, either on tangent or curve, the wear on the ties is noticeably less, especially on curves where the canting of the rail, when no tie plates are used, necessitates frequent pulling of spikes and re-adzing and soon destroys the ties. White oak ties are recommended for curves which are not tie plated, as these will probably last as long as the treated tie, the severe mechanical wear destroying the usefulness of either before they have time to decay. While tie plates will not eliminate this trouble entirely, they will assist materially.

"Cutting of both hard and soft wood treated ties on tangent track is due in some cases to loose spikes, low joints and poor drainage, but the cutting of the softwood ties in most places apparently can be attributed only to their inherent inability to stand up under present large power and equipment.

"About 68 per cent. of the 1908 treated ties are estimated to have been pole ties. These are in as good condition as squared hewn ties of the same face and thickness, but not quite so good as the sawed ties.

"The 1908 ties will not grade nearly so well in size as the ties received since 1910, containing many more thin, narrow-faced ties, which rail-cut much more readily.

"Section foremen report that more treated ties were removed from the track the first two or three years that treated ties were used than later, that some of them broke when unloading and some at the rail bearing after short service. These ties were undoubtedly defective when treated."

The creosoted ties referred to were treated by the Lowry process with a net average retention of 2½ gallons per tie. It is of interest to note that of the ties now in the track only .29 per cent. of the creosoted ties are marked as being unfit for further service at the end of the year, while over 40 per cent. of the white oaks are marked as unfit for further service.

SERVICE TESTS OF TIES IN THE CENTRAL RAILROAD COMPANY OF NEW JERSEY.

RECORD NO. 1.

In 1876 about 5000 creosoted ties were laid in the tracks of this railroad west of Boundbrook, N. J. The ties were creosoted at Elizabethport, N. J. The details of treatment, absorption and quality of preservative are not available. No tie plates were used on these ties. It was at one time thought that these ties were cedar and cypress, but this is not certain. It is possible that they may have been pine.

None of the ties were removed until 1888, when about 10 per cent. were taken out of the track. A few were then removed each year until in the summer of 1895, when the last ones were taken out. The ties gave very good satisfaction, as is shown by the length of time they were in service. The greatest difficulty experienced was in cutting down under the rail on account of the soft quality of the wood.

RECORD NO. 2.

In 1879 a number of ties were placed in the main tracks of this road in Pennsylvania. The number originally placed cannot be stated. Examinations made of these ties of late years indicate that the timber was probably a quick-growing coarse-grained Pennsylvania pine. The ties were creosoted at the Elizabethport plant, but the details of absorption, quality of preservative, method of treatment, etc., are not available. A number of these ties were removed in 1909 for examination, and all of them were removed by 1913. Those removed in 1909 and later show no evidence of decay. They had been adzed down considerably on account of rail cutting, and also because of renewals of rails having been made with various sizes of rails. The average life of these ties is stated to have been 15½ years.

REPORT OF COMMITTEE IV—ON RAIL.

J. A. Atwood, *Chairman;*
E. B. Ashby,
A. S. Baldwin,
J. B. Berry,
Chas. S. Churchill,
W. C. Cushing,
G. M. Davidson,
Dr P. H. Dudley,
C. F. W. Felt,
L. C. Fritch,
A. W. Gibbs,
C. W. Huntington,
John D. Isaacs,
R. Montfort, *Vice-Chairman;*
Howard G. Kelley,
C. F. Loweth,
H. B. MacFarland,
C. A. Morse,
J. R. Onderdonk,
J. P. Snow,
F. S. Stevens,
A. W. Thompson,
Robert Trimble,
Geo. W. Vaughan,
M. H. Wickhorst,
Committee.

To the Members of the American Railway Engineering Association:

The subjects assigned by the Board of Direction for investigation and report are as follows:

1. *Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.*
2. *Report on rail failures, statistics and conclusions.*
3. *Report on effect on rail of defective equipment and improper maintenance.*
4. *Continue special investigations of rails.*
5. *Track bolts and nutlocks.*

Meetings were held during the year 1915 as follows: Pittsburgh, April 20, with 9 present; New York, June 21, with 15 present; Pittsburgh, October 26, with 15 present; jointly with the rail manufacturers at Pittsburgh, October 27, with 14 representatives of the Rail Committee and 6 representatives of the manufacturers; Chicago, December 14, with 9 present.

(1) REVISION OF MANUAL.

Your Committee has no changes to suggest in the chapter on Rail, as shown in the 1915 Manual, at the present time.

By reference to the recommendations, it will be noted that certain specifications now embodied in the Manual under the chapter on Track are to be withdrawn and those submitted in this report substituted, if approved by the Association.

(2) RAIL FAILURES, STATISTICS AND CONCLUSIONS.

The statistics covering rail failures for the period ending October 31, 1914, were issued in Bulletin 179 for September, 1915. (See Appendix B.) They show a decrease in the number of failures of rails rolled in successive years since 1908, as indicated by the figures showing the failures of open-hearth rails rolled by all the mills, expressed as number of failures per 10,000 tons of rail laid.

Year		—Years of Service of Rails—				
Rolled	0 Year	1 Year	2 Years	3 Years	4 Years	5 Years
1908	..	...	...	...	...	268.9
1909	..	...	...	...	109.0	141.7
1910	..	...	...	57.6	76.3	...
1911	..	...	37.4	58.8	...	...
1912	..	18.4	20.1	...	...	...
1913	1.2	7.9	...	...	...	...
1914	0.8	...	...	...	...	...

The final basis of comparison is the number of failures per 10,000 tons for five years' service, but when this age has not been reached for the later rollings, a comparison can be made in the meantime on a less number of years' service, and a study of this table indicates an improvement for the successive years' rollings as compared with the rollings of previous years.

The statistics for the year 1915 are in process of compilation. The basis of comparison has also been changed from "failures per 10,000 tons of rail laid" to "failures per 100 track miles of rail laid," and the next report will be on this basis.

(3) EFFECT ON RAILS OF DEFECTIVE EQUIPMENT AND IMPROPER MAINTENANCE.

This subject was assigned with the object of determining the effect of bad spots in wheels on rails with a view to having the allowable defects in wheels changed if found to be necessary, and experiments in that line are being considered. This is rather a complex subject and we are unable to make any definite report until such time as the Joint Committee on Stresses in Railroad Track is prepared to go extensively into the matter of making experiments to develop just what the effect of bad flat spots on wheels is on the rail.

(4) SPECIAL INVESTIGAGTIONS OF RAILS.

During the year special reports have been presented to the Rail Committee as follows:

No. 49. Segregation and Sponginess in Ladle Test Ingots. By Robert W. Hunt & Co. (Bulletin 179.) See Appendix C.

No. 50. Influence on Rails of Method of Blooming. By M. H. Wickhorst. (Bulletin 179.) See Appendix D.

No. 51. American Rail Mill Practice. By Sub-Committee on Mill Practice, Charles S. Churchill, Chairman. (Bulletin 183.) See Appendix E.

No. 52. Internal Fissures in Rails. By Sub-Committee, W. C. Cushing, Chairman. (Bulletin 184.) See Appendix F.

No. 53. Some Causes of Rail Failures. By W. C. Cushing. (Bulletin 185.) See Appendix G.

No. 54. The Nick and Break Test in the Inspection of Steel Rails. By Robt. W. Hunt and C. W. Gennet, Jr. See Appendix H.

The paper on Ladle Test Ingots calls attention to the importance of obtaining the test ingots free from sponginess, if it is to correctly represent the composition of the steel in the heat. A spongy test ingot is apt to be of very heterogeneous composition, and aluminum is suggested as a desirable addition to the test ingot to prevent sponginess in it.

The paper on Methods of Blooming is a contribution to the study by the experimental method, of the influence of various methods of rolling the bloom, on the properties of the rails and the production of seams. Taking the country as a whole, a large proportion of the rail failures originate from seams in the base of the rail or from low transverse ductility in the base. This is a rather difficult field to work in and will require a great amount of experimental work, but improvement of rails along the directions mentioned can be expected to materially reduce rail breakages.

The paper on Rail Mill Practice covers a report of a Sub-Committee that visited the different rail mills of the country. Brief descriptions are given of the several rail plants; representative analyses are presented of the materials used; comparisons are made of each of the stages of manufacture; attention is called to the changes and improvements made in the last few years, and finally a discussion is given of the relation of mill practice to rail failures.

The paper on Internal Fissures in Rails covers a report of a Sub-Committee concerning particularly the state of information on this subject. The different types of internal fissure are discussed and a bibliography of the subject is given. From the study of a large number of chemical examinations made by the Altoona Laboratory it appeared that transverse fissures occur indiscriminately in the several rails of the ingot and that segregation is not an important factor in causing the fissures.

Mr. Cushing's paper on Causes of Rail Failures presents a large number of illustrations of the different types of failures, gives tabulations and diagram of results of tests and a discussion of the causes of the failures.

The paper by Messrs. Hunt and Gennet gives the results of experience with the inspection of rails by the "nick and break test" of a rail from each ingot, and in which segregation is judged by the appearance of the fracture. It is concluded that this method of inspection insures greater protection to the purchaser of rails and better conserves the interests of the maker of the rails.

(5) TRACK BOLTS AND NUT LOCKS.

This subject has had the attention of the Committee, and we submit below specifications for "Medium Carbon Steel Track Bolts with Nuts," and specifications for "Quenched Carbon and Quenched Alloy Steel Track Bolts with Nuts." These specifications are recommended to supersede those now in the Manual. Some attention has been given to the matter of specifications for spiral spring nut locks or spring washers for track bolts, but the Committee is not yet prepared to recommend new specifications to supersede those in the Manual.

SPECIFICATIONS FOR JOINT BARS.

The Manual now contains "Specifications for Heat Treated, Oil Quenched, Steel Joint Bars," which the Committee has thought should be revised so as to provide more satisfactorily for bars when made of alloy steel, and submits such revised specifications below. These specifications also call for carbon limits and a slight increase in elongation, together with a few other changes.

FUTURE WORK.

An outline is here given of the general lines of work which we think our Committee should continue to cover.

1. *Continue investigation of causes of rail failures.*

Our knowledge of the causes of the different types of failure has been put on a much more satisfactory and definite basis than existed a few years ago and some remedies are in progress of being applied. Much still remains to be done, particularly as to transverse fissures, a type of failure that has recently become prominent, and, of course, a thorough knowledge of causes must precede the adoption of effective means for applying remedies.

2. *Continue research concerning details of manufacture as they affect rail quality.*

Our work has consisted largely of such investigations, which have added to the knowledge of the rail mills as well as of the railroads, and this should continue to be the important feature of our work. While we probably cannot (and possibly also should not) take part directly in the improvement of methods of manufacture, still such investigations as referred to serve as a basis and an incentive for improvement work by the mills, which finally results in improved rails.

3. *Continue investigation and development of methods of inspection.*

The various investigations have been useful toward improving methods of rail inspection and this work should continue so as to more effectively prevent the acceptance of undesirable rails.

4. *Continue reports on Rail Mill Practice.*

Our recent comparison of rail mill practice has shown that betterments have been made in recent years and these comparisons should be continued in order to bring out the best practices in each detail of rail manufacture in so far as the quality of the rail is affected.

5. *Continue reports on Rail Failure Statistics.*

These statistics have given useful comparisons of the performance of rails from different mills, and they should be continued so as to maintain a healthy effort to continually improve the rail product.

6. *Keep in touch with the Federal and State Commissions.*

Several Federal and State bodies are giving considerable attention to accidents caused by broken rails and the Rail Committee should keep in touch with their investigations and reports.

RECOMMENDATIONS.

Your Committee submits the following recommendations for the approval of the Association:

1. That the Specifications for Quenched Carbon and Quenched Alloy Steel Joint Bars recommended above be adopted by the Association and that they be substituted in the Manual for the present Specifications for Heat Treated, Oil Quenched, Steel Joint Bars.

2. That the Specifications for Medium Carbon Steel Track Bolts with Nuts recommended above be adopted by the Association.

3. That the Specifications for Quenched Carbon and Quenched Alloy Steel Track Bolts with Nuts recommended above be adopted by the Association.

4. That these two specifications for track bolts be inserted in the Manual to supersede the Track Bolt Specifications now in the Manual.

Respectfully submitted,

COMMITTEE ON RAIL.

Appendix A.

SPECIFICATIONS FOR QUENCHED CARBON AND QUENCHED ALLOY STEEL JOINT BARS.

Access to Works.

1. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the joint bars have been made in accordance with the terms of the specifications.

Place for Tests.

2. All tests and inspection shall be made at the place of manufacture, prior to loading, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

Rejection at Destination.

3. Joint bars which show injurious defects subsequent to their acceptance at the place of manufacture or sale will be rejected and returned to the manufacturer, who must pay the freight charges both ways.

Material.

4. Material for joint bars shall be steel made by the Open-Hearth process or an acceptable alloy steel.

Chemical Properties.

5. The chemical composition of each melt of steel from which joint bars are manufactured shall be within the following limits:

Carbon, per cent	0.42 to 0.55
Phosphorus, per cent., maximum	0.04

Note.—In the event of nickel and chromium being present to the extent of 1.00 per cent. and 0.35 per cent., respectively, these elements will be considered as the equivalent of 0.07 per cent. of carbon in the above requirements.

6. The manufacturer shall furnish the inspector a complete report of ladle analysis, showing carbon, manganese, phosphorus and sulphur content of each melt represented in the finished material. The purchaser may make check analysis from the finished material; such analysis shall conform to the requirements of Section 5.

Physical Properties and Tests.

7. Joint bars shall conform to the following physical requirements:

	Quenched Steel.	*Alloy Steel.*
(a) Tensile strength, lbs. per sq. in., minimum	100,000	110,000
(b) Yield point, lbs. per sq. in., minimum	70.000	85,000
(c) Elongation, per cent. in 2 inches, not less than	$\frac{1,600,000}{\text{Ten. Str.}}$	
Minimum, 12 per cent.		
(d) Reduction in area, per cent. not less than	$\frac{3,500,000}{\text{Ten. Str.}}$	
Minimum, 25 per cent.		

(e) Cold bending of the quenched bar without sign of fracture on the outside of the bent portion through 90 degrees around an arc, the diameter of which is three times the thickness of the test piece.

8. All test pieces shall be cut from finished bars.

(a) The tension test specimens shall be about 4¼ inches long with threaded or unthreaded ends, and with the central 2-inch length turned to a ½-inch diameter, in accordance with the form and dimensions for tension test pieces of the American Society for Testing Materials.

(b) The bend test specimens shall be ½-inch square in section or a rectangular bar ½-inch thick with two parallel faces as rolled.

(c) The yield point to be determined by strain gage.

Quenching.

9. (a) Joint bars shall be quenched in oil, or water if so specified, from a temperature of about 810 degrees Centigrade (1490 degrees Fahrenheit) and shall be kept in the bath until cold enough to be handled. A group thus treated is known as a quenching charge.

(b) Material which requires quenching in water will be acceptable at the option of the purchaser, provided it meets the requirements of the specification in all other respects.

General Requirements.

10. Joint bars shall be rolled to dimensions specified in drawing furnished by the purchaser. No variation will be allowed in the dimensions affecting the fit and the fishing spaces of the rail. The maximum camber in either plane shall not exceed 1/32-inch in 24 inches.

11. Joint bars shall be sheared to the length prescribed by the purchaser and shall not vary therefrom by more than ⅛-inch.

12. (a) All joint bars shall be punched, slotted and shaped at a temperature of not less than 800 degrees Centigrade (1470 degrees Fahrenheit).

(b) All bolt holes shall be punched in one operation without bulging or distorting the section, and the bars shall be slotted when required for spikes in accordance with the purchaser's drawing, the slotting being done in one operation. A variation of 1/32-inch in location of the holes will be allowed.

13. All types of joint bars must be finished smooth and true without swelling over or under the bolt holes, and must be free from flaws, seams, checks or fins. The fishing angles must be fully maintained.

Branding.

14. The rolled bar shall be branded or marked for identification in the following manner and a portion of this marking shall appear on each finished joint bar.

(a) A portion of the name of the manufacturer, the year of manufacture, the numbered design and the kind of material shall be rolled in raised letters and figures on the outside of the bars.

(b) The letters "O H" shall be used to indicate "Open-Hearth Steel."

(c) The letter "Q" shall be used to show that the joint bars have been "quenched." If the joint bars are also tempered, the letters "QT" shall be used to show that they have been "quenched and tempered."

(d) The number of the melt shall be plainly stenciled on each lot of bars.

Inspection.

15. The joint bars from each melt or heat treatment lot shall be piled separately until tested and inspected by the inspector. One joint bar for tension test shall be selected by the inspector for each melt or heat treatment lot represented in finished bars. One joint bar for bend test shall be selected by the inspector for each lot of 1000 bars or less presented or from each heat treatment lot.

SPECIFICATIONS FOR QUENCHED CARBON AND QUENCHED ALLOY STEEL TRACK BOLTS WITH NUTS.

Access to Works.

1. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the bolts and nuts have been made in accordance with the terms of the specifications.

Place for Tests.

2. All tests and inspection shall be made at the place of manufacture, prior to loading, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

Rejection at Destination.

3. Bolts and nuts which show injurious defects subsequent to their acceptance at the place of manufacture or sale will be rejected and returned to the manufacturer, who shall pay the freight charges both ways.

Material.

4. Material for bolts shall be made by the Open-Hearth process or an acceptable alloy steel. Material for the nuts shall be soft, untreated steel.

Chemical Properties.

5. The chemical composition of each melt of steel from which track bolts are manufactured shall be within the following limit:

Phosphorus, per cent., maximum............................0.04

6. The manufacturer shall furnish the inspector a complete report of ladle analysis showing carbon, manganese, phosphorus and sulphur content of each melt, represented in the finished material. The purchaser may make a check analysis from the finished material; such analysis shall conform to the requirements of Section 5. The drillings for check

analysis shall be taken parallel to the axis and from the end of the finished bolt.

Physical Properties and Tests.

7. Track bolts shall conform to the following physical requirements:

	Carbon Steel.	*Alloy Steel.*
(a) Tensile strength, lbs. per sq. in., minimum	100,000	110,000
(b) Yield point, lbs. per sq. in., minimum	70,000	85,000
(c) Elongation, per cent. in 2 inches, not less than	$\frac{1{,}600{,}000}{\text{Ten. Str.}}$	
Minimum, 12 per cent.		
(d) Reduction in area, per cent. not less than	$\frac{3{,}500{,}000}{\text{Ten. Str.}}$	
Minimum, 25 per cent.		

(e) Cold bending of the unthreaded portion of the finished bolt without fracture on the outside of the bent portion through 90 degrees around an arc, the diameter of which is three times the thickness of the test piece.

8. All test specimens shall be from the finished bolts.

(a) The tension test specimens shall be about 4¼ inches long with threaded or unthreaded ends, and with the central 2-inch length turned to a ½-inch diameter, in accordance with the form and dimensions for tension test pieces of the Americin Society for Testing Materials.

(b) The yield point shall be determined by the strain gage.

Quenching.

9. (a) Track bolts shall be treated by quenching in oil or water, if so specified, from a temperature of about 810 degrees Centigrade (1490 degrees Fahrenheit) and shall be kept in the bath until cold enough to be handled; a group thus treated being known as a quenching charge.

(b) Material which requires quenching in water will be acceptable at the option of the purchaser, provided it meets the requirements of the specification in all other respects.

General Requirements.

10. Track bolts and nuts shall be made to dimensions specified in drawing furnished by the purchaser with allowable variations in dimensions of bolts from standard as follows:

Length, ⅛-inch;
Diameter of shank, 1/64-inch;
Shoulder, 1/64-inch;
Diameter of rolled thread not more than 1/16-inch over the diameter of the body of ⅞-inch bolts;
Diameter of rolled thread not more than 3/32-inch over the diameter of the body of 1-inch bolts;
Variation in dimensions of elliptical shoulders under head of bolt of 1/32-inch.

11. The heads and nuts shall be free from checks or burrs of any kind. All finished pieces must be smooth, straight, of uniform size, with well-shaped symmetrical bends and well-filled heads, free from injurious mechanical defects, and be finished in a first-class workmanlike manner.

The head shall be concentric with and firmly joined to the bottom of the bolt with the underside of the head at right angles to the body of the bolt. The threads on the bolts shall be rolled. unless otherwise specified, shall be full and clean and shall be made in section and pitch according to the purchaser's standard. The fit between threads on the bolt and nut shall be accurate and nut shall go on with a 10-inch wrench from second to fifth turn. The force to turn the nut completely on the bolt with a 24-inch wrench shall not be more than 60 nor less than 40 lbs.

12. (a) The nuts shall be made of soft untreated steel and shall be ¼-inch thicker than the standard nuts used for untreated bolts. They shall be of sufficient strength to develop the ultimate breaking strength of the bolts.

(b) Nuts of standard thickness will be accepted at the option of the purchaser if proved to be of sufficient strength to equal the ultimate breaking strength of the bolts. The length of the bolts shall be correspondingly reduced.

Branding.

13. The heads of the bolts must bear the manufacturer's identification symbol. The letter "Q" shall be used to show that the bolts have been "quenched." If the bolts are also tempered, the letter "QT" shall be used to show that they have been "quenched and tempered."

Marking and Shipping.

14. When the bolts are shipped they shall have the nuts applied for at least two threads, and shall be packed in securely hooped kegs of 200 lbs. net. All kegs must be plainly marked as to material, size of bolts and name of manufacturer.

Inspection.

15. Tension and bend tests shall be made of the test pieces selected by the inspector from each lot of 50 kegs. One piece shall be selected for each test, and if it meets the requirements of the specification, the lot will be accepted. If the test piece fails, two additional pieces shall be tested in the same manner as the one which failed, and if they meet the requirements of the specification, the lot will be accepted. If, however, either one of the pieces fails, the lot will be rejected. Both tension and bend tests must pass the requirements for acceptance.

SPECIFICATIONS FOR MEDIUM CARBON STEEL TRACK BOLTS WITH NUTS.

Access to Works.

1. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the bolts and nuts have been made in accordance with the terms of the specifications.

Place for Tests.

2. All tests and inspection shall be made at the place of manufacture, prior to loading, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

Rejection at Destination.

3. Bolts and nuts which show injurious defects subsequent to their acceptance at the place of manufacture or sale will be rejected and returned to the manufacturer, who shall pay the freight charges both ways.

Material.

4. Material for bolts shall be steel made by the Open-Hearth or Bessemer process. Material for nuts shall be of soft steel.

Chemical Properties.

5. The chemical composition of each melt of steel from which track bolts are manufactured shall be within the following limits:

Phosphorus, Maximum.	Per Cent.
Open-Hearth	0.05
Bessemer	0.10

6. The manufacturer shall furnish the inspector a complete report of ladle analysis showing carbon, manganese, phosphorus and sulphur content of each melt represented in the finished material. The purchaser may make a check analysis from the finished material; such analysis shall conform to the requirements in Section 5. The drillings for check analysis shall be taken parallel to the axis and from the end of the finished bolt.

Physical Properties and Tests.

7. Track bolts shall conform to the following physical requirements:

(a) Tensile strength, lbs. per sq. in., minimum 55,000

(b) Yield point not less than 50 per cent. of the ultimate breaking stress ....

(c) Elongation, per cent. in 2 inches, not less than .... $\frac{1,500,000}{\text{Ten. Str.}}$

Minimum, 20 per cent.

(d) Reduction in area not less than .... $\frac{2,200,000}{\text{Ten. Str.}}$

Minimum, 30 per cent.

(e) Cold bending of the unthreaded part of the finished bolt without sign of fracture on the outside of the bent portion, through 180 degrees flat on itself.

8. All test specimens shall be from the finished bolts.

(a) The tension test specimens shall be about 4¼ inches long with threaded or unthreaded ends, and with the central 2-inch length turned to a ½-inch diameter, in accordance with the form and dimensions for tension test pieces of the American Society for Testing Materials.

General Requirements.

9. Track bolts and nuts shall be made to dimensions specified in drawing furnished by the purchaser, with allowable variation in dimensions of bolts from standard as follows:

Length, ⅛-inch;
Diameter of shank, 1/64-inch;
Shoulder, 1/64-inch;
Diameter of rolled thread not more than 1/16-inch over the diameter of the body of ⅞-inch bolts;
Diameter of rolled thread not more than 3/32-inch over the diameter of the body of 1-inch bolts;
Variation in dimensions of elliptical shoulders under head of bolt of 1/32-inch.

10. The heads and nuts shall be free from checks or burrs of any kind. All finished pieces must be smooth, straight, of uniform size, with well-shaped symmetrical bends and well-filled heads, free from injurious mechanical defects, and be finished in a first-class workmanlike manner. The head shall be concentric with and firmly joined to the bottom of the bolt, with the underside of the head at right angles to the body of the bolt. The thread on bolts shall be rolled, unless otherwise specified, shall be full and clean and shall be made in section and pitch according to the purchaser's standard. The fit between threads on the bolt and nut shall be accurate and nut shall go on with a 10-inch wrench from second to fifth turn. The force to turn the nut completely on the bolt with a 24-inch wrench shall not be more than 60 nor less than 40 lbs.

11. The nuts shall be made of soft, untreated steel and shall be of sufficient strength to develop the ultimate breaking strength of the bolts.

Branding.

12. Manufacturer's identification shall appear on the head of each bolt.

Marking and Shipping.

13. When the bolts are shipped they shall have the nuts applied for at least two threads and shall be packed in securely hooped kegs of 200 lbs. net. All kegs must be plainly marked as to material, size of bolts and name of manufacturer.

Inspection.

14. Tension and bend tests shall be made of the test pieces selected by the inspector from each lot of 50 kegs. One piece shall be selected for each test, and if they meet the requirements of the specifications the lot will be accepted. If one of the test pieces fails, two additional pieces shall be tested in the same manner as the one which failed, and if they meet the requirements of the specifications, the lot will be accepted. If, however, either one of the pieces fails, the lot will be rejected. Both tension and bend tests must pass the requirements for acceptance.

Appendix B.

RAIL FAILURE STATISTICS FOR 1914.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report deals with the statistics of rail failures collected for the year ending October 31, 1914, furnished by various railroads of the United States in response to a circular sent out by the American Railway Association. The information furnished by each railroad showed the number of tons laid of each year's rolling from each mill and the total number of failures that occurred in each year's rolling from the date laid until October 31, 1914.

The failures were divided into four classes, namely, head, web, base and "broken." They were reported by the railroads on American Railway Engineering Association from M. W. 408, as revised in 1913 and shown in the Proceedings for 1914, Vol. 15, after page 336. It is the same form that was used for collecting the statistics for 1913 and shown in the report covering that year. The reports cover rollings for 1909 and succeeding years, and the ages of the rollings would average in the track about the years shown below:

1909—5 years.
1910—4 years.
1911—3 years.
1912—2 years.
1913—1 year
1914—Several months.

One important purpose of these records is to show which rollings were defective and as most of the badly defective rails cause failures within a few years after being laid in track, the record was closed with a rail age of five years.

The tonnages of rail represented by the statistics in this report are shown below:

Year Rolled	Bessemer	Open-Hearth	Total
1909	421,210	514,302	935.512
1910	559,708	842,895	1,402,603
1911	233,270	630,694	863,954
1912	95,666	997,078	1,092,744
1913	72,496	1,202,060	1,274,556
1914	20,779	672,564	693,343

The failures were tabulated with reference particularly to the performance of the rails made by the different mills and were classified successively in the following order: kind of steel (Bessemer or Open-

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Hearth), mill, year rolled, weight per yard, section and railroad. The totals were figured for the groups by year rolled.

Lots of less than 1,000 tons—that is, less than 1,000 tons in any one year's rolling, were excluded from the tabulation, as they would unnecessarily extend the tables and not materially change the group totals and averages. The method of compiling the statistics was to make prints (generally blue-line whiteprints) of the reports submitted by the different railroads, after seeing that all the lines were fully filled out, and then cutting them up along the horizontal lines with a large card-cutter or trimming-board. These strips constituted the units in the tables, and after sorting in suitable order and collecting into the desired groups, the information was transcribed on a typewriter into tables, from which zinc cuts were made for printing in the report. The tabulation this year is limited to a classification by mills. It had been desired to make some other classifications, particularly a geographical one, but these were omitted for lack of sufficient appropriation for the work. For the same reason we have continued to use "failures per 10,000 tons" as the unit of comparison, instead of recalculating to "failures per 100 track miles," as we had expected to do. (Since the above was written, the tables have been calculated to "Failures per 100 Track Miles," and Table 1A is given herewith showing the summary for the various mills and years rolled. The average weights per yard are also given as Table 1B.)

FAILURES CLASSIFIED BY MILLS.

The detail tabulations by mills and years rolled are given in Table 5, Sheets 1 to 15 inclusive. A condensed table showing the failures of each year's rolling of each mill is given as Table 1. First, it is interesting to note from this table the comparative performance of Bessemer and Open-Hearth rails for the several years' rollings. Figuring the failures per 10,000 tons of Open-Hearth rails as 100 for each of the years 1909, 1910, 1911 and 1912, the relative number of failures of Bessemer rails, together with the failures per 10,000 tons, is shown below:

FAILURES OF BESSEMER AND OPEN-HEARTH COMPARED.

Year Rolled	Years Service	Failures per 10,000 Tons Open-Hearth	Failures per 10,000 Tons Bessemer	Comparative Failures Open-Hearth	Comparative Failures Bessemer
1909	5	141.7	268.7	100	190
1910	4	76.3	158.5	100	208
1911	3	58.8	113.4	100	193
1912	2	20.1	44.4	100	221

The rails for 1913 and 1914 are not included in this comparison, as they are probably too young for reliable comparison. It will be noted that the failures per 10,000 tons of Bessemer rails were about two times those of Open-Hearth rails.

RANKING OF MILLS.

In order to show more conveniently the relative number of failures from each of the mills and to show the ranking of the mills as regards the failure performance of the rails rolled by them, table 2 has been prepared. Taking the average number of failures per 10,000 tons of all the mills in any year's rolling as 100, the relative number of failures of each of the mills is shown for the years 1909, 1910, 1911 and 1912. The later rollings are not included because of being too young. The rank of each mill is also shown for each year's rolling.

COMPARISON WITH PREVIOUS YEAR.

One important purpose of these statistics is to enable comparisons to be made of the performance of rail rolled from year to year, and tables 3 and 4 are given, showing the general records for the years 1913 and 1914, one table for Bessemer rails and the other for Open-Hearth rails. The final comparison is made on the basis of five years' service, but before the closing of the record of any year's rolling, a comparison can be made on the performance of a less number of years in service. In general, the figures in these tables are consistent among themselves, but the 1912 rolling of Bessemer rails by the Illinois Steel Co. is a notable exception, as this showed less failures per 10,000 tons for two years' service than for one year. A comparison of this year's record with last year's shows the discrepancy in this case to be due to the absence, this year, of the record of the C. & N. W. Ry., which showed a large number of failures for this rolling.

The records are closed for the 1908 and 1909 rollings. The 1909 rails showed as a general average for all mills, a lower rate of failures than the 1908 rails, and it is gratifying to note that the later rollings also show a tendency toward continued improvement as a general average.

SUMMARY.

1. Statistics are given of rail failures collected for the year ending October 31, 1914, furnished by various railroads of the United States in response to a circular sent out by the American Railway Association. The information furnished by each railroad showed the number of tons laid of each year's rolling from each mill, and also showed the total

number of failures that occurred in each year's rolling from the date laid until October 31, 1914.

2. The basis of comparison is the number of failures per 10,000 tons laid that occurred in each year's rolling from date laid until October 31, 1914. The average failures per 100 track miles are also given.

3. As a general average, the failures per 10,000 tons of Bessemer rails were about two times those of Open-Hearth rails.

4. A table is given showing the ranking of the mills as regards rate of rail failures for the rollings of the years 1909, 1910, 1911 and 1912.

5. A comparison with last year's statistics indicates, as a general average of all the mills, a gradual decrease in the rate of rail failures of rollings for the successive years since 1908, with which year's rolling the records started.

Table 1B

AVERAGE WEIGHTS OF RAILS

Compiled from Tonnages Used in This Report

Mill	1909	1910	1911	1912	1913	1914
BESSEMER RAIL						
Cambria	91.9	95.1	88.0	87.8	86.5	85.0
Carnegie	91.7	90.2	92.1	100.0	96.3	100.0
Illinois	86.5	88.0	83.0	77.3	88.0	
Lackawanna	89.3	87.9	91.3	89.6	90.0	90.0
Maryland	87.4	88.6	91.0	92.3	98.7	94.2
Average	88.6	88.9	89.5	90.6	95.7	93.4
OPEN HEARTH RAIL						
Bethlehem	91.2	90.9	92.7	94.2	95.6	95.7
Cambria	90.6	96.6	91.7	96.0	90.6	98.4
Carnegie	93.5	88.9	95.6	95.1	96.9	97.0
Colorado	88.6	88.5	89.0	88.6	89.0	89.8
Illinois	89.9	90.0	90.3	91.1	92.1	92.6
Lackawanna	89.0	92.0	90.6	92.3	94.7	99.8
Maryland		85.6	91.3	87.1	92.3	91.3
Pennsylvania	92.3	90.4	97.0	92.6	96.7	95.3
Tennessee	83.7	85.4	85.1	86.8	87.7	88.3
Average	89.2	89.2	90.4	91.4	92.2	92.5

Table 1

Summary Showing Tons Of Rail, Total Failures and Failures Per 10,000 Tons By Years

For Period Ending October 31st, 1914

Manufacturer	1909			1910			1911			1912			1913			1914		
		Failures			Failures			Failures			Failures			Failures			Failures	
	Tons	Total	Per 10 M Tons	Tons	Total	Per 10 M Tons	Tons	Total	Per 10 M Tons	Tons	Total	Per 10 M Tons	Tons	Total	Per 10 M Tons	Tons	Total	Per 10 M Tons
BESSEMER																		
Cambria,	24,848	561	226.0	24,842	491	197.7	8,769	99	112.8	5,027	43	112.9	3,385	1	3.0	1,544	0	0.0
Carnegie,	78,980	6851	866.0	119,468	3040	254.6	64,124	554	86.4	4,098	19	46.4	33,537	35	10.4	2,425	0	0.0
Illinois,	145,120	1803	124.2	162,049	2301	141.9	47,306	694	146.7	8,359	9	10.7	4,507	1	2.2	-	-	-
Lackawanna,	106,241	789	74.2	190,097	2399	126.2	61,747	1132	183.3	14,071	112	79.6	4,160	0	0.0	3,320	0	0.0
Maryland,	66,021	1312	198.7	63,252	643	101.6	51,324	167	32.5	64,111	242	37.7	26,907	103	38.2	13,490	3	2.2
Totals,	421,210	11316	268.7	559,708	8874	158.5	233,270	2646	113.4	95,666	425	44.4	72,496	140	19.3	20,779	3	1.4
OPEN HEARTH																		
Bethlehem,	68,344	2532	370.4	84,237	1444	171.4	89,152	1195	134.0	90,238	195	21.6	128,114	114	8.8	50,040	0	0.0
Cambria,	11,522	264	229.1	24,589	221	89.9	38,946	341	87.5	84,163	233	27.7	82,709	155	18.7	36,530	4	1.1
Carnegie,	18,898	177	93.6	27,967	226	80.7	42,206	306	72.5	95,232	197	20.6	96,159	56	5.8	39,423	2	0.5
Colorado,	72,442	178	24.6	156,086	262	16.7	92,047	204	22.2	142,581	419	29.4	136,272	38	2.8	83,552	6	0.7
Illinois,	206,535	3213	155.6	301,778	2917	96.6	142,895	946	66.2	219,441	355	16.2	273,574	189	6.9	159,053	11	0.6
Lackawanna,	14,599	123	84.2	30,905	193	62.4	59,580	239	40.1	152,769	212	13.9	159,846	185	11.6	62,472	1	0.2
Maryland,	-	-		29,530	230	77.8	52,162	180	34.5	9,497	4	4.2	40,523	80	19.7	38,688	3	0.8
Pennsylvania,	41,909	293	69.9	64,163	501	78.1	24,876	130	52.3	73,645	79	10.7	89,466	57	6.3	29,898	5	1,6
Tennessee,	80,053	509	63.8	123,640	441	35.7	88,830	167	18.8	129,512	312	24.1	195,397	81	4.1	172,908	21	1.2
Totals,	514,302	7289	141.7	842,895	6435	76.3	630,694	3708	58.8	997,078	2006	20.1	1202,060	955	7.9	672,564	53	0.8

Table 1A

Summary Showing Track Miles of Rail, Total Failures and Failures per 100 Track Miles

GROUPED BY MILLS AND YEARS

Mill	1909			1910			1911			1912			1913			1914		
	Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures	
		Total	per 100 Trk Mls		Total	per 100 Trk Mls		Total	per 100 Trk Mls		Total	per 100 Trk Mls		Total	per 100 Trk Mls		Total	per 100 Trk Mle
BESSEMER RAIL																		
Cambria	172.15	561	325.9	166.18	491	295.4	63.39	99	157.6	36.44	43	118.0	24.89	1	4.0	11.56	0	0.0
Carnegie	548.27	6,851	1,249.0	842.33	3,040	361.0	443.29	554	125.0	26.08	19	72.9	221.59	35	15.8	15.43	0	0.0
Illinois	1068.00	1,803	168.8	1171.79	2,301	196.4	362.87	694	191.3	68.28	9	13.1	32.58	1	3.1			
Lackawanna	756.63	789	104.3	1375.61	2,399	174.4	430.13	1,132	263.2	99.26	112	112.1	29.41	0	0.0	23.47	0	0.0
Maryland	480.98	1,312	272.8	454.51	643	141.5	358.55	167	46.6	441.85	242	54.8	173.48	103	59.4	91.08	3	3.3
Totals	3026.03	11,316	373.9	4010.42	8,874	221.3	1658.23	2,646	159.6	671.91	425	63.3	481.95	140	29.1	141.64	3	2.1
OPEN HEARTH RAIL																		
Bethlehem	476.96	2,532	530.9	589.38	1,444	245.0	611.78	1,195	195.3	609.15	195	32.0	852.84	114	13.4	332.76	0	0.0
Cambria	80.83	264	326.6	162.01	221	136.4	270.30	341	126.1	557.73	233	41.8	579.71	155	26.7	236.22	4	1.7
Carnegie	128.54	177	137.7	200.21	226	112.9	280.95	306	108.9	637.58	197	30.9	632.00	56	8.9	258.62	2	0.8
Colorado	520.52	178	34.2	1121.92	262	23.4	657.89	204	31.0	1023.45	419	40.9	974.82	38	3.9	591.99	6	1.0
Illinois	1462.70	3,213	219.7	2134.31	2,917	136.8	1006.79	946	94.0	1532.36	355	23.2	1889.75	189	10.0	1073.81	11	1.0
Lackawanna	104.43	123	117.8	213.72	193	90.3	418.81	239	57.1	1053.31	212	20.1	1074.17	385	17.2	398.49	1	0.3
Maryland				219.47	230	104.8	363.92	180	49.5	69.45	4	5.8	279.39	80	28.6	269.76	3	1.1
Pennsylvania	288.99	293	101.4	451.82	501	110.9	163.26	130	79.6	506.28	79	15.6	592.46	57	9.6	199.75	5	2.5
Tennessee	608.39	509	83.7	921.59	441	47.8	664.65	167	25.1	949.38	312	32.9	1418.35	81	5.7	1245.40	21	1.7
Totals	3671.36	7,289	198.5	6014.43	6,435	107.1	4438.35	3,708	83.5	6938.69	2,006	28.9	8293.49	955	11.5	4626.80	53	1.1

Table 2

Comparison of Failures for the Different Mills, using 100 as the Average of Failures of all Mills for Each Year's Rolling.

Mill	1909		1910		1911		1912	
	Relative Failures	Rank	Relative Failures	Rank	Relative Failures	Rank	Relative Failures	Rank
BESSEMER								
Maryland	73.9	3	64.1	1	28.7	1	84.9	2
Illinois	46.2	2	89.5	3	129.4	4	24.1	1
Lackawanna	27.6	1	79.6	2	161.6	5	179.3	4
Cambria	84.1	4	124.7	4	99.5	3	254.3	5
Carnegie	322.3	5	160.0	5	76.2	2	104.5	3
OPEN HEARTH								
Colorado	17.4	1	21.8	1	37.8	2	146.3	9
Maryland	-	-	101.9	4	58.7	3	20.9	1
Tennessee	45.0	2	46.8	2	32.0	1	119.9	7
Lackawanna	59.4	4	81.8	3	68.2	4	69.2	3
Pennsylvania	49.3	3	102.4	5	88.9	5	53.2	2
Carnegie	66.1	5	105.8	6	123.3	7	102.5	5
Illinois	109.8	6	126.6	8	112.6	6	80.6	4
Cambria	161.7	7	117.8	7	148.8	8	137.8	8
Bethlehem	261.8	8	224.6	9	227.9	9	107.5	6

NOTE.-- These figures are not related to geographical or service conditions.

Table 3

Failures For Various Ages Of Rail
Per 10,000 Tons Laid.

BESSEMER

Year Rolled	Years Service											
	0	1	2	3	4	5	0	1	2	3	4	5
	ALGOMA						CAMBRIA					
1908						512.1						94.2
1909					251.0						222.5	226.0
1910				282.8						139.0	197.7	
1911			256.3						43.5	112.8		
1912		117.1						18.6	112.9			
1913	-						0.0	3.0				
1914							0.0					
	CARNEGIE						ILLINOIS					
1908						301.5						364.8
1909					716.0	866.0					105.7	124.2
1910				194.3	254.6					132.0	141.9	
1911			57.5	86.4					79.9	146.7		
1912		12.2	46.4					32.7	10.7			
1913	5.7	10.4					2.2	2.2				
1914	0.0						-					
	LACKAWANNA						MARYLAND					
1908						338.3						162.3
1909					38.4	74.2					194.9	198.7
1910				87.8	126.2					76.2	101.6	
1911			152.2	183.3					21.5	32.5		
1912		6.2	79.6					34.5	37.7			
1913	0.0	0.0					0.6	38.2				
1914	0.0						2.2					
	ALL MILLS											
1908						302.1						
1909					212.4	268.7						
1910				132.1	158.5							
1911			94.2	113.4								
1912		40.5	44.4									
1913	3.6	19.3										
1914	1.4											

Table 4

Failures For Various Ages Of Rail Per 10,000 Tons Laid.

OPEN HEARTH

Year Rolled	Years Service											
	0	1	2	3	4	5	0	1	2	3	4	5
	ALGOMA						BETHLEHEM					
1908						361.5						360.6
1909					151.2						325.3	370.4
1910				308.6						116.8	171.4	
1911			164.5						77.0	134.0		
1912		92.9						7.9	21.6			
1913	-						1.1	8.8				
1914							0.0					
	CAMBRIA						CARNEGIE					
1908						-						-
1909					172.1	229.1					70.5	93.6
1910				65.1	89.9					55.4	80.7	
1911			50.9	87.5					47.7	72.5		
1912		11.3	27.7					8.3	20.6			
1913	5.0	18.7					1.6	5.8				
1914	1.1						0.5					
	COLORADO						DOMINION					
1908						32.4						1062.3
1909					16.1	24.6					204.1	
1910				14.0	16.7					621.8		
1911			11.3	22.2					184.9			
1912		13.2	29.4					319.0				
1913	0.9	2.8					-					
1914	0.7											
	ILLINOIS						LACKAWANNA					
1908						-						96.5
1909					107.5	155.6					71.6	84.2
1910				62.2	96.6					29.7	62.4	
1911			46.6	66.2					20.6	40.1		
1912		5.1	16.2					3.3	13.9			
1913	0.8	6.9					1.4	11.6				
1914	0.6						0.2					
	MARYLAND						PENNSYLVANIA					
1908						-						49.9
1909					-						59.3	69.9
1910				51.7	77.8	-				57.4	78.1	
1911			23.0	34.5					22.9	52.3		
1912		7.6	4.2					3.7	10.7			
1913	0.6	19.7					0.7	6.3				
1914	0.8						1.6					
	TENNESSEE						ALL MILLS					
1908						63.1						268.9
1909					8.4	63.8					109.0	141.7
1910				24.8	35.7					57.6	76.3	
1911			11.6	18.8					37.4	58.8		
1912		5.5	24.1					18.4	20.1			
1913	1.1	4.1					1.2	7.9				
1914	1.2						0.8					

Table 5 - Sheet 1

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
					Bessemer - CAMBRIA STEEL COMPANY							
1909	85	ASCE	.43	.53	1,338	2	1	-	10	13	97.2	Southern
	85	P.S.	.45	.55	2,223	2	2	2	8	14	62.9	G.R.&I.
	85	P.S.	.45	.55	4,919	34	16	2	9	61	124.0	P.R.R.
	90	ARA-B	.45	.55	2,833	216	13	7	63	299	1055.4	B.&O.
	90	ARA-B	-	.50	1,210	4	-	-	3	7	57.9	H.V.
	90	ASCE	-	-	2,400	22	2	1	-	25	104.2	K.&M.
	100	P.S.	.45	.55	9,925	89	23	-	30	142	143.1	P.R.R.
		Totals			24,848	369	57	12	123	561	226.0	
1910	85	P.S.	.45	.55	1,713	-	2	-	15	17	99.2	G.R.&I.
	85	P.S.	.45	.55	1,607	3	6	-	2	11	68.5	P.R.R.
	90	ARA-B	.45	.55	4,180	86	14	1	57	158	378.0	B.&O.
	90	ASCE	.50	.60	2,000	7	-	2	11	20	100.0	P.&R.
	100	ARA-B	.46	.56	2,110	51	2	1	14	68	322.2	B.&O.
	100	P.S.	.45	.55	11,217	112	25	-	26	163	145.3	P.R.R.
	100	P.S.	.45	.55	2,015	33	7	-	14	54	268.0	Pa.-S.W.
		Totals			24,842	292	56	4	139	491	197.7	
1911	85	ASCE	.43	.53	2,989	17	1	4	4	26	87.0	Southern
	90	ASCE	.43	.53	5,780	67	3	2	1	73	126.3	K.&M.
		Totals			8,769	84	4	6	5	99	112.8	
1912	85	P.S.	.45	.55	1,002	-	-	-	1	1	10.0	G.R.&I.
	85	P.S.	.45	.55	1,162	4	1	1	3	9	77.0	Pa.-N.W.
	90	ASCE	.43	.53	2,863	33	-	-	-	33	115.3	K.&M.
		Totals			5,027	37	1	1	4	43	112.9	
1913	85	ASCE	.43	.53	2,298	-	1	-	-	1	4.4	Southern
	90	ASCE	.43	.53	1,087	-	-	-	-	0	0.0	K.&M.
		Totals			3,385	-	1	-	-	1	3.0	
1914	85	ASCE	.43	.53	1,544	-	-	-	-	0	0.0	Southern
					Bessemer - CARNEGIE STEEL COMPANY							
1909	75	M.P.	-	-	2,143	10	5	-	9	24	112.0	St.L.S.W.
	85	ASCE	-	-	1,060	8	-	-	-	8	75.5	C.H.&D.
	85	ASCE	-	-	4,000	-	-	-	-	0	0.0	C.&O.
	85	D&RG	-	.48	10,027	257	6	-	43	306	305.2	D.&R.G.
	85	P.S.	.45	.55	1,966	260	13	4	14	291	1480.2	Pa.-S.W.
	85	P.S.	.45	.55	4,109	1064	114	12	61	1251	3045.0	Pa.-N.W.
	90	ARA-B	.45	.55	16,584	2732	72	11	115	2930	1766.7	B.&O.
	90	ARA-B	-	.50	1,050	158	16	7	24	205	1952.4	H.V.
	90	ASCE	.45	.55	5,077	818	31	15	120	984	1938.1	Erie
	100	ARA-A	.46	.56	2,120	91	2	3	2	98	462.2	B.&O.
	100	ARA-A	.45	.55	1,535	169	10	-	5	184	1198.6	Pa.-S.W.
	100	ARA-B	.50	.60	3,150	26	6	-	47	79	250.8	B.&L.E.
	100	ARA-B	.48	.58	5,886	5	11	9	12	37	62.9	P.&L.E.
	100	ARA-B	.48	.58	4,147	13	4	-	17	34	82.0	P.&L.E.*
	100	P.S.	.45	.50	9,514	177	27	7	98	309	325.0	Pa.-N.W.
	100	P.S.	.45	.55	6,612	71	13	-	27	111	167.9	Pa.-S.W.
		Totals			78,980	5859	330	68	594	6851	866.0	
1910	80	ASCE	.45	.55	1,349	27	4	-	2	33	244.6	P.&L.E.
	85	ASCE	-	-	4,540	6	-	-	2	8	17.6	C.H.&D.
	85	P.S.	.45	.55	8,745	38	4	-	10	52	60.0	Pa.-N.W.
	85	P.S.	.45	.55	27,637	663	78	19	116	876	317.0	Pa.-S.W.
	85	P.S.	.45	.55	3,484	16	2	1	8	27	77.5	Vandalia
	90	ARA-A	.45	.55	3,175	79	16	25	140	260	818.9	B.&O.
	90	ARA-B	.45	.55	13,679	404	34	7	148	593	433.5	B.&O.
	90	ARA-B	.45	.55	11,758	288	31	8	31	358	304.5	N.P.
	90	ASCE	.45	.55	8,343	162	22	16	88	288	345.1	Erie
	90	ASCE	.50	.60	1,300	14	2	-	6	22	169.2	P.&R.
	90	ASCE	.46	.56	1,200	20	1	-	12	33	275.0	W.&L.E.
	100	ARA-B	.50	.60	7,380	108	14	-	138	260	352.3	B.&L.E.
	100	ARA-B	.48	.58	9,670	15	15	13	26	69	71.4	P.&L.E.
	100	ARA-B	.48	.58	1,880	1	1	-	-	2	10.6	P.&L.E.*
	100	P.&R.	.50	.60	3,700	47	2	-	6	55	148.6	P.&R.
	100	P.S.	.45	.50	5,997	2	1	-	5	8	13.0	Pa.-N.W.
	100	P.S.	.45	.55	5,631	31	5	-	60	96	170.5	Pa.-S.W.
		Totals			119,468	1921	232	89	798	3040	254.6	

PMcK&YDiv*

Table 5 - Sheet 2

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
Bessemer - CARNEGIE STEEL COMPANY - Continued												
1911	80	ASCE	.43	.53	3,174	-	2	1	5	8	25.2	T.&O.C.
	85	P.S.	.45	.55	3,349	12	3	5	33	53	158.0	Pa.-N.W.
	85	P.S.	.45	.55	6,652	21	1	-	10	32	48.1	Pa.-S.W.
	90	ARA-A	.45	.55	3,037	6	13	-	5	24	78.9	B.&O.
	90	ARA-B	.45	.55	5,707	24	11	-	48	83	145.6	B.&O.
	90	ARA-B	.45	.55	2,700	3	-	2	5	10	37.0	N.P.
	90	ASCE	.45	.55	15,342	113	10	7	86	216	140.8	Erie
	100	ARA-B	.50	.60	3,250	6	-	-	5	11	33.8	B.&L.E.
	100	ARA-B	.48	.58	2,882	-	5	-	2	7	24.3	P.&L.E.
	100	ARA-B	.48	.58	2,594	7	3	-	4	14	54.0	P.&L.E.*
	100	P.S.	.45	.50	10,955	6	3	5	17	31	28.0	Pa.-N.W.
	100	P.S.	.45	.55	4,482	15	2	1	47	65	145.0	Pa.-S.W.
		Totals			64,124	213	53	21	267	554	86.4	
1912	100	ARA-B	.50	.60	4,098	5	-	-	14	19	46.4	B.&L.E.
1913	85	P.S.	.45	.55	5,162	2	1	-	2	5	10.0	Pa.-N.W.
	85	P.S.	.45	.55	2,111	8	1	-	7	16	75.8	Pa.-S.W.
	100	ARA-B	.50	.60	6,865	6	-	-	3	9	13.1	B.&L.E.
	100	P.S.	.45	.50	10,127	-	-	-	1	1	1.0	Pa.-N.W.
	100	P.S.	.45	.55	9,272	1	1	-	2	4	4.3	Pa.-S.W.
		Totals			33,537	17	3	-	15	35	10.4	
1914	100	P.S.	.45	.55	2,425	-	-	-	-	0	0.0	Pa.-S.W.
Bessemer - ILLINOIS STEEL COMPANY												
1909	75	ASCE	.40	.50	2,886	9	4	13	150	176	609.8	C.I.&L.
	75	CS	.45	.55	12,043	2	2	1	4	9	7.5	St.J.&GI
	75	MP	-	-	3,996	-	-	-	-	0	0.0	St.L.S.W.
	80	ARA-A	.40	.50	1,047	-	-	-	-	0	0.0	T.P.&W.
	80	ASCE	-	-	3,750	7	-	1	3	11	29.3	D.&I.R.
	85	ASCE	.43	.53	33,655	36	8	29	315	388	115.2	C.R.I.&P.
	85	P.S.	.45	.55	1,283	20	1	2	4	27	210.0	Pa.-N.W.
	85	P.S.	.45	.55	10,289	97	13	9	76	195	189.5	Pa.-S.W.
	85	P.S.	.45	.55	3,482	79	-	1	12	92	264.2	Vandalia
	90	ARA-A	.45	.55	4,533	28	5	8	58	99	218.5	B.&O.
	90	ARA-A	-	-	34,197	34	11	1	51	97	28.4	S.P.
	90	ARA-B	.45	.55	2,033	35	-	-	53	88	432.8	B.&O.
	90	ARA-B	.45	.55	12,103	32	2	9	15	58	47.9	N.P.
	90	ASCE	.44	.54	5,235	58	7	140	143	348	664.7	CCC&StL.
	90	ASCE	.45	.55	1,302	11	-	2	33	46	553.3	Erie
	100	ARA-A	.46	.56	1,860	5	3	1	6	15	80.8	B.&O.
	100	ASCE	.45	.55	7,973	6	-	55	83	114	180.6	M.C.
	100	P.S.	.45	.50	3,453	4	-	-	6	10	29.0	Pa.-N.W.
		Totals			145,120	463	56	272	1012	1803	124.2	
1910	75	ASCE	.55	.65	3,355	-	-	-	1	1	3.0	StL&SF.
	75	C.S.	.45	.55	2,076	2	-	-	-	2	9.6	St.J.&GI
	75	M.P.	-	-	14,377	4	-	1	5	10	7.0	St.L.S.W.
	80	ASCE	-	-	4,055	12	3	6	108	129	318.1	D.&I.R.
	85	ASCE	.43	.53	5,123	3	1	4	8	16	31.2	C.I.&S.
	90	ARA-A	.45	.55	8,790	26	1	47	385	459	522.1	B.&O.
	90	ARA-A	-	-	52,321	42	7	13	91	153	29.2	S.P.
	90	ARA-A	.55	.65	26,460	132	8	2	52	194	73.3	U.P.
	90	ARA-B	.45	.55	5,439	11	1	8	16	36	66.2	N.P.
	90	ASCE	.44	.54	27,750	92	6	469	451	1018	366.8	CCC&StL.
	90	ASCE	.45	.55	1,303	48	6	43	171	268	2056.7	Erie
	100	ARA-B	-	.47	11,000	7	3	-	5	15	13.6	C.&O.
		Totals			162,049	379	36	593	1293	2301	141.9	
1911	75	ASCE	.55	.65	2,000	-	-	-	-	0	0.0	StL&SF.
	75	M.P.	-	-	6,936	-	-	-	-	0	0.0	StL&SW.
	80	ASCE	.40	.50	3,570	-	-	-	2	2	5.6	C.N.
	85	ASCE	.43	.53	1,867	2	-	14	2	18	96.4	Southern
	85	P.S.	.45	.55	1,055	4	-	9	14	27	256.0	Pa.-N.W.
	85	P.S.	.45	.55	9,946	18	3	23	100	144	144.8	Pa.-S.W.
	85	P.S.	.45	.55	3,800	10	2	7	18	37	97.4	Vandalia
	90	ARA-A	-	-	7,214	2	-	1	1	4	5.5	S.P.
	90	ARA-B	.43	.53	4,210	2	-	8	24	34	80.8	CI&L.
	90	ASCE	.45	.55	4,791	30	14	43	306	393	820.2	Erie
	100	P.S.	.45	.55	1,917	17	3	1	14	35	182.6	Pa.S.W.
		Totals			47,306	85	22	106	481	694	146.7	

PMcK&YDiv.*

Table 5. - Sheet 3

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
Bessemer - ILLINOIS STEEL COMPANY - Continued												
1912	75	M.P.	-	-	5,674	5	-	-	-	5	8.8	St.L.S.W.
	85	ASCE	.43	.53	2,685	2	1	1	-	4	14.9	Southern
		Totals			8,359	7	1	1	-	9	10.7	
1913	85	ASCE	.43	.53	1,741	1	-	-	-	1	5.7	Southern
	90	ARA-B	.45	.55	2,766	-	-	-	-	0	0.0	N.P.
		Totals			4,507	1	-	-	-	1	2.2	
Bessemer - LACKAWANNA STEEL COMPANY												
1909	75	ASCE	.45	.55	1,273	1	-	23	24	48	377.1	SPLA&SL.
	80	ASCE	.43	.53	1,167	-	-	-	2	2	17.1	N.Y.S.&W
	80	Dudley	.43	.53	2,370	-	-	-	1	1	4.2	NYC&HR.
	*80	Dudley	.43	.53	30,521	16	13	46	46	121	39.6	NYC&HR.
	80	Dudley	.43	.53	2,000	6	22	40	34	102	510.0	Rutland
	85	P.S.	.45	.55	8,401	10	3	1	6	20	23.8	P.R.R.
	90	ARA-A	.44	.54	1,052	7	-	1	13	21	199.6	AT&SF.
	90	ARA-A	.43	.53	5,000	11	6	9	16	42	84.0	C.B.&Q.
	90	ARA-B	.45	.55	1,251	8	1	18	18	45	359.7	N.P.
	90	ASCE	.45	.55	7,279	41	9	32	71	153	210.2	Erie
	90	ASCE	.43	.53	1,035	3	2	8	3	16	154.6	L.V.
	100	ASCE	.45	.55	2,451	9	-	4	9	22	89.7	Erie
	100	ASCE	.45	.55	5,335	4	-	1	16	21	39.3	M.C.
	*100	ASCE	.45	.55	2,028	-	-	2	4	6	29.5	M.C.
	100	Dudley	.45	.55	2,500	4	1	-	6	11	44.0	B.& A.
	*100	Dudley	.48	.48	7,940	3	2	2	12	19	23.9	B.& A.
	100	Dudley	.45	.55	19,257	4	3	9	10	26	13.5	NYC&HR.
	*100	Dudley	.43	.55	4,098	7	1	40	22	70	170.8	NYC&HR.
	100	Dudley	.45	.55	1,283	33	2	-	8	43	335.2	P.R.R.
		Totals			106,241	167	65	236	321	789	74.2	
1910	80	ARA-B	.40	.50	2,479	20	-	-	-	20	80.6	TStL&W.
	80	ASCE	.40	.50	3,457	28	14	10	44	96	277.7	C.V.
	80	ASCE	.43	.53	3,222	8	3	-	2	13	40.3	N.Y.S.&W
	*80	Dudley	.43	.53	47,324	60	4	687	230	981	207.3	NYC&HR.
	80	Dudley	.43	.53	1,500	1	-	53	4	58	386.6	Rutland
	85	ASCE	-	-	5,300	2	-	-	1	3	5.7	CH&D.
	85	P.S.	.45	.55	5,998	9	3	2	11	25	41.7	P.R.R.
	90	ARA-A	.43	.53	5,000	45	7	54	112	218	436.0	C.B.&Q.
	90	ARA-B	.45	.55	30,234	29	8	13	60	110	36.4	N.P.
	*90	ARA-B	.44	.54	5,796	3	1	8	36	48	82.8	N.P.
	90	ASCE	.45	.55	15,318	30	1	21	32	84	54.8	Erie
	*90	ASCE	.47	.57	9,082	24	8	106	52	190	209.2	L.V.
	90	ASCE	.45	.55	3,000	4	1	8	25	38	126.6	P.& R.
	*90	ASCE	.44	.54	1,679	14	1	-	5	20	119.1	W.&L.E.
	*91	DL&W	-	-	3,141	3	1	3	2	9	28.6	D.L.&W.
	100	ARA-A	.50	.60	1,797	46	1	3	14	64	355.6	CofN.J.
	100	ASCE	.45	.55	3,007	5	-	2	4	11	36.6	Erie
	100	ASCE	.45	.55	1,049	4	-	-	-	4	38.1	M.C.
	*100	Dudley	.45	.55	9,515	22	6	19	20	67	70.4	B.& A.
	*100	Dudley	.43	.55	25,407	55	21	164	91	331	130.3	NYC&HR.
	100	P.S.	.45	.55	6,792	3	4	-	2	9	13.3	P.R.R.
		Totals			190,097	415	84	1153	747	2399	126.2	
1911	80	ASCE	.43	.53	1,794	-	-	-	1	1	5.6	N.Y.S.&W
	*80	Dudley	.55	.65	9,043	12	1	39	93	145	160.3	NYC&HR.
	*80	Dudley	.52	.65	2,750	-	3	420	58	481	1749.0	Rutland
	85	P.S.	.45	.55	3,037	5	1	-	1	7	23.0	P.R.R.
	90	ARA-A	.43	.53	3,000	19	4	14	148	185	616.7	C.B.&Q.
	90	ARA-B	.45	.55	5,658	-	-	-	1	1	1.8	N.P.
	90	ASCE	.45	.55	4,317	2	2	-	4	8	18.5	Erie
	*90	ASCE	.45	.55	1,072	-	-	-	4	4	37.3	Erie
	90	ASCE	.45	.55	3,150	9	1	2	15	27	85.7	P.& R.
	100	ARA-A	.45	.55	7,000	20	3	-	4	27	38.6	C.B.&Q.
	100	ASCE	.45	.55	2,301	13	2	1	4	20	86.9	Erie
	*100	ASCE	.60	.70	2,630	2	-	3	3	8	30.4	M.C.
	*100	Dudley	.60	.70	5,540	6	-	7	19	32	57.8	B.& A.
	*100	Dudley	.60	.70	6,404	25	1	67	73	166	259.2	NYC&HR.
	100	P.S.	.45	.55	4,051	12	3	1	4	20	49.4	P.R.R.
		Totals			61,747	125	21	554	432	1132	183.3	

* Ferro Titanium Alloy Added

Table 5 - Sheet 4

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
Bessemer - LACKAWANNA STEEL COMPANY - Continued												
1912	80	ASCE	.40	.50	4,750	29	6	4	11	50	105.2	C.V.
	* 90	ARA-B	.45	.55	3,046	1	-	-	1	2	6.6	N.P.
	100	P.S.	.45	.55	1,254	10	2	2	3	17	135.6	P.R.R.
	*100	P.S.	.45	.55	6,021	39	3	-	1	43	85.6	P.R.R.
		Totals			14,071	79	11	6	16	112	79.6	
1913	90	ARA-B	.45	.55	4,160	-	-	-	-	0	0.0	N.P.
1914	90	ARA-B	.45	.56	3,320	-	-	-	-	0	0.0	N.P.
Bessemer - MARYLAND STEEL COMPANY												
1909	70	P.S.	-	-	9,700	-	2	-	3	5	5.1	B.& A.
	75	B&M	.40	.50	2,500	2	-	3	7	12	48.0	B.& M.
	85	ASCE	.43	.53	2,500	1	-	4	2	7	28.0	B.& M.
	86	ASCE	.43	.53	4,187	35	1	-	7	43	102.7	Southern
	85	P.S.	-	-	3,827	4	4	15	4	27	70.5	B.& A.
	85	P.S.	.45	.55	4,637	20	2	-	-	22	47.4	P.R.R.
	90	ARA-B	.45	.55	7,062	163	7	-	74	244	345.6	B.& O.
	90	ASCE	.54	.64	10,000	153	15	8	21	197	197.0	P.& R.
	100	ARA-A	.58	.68	1,437	120	2	-	13	135	939.4	CofN.J.
	100	ARA-B	.46	.56	11,394	374	15	4	80	473	415.1	B.& O.
	100	P.S.	.45	.55	6,277	28	25	2	21	76	121.1	P.R.R.
	100	P&R.	.55	.65	2,500	50	14	-	7	71	284.0	P.& R.
		Totals			66,021	950	87	36	239	1312	198.7	
1910	70	P.S.	-	-	4,690	1	-	18	7	26	55.4	B.& A.
	85	ASCE	.43	.53	14,435	64	2	-	18	84	58.2	Southern
	85	P.S.	-	-	4,038	-	1	29	12	42	104.0	B.& A.
	85	P.S.	.45	.55	5,587	12	9	1	5	27	48.3	P.R.R.
	90	ARA-B	.45	.55	4,209	91	3	1	47	142	337.3	B.& O.
	* 90	ARA-B	.45	.55	2,407	30	3	3	20	56	232.6	B.& O.
	90	ARA-B	-	.49	7,000	-	-	-	2	2	2.9	C.& O.
	90	ASCE	.53	.63	3,574	2	-	-	-	2	5.5	P.& R.
	100	ARA-B	.46	.56	7,180	113	6	-	70	189	263.2	B.& O.
	100	ARA-B	-	.50	1,000	-	-	-	-	0	0.0	C.& O.
	100	P&R	.55	.65	2,700	4	3	-	2	9	33.3	P.& R.
	100	P.S.	.45	.55	6,432	16	24	1	23	64	99.5	P.R.R.
		Totals			63,252	333	51	53	206	643	101.6	
1911	70	ARA-B	.40	.50	5,300	-	1	-	-	1	1.9	SA& AP.
	85	ASCE	.43	.53	3,373	1	-	-	-	1	3.0	Southern
	85	P.S.	.45	.55	7,183	12	5	2	10	29	40.4	P.R.R.
	* 90	ARA-B	.45	.55	2,543	5	-	-	4	9	35.4	B.& O.
	90	ARA-B	.43	.53	4,000	-	-	-	3	3	7.5	C.& O.
	90	ASCE	.42	.52	1,400	1	1	-	3	5	35.7	P.& R.
	100	ARA-A	.50	.60	7,561	5	-	5	1	11	42.9	C.ofN.J.
	100	ARA-B	.46	.56	1,904	15	-	-	18	33	173.6	B.& O.
	*100	ARA-B	.46	.56	1,732	13	1	1	5	20	115.4	B.& O.
	100	ARA-B	.62	.75	1,967	2	1	-	-	3	15.2	N.& W.
	100	NYNH	.44	-	1,003	-	-	-	1	1	1.0	B.& M.
	100	NYNH&H	.45	.55	1,022	1	-	-	-	1	9.8	NYNH& H.
	100	P.S.	.45	.55	11,336	15	3	3	18	39	34.4	P.R.R.
	100	P&R.	.55	.65	1,000	9	2	-	-	11	110.0	P.& R.
		Totals			51,324	79	14	11	63	167	32.5	
1912	70	ARA-B	.40	.50	4,400	1	-	-	-	1	2.2	SA& AP.
	80	ASCE	.45	.55	1,702	-	-	-	-	0	0.0	NYNH& H.
	80	Dudley	.40	.50	4,876	1	10	8	5	24	49.2	NYC& HR.
	90	ARA-B	-	-	7,000	-	-	-	-	0	0.0	C.& O.
	90	ARA-B	.45	.55	1,715	3	-	-	-	3	17.6	N.P.
	90	GN	.43	.53	4,660	2	-	14	29	45	96.6	G.N.
	*100	ARA-B	.46	.56	9,833	12	3	-	16	31	31.6	B.& O.
	100	NYNH	-	-	1,670	1	37	20	-	58	347.3	B.& M.
	100	NYNH&H	.45	.55	5,148	1	1	2	-	4	7.7	NYNH& H.
	100	P.S.	.45	.55	19,123	24	34	1	10	69	36.1	P.R.R.
	100	P.S.	.45	.55	3,984	3	2	2	-	7	18.0	Pa.-N.W.
		Totals			64,111	48	87	47	60	242	37.7	

* Ferro Titanium Alloy Added

Table 5 - Sheet 5

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
Bessemer - MARYLAND STEEL COMPANY - Continued												
1913	90	ARA-B	-	-	2,000	2	-	1	-	3	15.0	C.& O.
	90	ARA-B	.45	.55	1,196	-	-	-	-	0	0.0	N.P.
	100	P.S.	-	-	1,158	5	-	-	-	5	43.2	C.V.
	100	P.S.	.45	.55	17,895	10	4	1	5	20	11.2	P.R.R.
	100	P.S.	.45	.55	2,627	2	-	-	-	2	8.0	Pa.-N.W.
	100	P.S.	.45	.55	1,030	3	-	-	-	3	29.1	Pa.-S.W.
	100	P&R.	.42	.52	1,001	70	-	-	-	70	699.2	P.& R.
		Totals			26,907	92	4	2	5	103	38.2	
1914	85	ASCE	.43	.53	3,403	-	-	-	-	0	0.0	Southern
	90	ARA-B	.43	.53	2,000	-	-	-	-	0	0.0	C.& O.
	100	ARA-B	.45	.55	5,342	-	-	-	-	0	0.0	B.& O.
	100	P.S.	-	-	1,500	-	-	-	-	0	0.0	C.V.
	100	P.S.	.45	.55	1,245	2	-	-	1	3	24.1	Pa.-S.W.
		Totals			13,490	2	-	-	1	3	2.2	
Open Hearth - BETHLEHEM STEEL COMPANY												
1909	80	ASCE	-	-	1,218	1	7	-	1	9	73.9	C.N.E.
	85	ASCE	.62	.75	5,000	5	2	5	44	56	112.0	B.& M.
	85	ASCE	.62	.75	2,500	9	3	-	15	27	108.0	N.& W.
	85	P.S.	.62	.72	2,174	23	2	-	34	59	271.4	P.R.R.
	90	ARA-B	.55	.80	4,018	215	18	5	424	662	1647.0	B.& O.
	90	ARA-B	-	-	7,000	6	1	0	5	12	17.1	C.& O.
	90	ASCE	.65	.75	4,033	34	4	-	27	65	161.1	D.& H.
	90	G.N.	.65	.80	17,110	367	18	13	380	778	454.7	G.N.
	91	DL&W.	.70	.83	11,260	114	9	10	471	604	536.6	D.L.& W.
	100	ASCE	-	-	2,105	-	1	-	1	2	9.5	L.I.
	100	Dudley	.65	.75	2,176	3	-	-	4	7	32.2	NYC& HR.
	100	NYNH&H	.70	.80	4,735	41	17	15	66	139	293.6	NYNH& H.
	100	P.S.	.62	.75	5,015	49	2	-	61	112	223.3	P.R.R.
		Totals			68,344	867	84	48	1533	2532	370.4	
1910	80	ASCE	-	-	2,500	4	4	1	4	13	52.0	L.I.
	80	ASCE	.70	.80	4,123	1	18	4	8	31	75.2	NYNH& H.
	85	ASCE	.63	.76	9,000	6	8	13	38	65	72.2	B.& M.
	85	ASCE	.62	.75	5,500	32	5	1	28	66	120.0	N.& W.
	85	P.S.	.62	.75	2,800	4	5	2	7	18	64.3	P.R.R.
	90	ARA-A	.35	.67	5,000	47	6	5	3	61	122.0	C.B.& Q.
	90	ARA-B	.62	.75	4,067	2	2	-	7	11	27.0	N.P.
	90	ASCE	.65	.75	8,122	66	9	-	60	135	166.2	D.& H.
	91	DL&W	.67	.80	17,800	62	3	13	145	223	125.3	D.L.& W.
	100	ARA-A	.70	.83	7,600	285	16	5	270	576	757.9	C.of N.J.
	100	ARA-B	.70	.80	1,493	40	-	-	45	85	569.3	B.& O.
	100	ASCE	-	-	2,695	-	3	2	1	6	22.2	L.I.
	100	Dudley	.62	.75	6,758	9	-	2	17	28	41.4	NYC& HR.
	100	NYNH&H	.70	.86	3,427	10	1	15	36	62	180.9	NYNH& H.
	100	P.S.	.62	.75	3,352	8	9	2	45	64	190.9	P.R.R.
		Totals			84,237	576	89	65	714	1444	171.4	
1911	80	ASCE	.62	.75	3,297	-	4	4	2	10	30.3	NYNH& H.
	85	ASCE	.67	.80	17,200	7	2	14	53	76	44.2	B.& M.
	85	ASCE	.67	.80	7,080	4	2	18	180	204	288.1	Me.C.
	85	ASCE	.62	.75	2,963	3	2	-	14	19	64.1	N.& W.
	90	ARA-B	.65	.80	2,153	25	4	-	9	38	176.5	B.& O.
	90	ASCE	.52	.65	8,166	46	-	-	23	69	84.4	D.& H.
	90	ASCE	.70	.85	4,950	43	1	1	130	175	353.5	P.& R.
	91	DL&W.	.67	.80	1,962	12	1	2	17	32	152.9	D.L.& W.
	100	ARA-A	.72	.85	11,606	128	8	14	269	419	361.0	C.of N.J.
	100	ASCE	-	-	2,602	-	-	-	1	1	3.8	L.I.
	100	ASCE	.62	.75	3,927	11	-	4	2	17	43.2	L.S.&M.S.
	100	Dudley	.62	.75	2,299	-	-	-	-	0	0.0	NYC& HR.
	100	NYNH&H	.70	.83	4,383	1	1	1	1	4	9.1	NYNH& H.
	100	P.S.	.62	.75	2,887	2	-	-	8	10	34.6	P.R.R.
	101	DL&W.	.70	.83	7,613	16	1	7	19	43	56.5	D.L.& W.
	*101	DL&W.	-	-	1,097	2	-	-	41	43	392.0	D.L.& W.
	110	LV.	.63	.76	4,967	28	1	1	5	35	70.5	L.V.
		Totals			89,152	328	27	66	774	1195	134.0	

* Ferro Titanium Alloy Added

Table 6 - Sheet 6

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
Open Hearth - BETHLEHEM STEEL COMPANY - Continued												
1912	80	ASCE	. -	-	1,981	-	1	-	-	1	5.0	C.N.E.
	80	ASCE	.62	.75	3,116	-	-	-	1	1	3.2	NYNH& H.
	85	ASCE	.67	.80	1,571	-	4	11	33	48	305.5	B.& M.
	85	ASCE	.59	.72	1,623	2	-	-	-	2	12.3	Southern
	90	ARA-B	.59	.72	2,428	2	-	-	-	2	8.2	N.P.
	90	ASCE	.62	.75	14,259	11	-	-	4	15	10.5	D.& H.
	90	ASCE	.67	.80	5,045	-	-	-	-	0	0.0	P.& R.
	90	GN	.59	.72	9,982	1	-	1	-	2	2.0	G.N.
	91	DL&W	.64	.77	3,587	3	-	-	4	7	19.5	D.L.& W.
	100	ARA-A	.67	.80	2,735	-	-	-	-	0	0.0	C.of N.J.
	100	ARA-A	.63	.76	15,150	48	1	-	4	53	35.0	L.V.
	100	ARA-B	.70	.80	2,665	12	2	1	11	26	97.4	B.& O.
	100	ARA-B	.62	.75	3,800	2	-	-	-	2	5.3	N.& W.
	100	Dudley	.62	.75	7,386	-	-	-	-	0	0.0	NYC& HR.
	100	NYNH	.70	.83	1,000	-	-	2	2	4	40.0	B.& M.
	100	NYNH&H	.70	.83	3,433	2	1	-	1	4	11.7	NYNH& H.
	100	P.S.	.62	.75	4,440	-	-	1	1	2	4.5	P.R.R.
	101	DL&W	.70	.83	3,897	5	-	1	5	11	28.2	D.L.& W.
	110	L.V.	.63	.76	2,140	14	-	1	-	15	70.1	L.V.
		Totals			90,238	102	9	18	66	195	21.6	
1913	72	N.P.	.52	.65	3,984	-	-	-	-	0	0.0	N.P.
	85	ASCE	.67	.80	4,600	-	2	1	2	5	10.8	B.& M.
	85	ASCE	.67	.80	10,000	1	-	2	25	28	28.0	Me.C.
	90	ARA-B	.63	.76	2,285	-	-	-	1	1	4.3	B.& O.
	90	ARA-B	.59	.72	1,444	-	-	-	-	0	0.0	N.P.
	90	ASCE	.67	.80	3,005	-	-	-	-	0	0.0	C.ofN.J.
	90	ASCE	.62	.75	7,376	-	-	-	-	0	0.0	D.& H.
	90	ASCE	.62	.75	1,200	-	-	-	-	0	0.0	L.&N.E.
	90	ASCE	.67	.80	5,310	-	-	-	-	0	0.0	P.& R.
	90	G.N.	.59	.72	10,060	3	-	11	11	25	25.0	G.N.
	91	DL&W.	.64	.77	1,902	-	-	-	1	1	5.2	D.L.& W.
	100	ARA-A	.67	.80	4,325	1	1	-	-	2	4.6	C.of N.J
	100	ARA-A	.63	.76	1,522	-	-	-	-	0	0.0	C.R.I.&P
	100	ARA-A	.70	.85	2,123	-	-	-	4	4	18.8	L.& N.
	100	ARA-A	.63	.76	18,374	9	-	-	2	11	6.0	L.V.
	100	ARA-B	.62	.75	5,300	1	-	-	1	2	3.7	N.& W.
	100	NYNH	.70	.83	3,500	-	1	1	1	3	8.5	B.& M.
	100	NYNH&H	.70	.83	10,072	-	-	1	-	1	1.0	NYNH& H.
	100	P.S.	.62	.75	3,183	-	-	-	-	0	0.0	P.R.R.
	100	P.&R.	.67	.80	2,720	-	-	-	-	0	0.0	P.& R.
	105	Dudley	.62	.75	8,991	-	-	-	-	0	0.0	NYC& HR.
	*105	Dudley	.62	.75	2,734	1	-	-	2	3	10.9	NYC& HR.
	110	L.V.	.63	.76	12,903	17	4	1	-	22	17.1	L.V.
	*110	L.V.	.63	.76	1,201	4	1	-	1	6	50.0	L.V.
		Totals			128,114	37	9	17	51	114	8.8	
1914	80	ASCE	-	-	1,296	-	-	-	-	0	0.0	C.N.E.
	80	ASCE	.55	.68	2,000	-	-	-	-	0	0.0	C.V.
	85	ASCE	.63	.76	1,630	-	-	-	-	0	0.0	B.& M.
	90	ASCE	.62	.75	6,429	-	-	-	-	0	0.0	D.& H.
	90	ASCE	.62	.75	1,500	-	-	-	-	0	0.0	L.&N.E.
	90	ASCE	.67	.80	5,042	-	-	-	-	0	0.0	P.& R.
	91	DL&W.	.64	.77	2,350	-	-	-	-	0	0.0	D.L.& W.
	100	L.V.	.63	.76	16,040	-	-	-	-	0	0.0	L.V.
	100	ARA-B	.62	.75	3,000	-	-	-	-	0	0.0	C.& O.
	100	ARA-B	.62	.75	4,100	-	-	-	-	0	0.0	N.& W.
	100	NYNH	.63	.76	1,798	-	-	-	-	0	0.0	B.& M.
	110	L.V.	.63	.76	4,855	-	-	-	-	0	0.0	L.V.
		Totals			50,040	-	-	-	-	0	0.0	
Open Hearth - CAMBRIA STEEL COMPANY												
1909	85	ASCE	.62	.75	4,000	6	10	-	5	21	52.5	N.& W.
	85	P.S.	.62	.75	2,639	14	51	4	14	83	314.5	P.R.R.
	100	P.S.	.62	.75	4,883	71	27	5	57	160	327.7	P.R.R.
		Totale			11,522	91	88	9	76	264	229.1	

* Ferro Titanium Alloy Added

Table 5 - Sheet 7

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
Open Hearth - CAMBRIA STEEL COMPANY- Continued												
1910	85	P.S.	.62	.75	1,000	-	-	-	-	0	0.0	G.R.& I.
	85	P.S.	.62	.75	3,969	13	14	2	2	31	78.1	P.R.R.
	100	ARA-B	.70	.80	2,152	11	1	-	2	14	65.0	B.& O.
	100	P.S.	.62	.75	13,327	50	30	-	31	111	83.3	P.R.R.
	100	P.S.	.62	.75	2,005	28	6	-	15	49	244.0	Pa.-N.W.
	100	P.S.	.62	.75	2,136	10	3	1	2	16	74.9	Pa.-S.W.
	Totals				24,589	112	54	3	52	221	89.9	
1911	85	ASCE	.62	.75	3,390	2	1	1	1	5	14.8	N.& W.
	85	P.S.	.62	.75	8,459	15	27	2	7	51	60.3	P.R.R.
	90	ARA-B	.65	.80	6,469	11	8	-	51	70	108.2	B.& O.
	90	ARA-B	.63	.76	6,490	14	8	1	5	28	43.1	H.V.
	100	ARA-B	.70	.80	1,189	7	3	1	5	16	134.4	B.& O.
	100	P.S.	.62	.75	12,949	55	67	3	46	171	132.1	P.R.R.
	Totals				38,946	104	114	8	115	341	87.5	
1912	72	N.P.	.52	.65	1,172	-	-	-	1	1	8.5	N.P.
	85	ASCE	.62	.75	3,300	-	-	-	6	6	18.2	N.& W.
	85	P.S.	.62	.75	1,909	3	2	-	2	7	36.0	G.R.&I.
	90	ARA-A	.63	.76	1,697	-	-	-	-	0	0.0	U.P.
	90	ARA-B	.65	.80	1,603	8	2	-	2	12	75.0	B.& O.
	90	ARA-B	.63	.76	1,000	-	-	-	-	0	0.0	C.I.& L.
	90	ARA-B	.63	.76	5,108	2	1	-	1	4	7.8	H.V.
	90	G.N.	.59	.72	9,840	3	-	-	-	3	3.0	G.N.
	100	ARA-A	.63	.76	2,360	2	2	1	-	5	21.2	L.V.
	100	ARA-B	.70	.80	23,936	25	11	-	23	59	24.6	B.& O.
	100	ARA-B	.62	.75	1,097	1	-	-	-	1	9.1	N.& W.
	100	P.S.	.62	.75	21,648	63	20	1	45	129	59.6	P.R.R.
	100	P.S.	.62	.75	8,064	3	1	-	1	5	6.0	Pa.-N.W.
	100	P.S.	.62	.75	1,429	-	1	-	-	1	7.0	Pa.-S.W.
	Totals				84,163	110	40	2	81	233	27.7	
1913	72	N.P.	.52	.65	6,965	-	-	-	1	1	1.4	N.P.
	85	ASCE	.62	.75	2,559	-	-	-	1	1	3.9	N.& W.
	85	P.S.	.62	.75	2,589	-	13	-	-	13	50.2	G.R.&I.
	85	P.S.	.62	.75	1,916	-	41	1	-	42	219.2	P.R.R.
	90	ARA-B	.63	.76	1,000	-	-	-	-	0	0.0	C.I.& L.
	90	ARA-B	.63	.76	3,793	1	4	-	5	10	26.3	H.V.
	90	ASCE	.59	.75	1,717	-	-	-	-	0	0.0	C.of N.J.
	90	ASCE	.59	.72	1,566	-	-	-	-	0	0.0	N.& M.
	90	G.N.	.59	.72	4,860	1	3	1	-	5	10.3	G.N.
	100	ARA-A	.63	.76	1,377	-	-	-	-	0	0.0	B.& O.
	100	ARA-A	.62	.75	1,883	-	1	-	-	1	5.3	C.of N.J.
	100	ARA-B	.63	.76	28,097	10	-	-	8	18	6.4	B.&O.
	100	ARA-B	.62	.75	2,683	1	-	-	1	2	7.4	N.& W.
	100	P.S.	.62	.75	24,704	32	18	-	12	62	25.1	P.R.R.
	Totals				82,709	45	80	2	28	155	18.7	
1914	90	ARA-A	.63	.76	1,176	-	-	-	-	0	0.0	B.& O.
	90	ARA-B	.63	.76	1,070	-	1	-	-	1	9.3	H.V.
	90	ARA-B	.62	.75	3,099	-	-	-	-	0	0.0	N.P.
	100	ARA-B	.63	.76	10,907	-	-	-	2	2	1.8	B.& O.
	100	ARA-B	.63	.76	1,535	-	-	-	-	0	0.0	H.V.
	100	ARA-B	.62	.75	2,304	-	-	-	-	0	0.0	N.& W.
	100	P.S.	.62	.75	16,439	1	-	-	-	1	0.6	P.R.R.
		Totals			36,530	1	1	-	2	4	1.1	
Open Hearth - CARNEGIE STEEL COMPANY												
1909	85	ASCE	.62	.75	3,000	2	-	-	-	2	6.7	N.& W.
	85	P.S.	.62	.75	1,158	3	1	-	-	4	34.5	P.R.R.
	85	P.S.	.62	.75	3,205	17	2	1	6	26	81.0	Pa.-N.W.
	100	P.S.	.62	.75	4,450	10	7	-	21	38	85.4	P.R.R.
	100	P.S.	.62	.75	3,504	38	6	-	39	83	237.0	Pa.-N.W.
	100	P.S.	.62	.75	1,054	2	1	-	11	14	132.8	Pa.-S.W.
	100	P.S.	.70	.83	2,527	1	1	-	8	10	39.6	Pa.-S.W.
	Totals				18,898	73	18	1	85	177	93.6	
1910.	85	ASCE	.62	.75	15,000	13	28	-	14	55	36.7	N.& W.
	90	ARA-B	.63	.76	5,091	70	4	1	14	89	174.8	H.V.
	90	ASCE	.62	.72	2,507	6	6	-	1	13	51.9	L.V.
	100	P.S.	.62	.75	5,369	31	8	-	30	69	128.0	Pa.-N.W.
	Totals				27,967	120	46	1	59	226	80.7	

Table 5 - Sheet 8

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
Open Hearth - CARNEGIE STEEL COMPANY - Continued												
1911	85	P.S.	.62	.75	2,121	5	8	-	-	13	61.3	P.R.R.
	90	ARA-A	.65	.80	4,729	5	8	-	16	29	61.3	B.& O.
	90	ARA-B	.65	.85	2,850	26	11	2	55	94	329.8	B.& O.
	90	ASCE	.70	.85	1,504	2	9	-	6	17	113.0	L.V.
	90	ASCE	.70	.85	5,040	-	-	-	6	6	11.9	P.& R.
	100	ARA-A	.63	.76	1,024	-	3	-	4	7	68.4	L.V.
	100	ARA-B	.62	.75	4,228	10	4	-	6	20	47.3	P.& L.E.*
	100	ARA-B	.62	.75	2,976	4	11	-	-	15	50.4	P.& L.E.
	100	P.S.	.62	.75	11,501	18	33	-	20	71	61.7	P.R.R.
	100	P.S.	.62	.75	6,233	10	5	-	19	34	54.0	Pa.-N.W.
	Totals				42,206	80	92	2	132	306	72.5	
1912	80	ARA-B	.52	.65	2,171	5	-	-	1	6	27.6	N.Y.S.&W.
	85	P.S.	.62	.75	3,986	-	-	-	-	0	0.0	Pa.-N.W.
	90	ARA-A	.65	.80	10,748	9	-	-	3	12	11.2	B.& O.
	90	ARA-A	. -	-	1,385	-	2	-	3	5	36.1	C.H.& D.
	90	ARA-B	.65	.85	3,225	41	7	-	4	52	161.2	B.& O.
	90	ARA-B	.59	.72	16,640	7	-	-	2	9	5.4	Erie
	90	ASCE	.60	.73	1,455	1	2	-	4	7	48.1	W.& L.E.
	100	ARA-A	.70	.80	1,045	2	9	-	3	14	133.9	B.& O.
	100	ARA-B	.70	.80	6,691	1	2	1	2	6	9.0	B.& O.
	100	ARA-B	.62	.75	15,500	11	6	-	8	25	16.1	N.& W.
	100	ARA-B	.62	.75	1,470	-	1	-	-	1	6.8	P.& L.E.*
	100	ARA-B	.62	.75	4,829	-	1	-	6	7	14.5	P.& L.E.
	100	P.S.	.62	.75	9,459	8	3	-	7	18	19.0	Pa.-S.W.
	100	P.S.	.62	.75	16,628	2	27	-	6	35	21.0	Pa.-N.W.
	Totals				95,232	87	60	1	49	197	20.6	
1913	80	ARA-A	.53	.66	2,370	-	-	-	-	0	0.0	Erie
	85	ASCE	.62	.75	4,275	1	-	-	1	2	4.7	N.& W.
	90	ARA-A	.63	.76	7,466	-	-	-	-	0	0.0	B.& O.
	90	ASCE	.70	.85	4,994	1	-	-	1	2	4.0	P.& R.
	90	ASCE	.60	.73	1,105	2	-	-	-	2	18.1	W.& L.E.
	100	ARA-A	.63	.76	7,467	-	1	-	5	6	8.0	B.& O.
	100	ARA-A	.63	.76	13,135	2	2	-	1	5	3.7	Erie
	*100	ARA-A	.63	.76	3,650	3	-	-	1	4	10.9	Erie
	100	ARA-A	.63	.76	7,327	7	-	-	-	7	9.5	L.V.
	100	ARA-B	.63	.76	5,084	4	-	-	-	4	7.8	B.& O.
	100	ARA-B	.62	.75	13,252	-	1	-	-	1	0.7	N.& W.
	100	ARA-B	.62	.75	3,379	-	-	-	1	1	3.0	P.& L.E.*
	100	ARA-B	.62	.75	2,715	1	-	-	-	1	3.7	P.& L.E.
	100	P.S.	.62	.75	12,282	10	1	-	4	15	12.0	Pa.-N.W.
	100	P.S.	.62	.75	7,658	2	1	-	3	6	7.8	Pa.-S.W.
	Totals				96,159	33	6	-	17	56	5.8	
1914	80	ASCE	.40	.50	2,000	-	-	-	-	0	0.0	T.StL.&W.
	90	ARA-A	-	-	1,414	-	-	-	-	0	0.0	C.H.& D.
	90	ASCE	.67	.80	5,028	-	-	-	-	0	0.0	P.& R.
	100	ARA-A	.63	.76	4,202	1	-	-	-	1	2.4	B.& O.
	100	ARA-B	.63	.76	3,151	-	-	-	-	0	0.0	B.& O.
	100	ARA-B	.62	.75	8,400	-	-	-	-	0	0.0	N.& W.
	100	P.S.	.62	.75	9,939	-	-	-	-	0	0.0	Pa.-N.W.
	100	P.S.	.62	.75	5,289	1	-	-	-	1	1.9	Pa.-S.W.
	Totals				39,423	2	-	-	-	2	0.5	
Open Hearth - COLORADO FUEL & IRON COMPANY												
1909	85	CB&Q	.55	.65	20,000	26	4	8	12	50	25.0	C.B.& Q.
	90	ARA-A	. -	-	6,478	3	1	-	-	4	6.2	S.P.
	90	CB&Q	.58	.68	20,000	56	5	3	1	65	32.5	C.B.& Q.
	90	SF	.59	.72	25,964	46	8	-	5	59	22.7	A.T.&S.F.
	Totals				72,442	131	18	11	18	178	24.6	
1910	75	C.S.	.45	.63	1,604	-	-	-	-	0	0.0	H.& T.C.
	75	C.S.	.55	.68	6,467	-	-	-	-	0	0.0	T.& N.O.
	85	ASCE	.60	.73	8,224	7	1	-	1	9	10.9	SPLA& SL.
	85	CB&Q	.55	.65	5,000	12	1	-	-	13	26.0	C.B.& Q.
	85	D&RG	.58	.68	3,348	15	1	-	4	20	59.6	D.& R.G.
	90	ARA-A	.58	.68	32,800	61	5	-	2	68	20.7	C.B.& Q.
	90	ARA-A	. -	-	37,167	28	1	-	5	34	9.1	S.P.
	90	ARA-A	.63	.76	19,940	43	1	1	2	47	23.6	U.P.
	90	SF	.59	.72	41,536	60	7	1	3	71	17.1	A.T.&S.F.
	Totals				156,086	226	17	2	17	262	16.7	

* Ferro Titanium Alloy Added

PMcK&Y Div.*

Table 5 - Sheet 9

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
		Open Hearth - COLORADO FUEL & IRON COMPANY - Continued										
1911	75	C.S.	.45	.63	2,384	-	-	-	-	0	0.0	H.& T.C.
	75	C.S.	.55	.68	1,773	-	-	-	-	0	0.0	T.& N.O.
	85	D&RG.	.58	.68	2,855	1	-	-	2	3	10.5	D.& R.G.
	90	ARA-A	.58	.68	17,200	39	1	3	9	52	30.2	C.B.& Q.
	90	ARA-A	-	-	17,120	14	1	-	3	18	10.5	S.P.
	90	ARA-A	.63	.76	5,065	-	-	-	-	0	0.0	U.P.
	90	SF.	.59	.72	45,650	126	2	-	3	131	28.7	A.T.&S.F.
		Totals			92,047	180	4	3	17	204	22.2	
1912	75	ASCE	.53	.66	4,253	-	-	-	-	0	0.0	SPLA& SL.
	75	C.S.	.55	.68	5,203	-	-	-	-	0	0.0	U.P.
	85	D&RG.	.58	.68	10,000	-	-	-	-	0	0.0	D.& R.G.
	90	ARA-A	.58	.68	35,000	51	1	-	6	58	16.6	C.B.& Q.
	90	ARA-A	-	-	5,647	-	-	-	1	1	1.8	S.P.
	90	ARA-B	.58	.68	4,337	6	-	1	1	8	18.4	N.P.
	90	G.N.	.60	.70	30,038	215	7	2	19	243	80.9	G.N.
	90	SF.	.59	.72	45,000	93	6	1	8	108	24.0	A.T.&S.F.
	100	ARA-B	.60	.70	3,103	1	-	-	-	1	3.2	N.P.
		Totals			142,581	366	14	4	35	419	29.4	
1913	75	C.S.	.55	.68	4,812	-	-	-	-	0	0.0	U.P.
	85	D&RG.	.58	.68	10,000	-	-	-	-	0	0.0	D.& R.G.
	90	ARA-A	.58	.68	30,000	13	1	-	1	15	5.0	C.B.& Q.
	90	ARA-A	-	-	2,404	1	-	-	1	2	8.3	S.P.
	90	ARA-A	.63	.76	4,891	-	-	-	-	0	0.0	SPLA& SL.
	90	ARA-B	.58	.68	14,655	9	-	1	1	11	7.5	N.P.
	90	D&RG	.58	.68	4,400	1	-	-	-	1	2.3	D.& R.G.
	90	S.F.	.59	.72	65,110	5	-	-	4	9	1.4	A.T.&S.F.
		Totals			136,272	29	1	1	7	38	2.8	
1914	85	D&RG	.58	.68	2,990	-	-	-	-	0	0.0	D.& R.G.
	90	ARA-A	.62	.75	20,000	4	-	-	-	4	2.0	C.B.& Q.
	90	ARA-A	-	-	2,752	-	-	-	-	0	0.0	SPLA& SL.
	90	ARA-B	.58	.68	1,010	-	-	-	-	0	0.0	N.P.
	90	D&RG	.58	.68	9,000	1	-	-	-	1	1.1	D.& R.G.
	90	S.F.	.65	.73	47,800	1	-	-	-	1	0.2	A.T.&S.F.
		Totals			83,552	6	-	-	-	6	0.7	
		Open Hearth - ILLINOIS STEEL COMPANY										
1909	85	ARA-A	.59	.72	4,493	34	2	2	6	44	100.0	A.T.&S.F.
	85	ASCE	.59	.72	2,836	9	1	-	13	23	81.1	C.& E.I.
	85	ASCE	.59	.72	11,446	15	2	2	76	95	83.0	C.R.I.&P.
	85	P.S.	.70	.83	1,988	70	2	1	3	76	382.3	Pa.-S.W.
	85	P.S.	.62	.75	1,343	35	4	1	2	42	312.7	Pa.-S.W.
	85	P.S.	.62	.75	1,951	24	2	-	6	32	164.0	Vandalia
	90	ARA-A	.65	.80	1,970	16	-	5	38	59	299.5	B.& O.
	90	ARA-A	.62	.75	45,000	691	92	33	107	923	205.1	C.B.& Q.
	90	ARA-A	-	-	11,268	67	7	1	61	136	120.7	S.P.
	90	ARA-B	.62	.75	23,615	298	4	145	247	694	293.9	N.P.
	90	G.N.	.62	.75	16,790	200	26	297	301	824	490.8	G.N.
	90	S.F.	.59	.72	73,004	183	12	4	5	204	28.0	A.T.&S.F.
	100	ARA-B	-	-	8,000	6	1	-	2	9	11.3	C.& O.
	100	P.S.	.62	.75	2,831	37	1	-	14	52	184.0	Pa.-N.W.
		Totals			206,535	1685	156	491	881	3213	155.6	
1910	75	ASCE	.52	.65	5,002	35	3	2	29	69	137.9	C.I.& L.
	75	ASCE	.55	.68	4,923	-	2	-	3	5	10.2	I.C.
	85	ASCE	.59	.72	5,926	17	1	1	21	40	67.5	C.&E.I.
	85	ASCE	.59	.72	15,756	5	1	4	24	34	21.6	C.R.I.&P.
	85	P.S.	.62	.75	3,617	59	1	-	17	77	212.9	Vandalia
	90	ARA-A	.62	.75	40,000	237	15	45	144	441	110.3	C.B.& Q.
	90	ARA-A	.63	.76	1,900	62	3	-	7	72	378.9	I.C.
	90	ARA-A	-	-	25,194	88	26	6	15	135	53.6	S.P.
	90	ARA-B	.65	.80	10,482	157	3	2	43	205	195.5	B.& O.
	90	ARA-B	.62	.75	49,181	198	4	62	94	358	72.6	N.P.
	90	G.N.	.62	.75	13,470	127	10	279	590	1006	746.8	G.N.
	90	S.F.	.59	.72	92,323	160	23	7	12	202	21.9	A.T.&S.F.
	100	ARA-A	.63	.76	16,140	8	1	4	34	47	29.1	C.R.I.&P.
	100	ARA-B	.62	.75	14,000	23	-	1	21	45	32.1	N.& W.
	100	P.S.	.62	.75	3,864	148	6	3	24	181	468.4	Pa.-N.W.
		Totals			301,778	1324	99	416	1078	2917	96.6	

Table 5 - Sheet 10

Total Rail Failures From Date Rolled to October 31st, 1914.

Open Hearth - ILLINOIS STEEL COMPANY - Continued

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
1911	80	ARA-A	.59	.72	1,400	2	-	2	5	9	64.3	MSP&SStM.
	80	ASCE	. -	-	2,701	2	-	1	22	25	92.5	D.& I.R.
	85	ASCE	.58	.71	3,369	-	-	-	1	1	2.9	C.I. &S.
	85	ASCE	.59	.72	1,961	-	-	-	6	6	30.6	C.& E.I.
	85	ASCE	.62	.75	18,108	1	-	31	51	83	45.8	C.R.I.&P.
	85	P.S.	.62	.75	1,523	16	-	4	7	27	177.3	Vandalia
	90	ARA-A	.65	.80	1,078	1	-	8	30	39	361.7	B.& O.
	90	ARA-A	.62	.75	10,000	51	7	31	62	151	151.0	C.B.& Q.
	90	ARA-A	. -	-	2,420	-	-	-	-	0	0.0	C.H.& D.
	90	ARA-A	.63	.76	8,687	20	5	17	13	55	63.3	I.C.
	90	ARA-B	.65	.80	1,934	2	-	-	-	2	10.4	B.& O.
	90	ARA-B	.59	.72	6,000	-	-	-	-	0	0.0	C.& O.
	90	ARA-B	.62	.75	15,420	35	2	34	31	102	66.1	N.P.
	90	ASCE	.60	.73	12,000	9	13	4	60	86	71.6	CCC&St.L.
	90	ASCE	.60	.73	3,149	-	2	-	6	8	25.4	T.& O.C.
	90	G.N.	.62	.75	25,880	68	4	71	143	286	110.5	G.N.
	90	S.F.	.59	.72	3,037	11	7	2	1	21	69.2	A.T.&S.F.
	100	ARA-B	.62	.75	5,000	3	-	1	12	16	32.0	C.& O.
	100	ASCE	.62	.75	13,159	3	-	3	12	18	13.7	M.C.
	100	P.S.	.62	.75	6,069	4	3	1	3	11	18.0	Pa.-N.W.
		Totals			142,895	228	43	210	465	946	66.2	
1912	72	N.P.	.52	.65	3,110	-	-	-	-	0	0.0	N.P.
	80	ASCE	.65	.80	1,432	5	-	-	-	5	34.9	B.& O.C.T
	80	ASCE	.55	.68	3,919	1	-	-	5	6	15.3	T.& O.C.
	85	ARA-A	.59	.72	19,815	7	1	17	9	34	17.2	MSP&SStM.
	85	ASCE	.58	.71	3,392	-	-	-	3	3	8.8	C.I.& S.
	85	ASCE	.58	.71	1,674	2	-	-	1	3	17.9	I.H.Belt
	85	P.S.	.62	.75	10,165	16	-	-	7	23	22.6	Pa.-S.W.
	90	ARA-A	.65	.80	3,166	3	3	-	3	9	28.4	B.& O.
	90	ARA-A	.62	.75	15,000	16	-	1	12	29	19.3	C.B.& Q.
	90	ARA-A	. -	.64	5,845	-	1	-	-	1	1.7	C.& E.I.
	90	ARA-A	. -	-	1,080	-	-	-	-	0	0.0	C.H.& D.
	90	ARA-A	.63	.76	8,495	-	-	-	-	0	0.0	C.R.I.&P.
	90	ARA-A	.63	.76	3,516	10	5	6	4	25	71.0	I.C.
	90	ARA-A	.63	.76	2,947	-	-	-	-	0	0.0	U.P.
	90	ARA-B	.63	.76	6,000	15	1	-	2	18	30.0	C.I.& L.
	90	ARA-B	. -	-	4,000	1	-	-	-	1	2.5	C.& O.
	90	ARA-B	.59	.72	31,250	4	3	1	15	23	7.3	Erie
	90	ARA-B	.62	.75	9,078	32	-	25	11	68	74.9	N.P.
	90	ASCE	.60	.73	10,500	3	-	1	3	7	6.6	CCC&St.L.
	90	ASCE	-	-	1,850	9	-	-	1	10	54.1	D.& I.R.
	90	ASCE	.60	.73	4,149	1	-	-	-	1	2.4	T.& O.C.
	90	S.F.	.63	.76	6,745	2	-	-	-	2	3.0	A.T.&S.F.
	100	ARA-A	.70	.80	7,123	7	-	2	7	16	22.4	B.& O.
	100	ARA-A	.64	.77	5,000	1	1	-	5	7	14.0	C.B.& Q.
	100	ARA-A	. -	-	3,012	1	1	-	-	2	6.6	C.& E.I.
	100	ARA-A	.63	.76	17,446	9	1	-	1	11	6.3	C.R.I.&P.
	100	ARA-B	-	-	6,000	3	1	-	1	5	8.3	C.& O.
	100	ASCE	.62	.75	3,673	4	-	1	1	6	16.3	M.C.
	100	P.S.	.62	.75	3,325	10	-	-	15	25	75.2	Pa.-S.W.
	100	P.S.	.62	.75	10,780	5	3	-	1	9	8.0	Pa.-N.W.
	100	P.S.	.62	.75	5,954	5	-	-	1	6	10.0	Vandalia
		Totals			219,441	172	21	54	108	355	16.2	
1913	80	ASCE	.53	.66	1,638	-	-	-	-	0	0.0	B.&O.C.T.
	80	ASCE	.55	.68	4,151	-	-	-	-	0	0.0	L.E.& W.
	80	ASCE	.55	.68	2,850	1	-	-	-	1	3.5	L.S.&M.S.
	80	ASCE	.55	.68	2,577	-	2	1	3	6	23.3	T.& O.C.
	85	ARA-A	.59	.72	14,701	3	-	-	-	3	2.1	MSP&SStM.
	85	ASCE	.58	.71	8,141	-	-	-	1	1	1.2	C.I.& S.
	85	ASCE	.58	.71	1,350	-	-	-	1	1	7.4	I.H.Belt
	85	P.S.	.62	.75	1,202	-	-	-	1	1	8.3	G.R.& I.
	90	ARA-A	.63	.76	3,578	-	-	3	1	4	11.1	B.& O.
	90	ARA-A	.62	.75	25,000	8	1	1	29	39	15.6	C.B.& Q.
	90	ARA-A	.59	.72	7,755	3	-	-	-	3	3.9	C.& E.I.
	90	ARA-A	.63	.76	13,076	1	-	-	-	1	o.7	C.R.I.&P.
	90	ARA-A	.63	.76	11,863	7	2	3	11	23	19.3	I.C.
	90	ARA-A	.63	.76	7,990	1	-	-	-	1	1.3	U.P.
	90	ARA-B	-	-	2,000	-	-	-	-	0	0.0	C.& O.
	90	ARA-B	.63	.76	4,000	3	-	-	-	3	7.5	C.I.& L.

Table 5 - Sheet 11

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon Min	Spec. Carbon Max	Tons Laid	Total Failures To Date Head	Web	Base	Brkn	Total	Failures Per 10 M Tons	Railroad
Open Hearth - ILLINOIS STEEL COMPANY - Continued												
1913	90	ARA-B	.62	.75	23,475	16	1	-	8	25	10.6	N.P.
	90	ASCE	.60	.73	12,600	-	-	1	3	4	3.1	CCC& StL.
	90	ASCE	.60	.73	5,503	-	1	-	-	1	1.8	T.& O.C.
	90	G.N.	.59	.72	14,590	5	1	10	2	18	12.3	G.N.
	90	S.F.	.63	.76	13,480	4	-	-	2	6	4.4	A.T.&S.F.
	100	ARA-A	.63	.76	9,074	2	-	-	1	3	3.3	B.& O.
	100	ARA-A	.64	.77	5,000	1	-	-	-	1	2.0	C.B.& Q.
	100	ARA-A	.62	.75	1,939	1	-	-	-	1	5.1	C.& E.I.
	100	ARA-A	.63	.76	9,331	5	-	-	-	5	5.4	C.R.I.&P.
	100	ARA-A	.63	.76	4,500	2	-	1	-	3	6.6	Erie
	100	ARA-B	. -	-	4,300	3	1	-	-	4	9.3	C.& O.
	100	ASCE	.62	.75	15,288	-	-	2	6	8	5.2	L.S.&M.S.
	*100	ASCE	.62	.75	2,000	-	-	-	-	0	0.0	L.S.&M.S.
	100	ASCE	.62	.75	15,567	4	-	-	3	7	4.5	M.C.
	100	P.S.	.62	.75	13,246	2	1	-	2	5	4.0	Pa.-N.W.
	100	P.S.	.62	.75	2,322	3	-	-	2	5	21.5	Pa.-S.W.
	100	P.S.	.62	.75	9,487	6	-	-	-	6	6.3	Vandalia
	Totals				273,574	81	10	22	76	189	6.9	
1914	80	ASCE	.55	.68	2,052	-	-	-	-	0	0.0	L.S.&M.S.
	80	ASCE	.55	.68	1,573	-	-	-	-	0	0.0	M.C.
	80	ASCE	.55	.68	1,578	-	-	-	-	0	0.0	T.& O.C.
	85	ARA-A	.59	.72	12,930	-	-	-	-	0	0.0	MSP&SStM.
	85	ASCE	.58	.71	1,770	-	-	-	-	0	0.0	C.I.& S.
	90	ARA-A	.62	.75	17,500	-	-	-	-	0	0.0	C.B.& Q.
	90	ARA-A	.63	.76	27,100	-	-	-	-	0	0.0	I.C.
	90	ARA-B	.60	.73	4,000	-	-	-	-	0	0.0	C.& O.
	90	ARA-B	.62	.75	13,906	1	-	-	-	1	0.7	N.P.
	90	ASCE	.60	.73	7,875	1	-	-	-	1	1.2	CCC&St.L.
	90	ASCE	.60	.73	1,050	-	-	-	-	0	0.0	T.& O.C.
	90	G.N.	.59	.72	9,010	1	-	-	-	1	1.0	G.N.
	100	ARA-A	.63	.76	4,773	-	-	-	-	0	0.0	B.& O.
	100	ARA-A	.64	.77	7,500	-	-	-	-	0	0.0	C.B.& Q.
	100	ARA-A	.63	.76	3,150	-	-	-	-	0	0.0	C.I.& L.
	100	ARA-A	.63	76	7,232	-	-	-	-	0	0.0	C.R.I.&P.
	100	ARA-B	.62	.75	3,100	7	-	-	-	7	22.6	C.& O.
	100	ASCE	.62	.75	10,340	-	-	-	-	0	0.0	L.S.&M.S.
	100	ASCE	.62	.75	3,680	-	-	1	-	1	2.7	M.C.
	100	P.S.	.62	.75	13,126	-	-	-	-	0	0.0	Pa.-N.W.
	100	P.S.	.45	.55	5,808	-	-	-	-	0	0.0	Vandalia
	Totals				159,053	10	-	1	-	11	0.6	
Open Hearth - LACKAWANNA STEEL COMPANY												
1909	85	P.S.	.62	.75	6,920	16	2	1	1	20	28.9	P.R.R.
	91	DL&W.	.70	.83	5,956	6	-	1	15	22	36.8	D.L.& W.
	100	P.S.	.62	.75	1,723	35	4	-	42	81	470.1	P.R.R.
	Totals				14,599	57	6	2	58	123	84.2	
1910	85	ASCE	.63	.76	2,000	1	-	5	2	8	40.0	B.& M.
	85	P.S.	.62	.75	3,990	14	2	-	5	21	52.6	P.R.R.
	90	G.N.	.62	.75	10,830	67	1	23	23	114	105.3	G.N.
	91	DL&W.	.67	.80	4,255	11	-	4	16	31	72.9	D.L.& W.
	100	Dudley	.62	.75	6,482	5	-	1	2	8	12.3	NYC& HR.
	100	P.S.	.62	.75	3,348	6	3	-	2	11	32.8	P.R.R.
	Totals				30,905	104	6	33	50	193	62.4	
1911	80	Dudley	.55	.68	17,834	7	1	6	22	36	20.2	NYC& HR.
	85	P.S.	.62	.75	1,615	1	-	-	1	2	12.4	P.R.R.
	90	ASCE	.70	.85	1,564	6	1	7	-	14	89.5	L.V.
	91	DL&W.	.67	.80	12,485	13	4	7	22	46	36.6	D.L.& W.
	100	ARA-A	.63	.76	1,072	29	2	1	1	33	307.8	L.V.
	100	Dudley	.62	.75	7,013	7	3	1	3	14	20.0	B.& A.
	100	Dudley	.62	.75	12,549	7	1	5	12	25	19.9	NYC& HR.
	100	P.S.	.62	.75	2,079	22	4	-	18	44	211.0	P.R.R.
	101	DL&W.	.70	.83	3,369	17	2	1	5	25	74.2	D.L.& W.
	Totals				59,580	109	18	28	84	239	40.1	
1912	72	N.P.	.52	.65	3,404	-	-	-	-	0	0.0	N.P.
	80	Dudley	.55	.68	20,000	36	2	1	15	54	27.0	NYC& HR.
	85	ASCE	.65	.78	4,400	-	-	-	-	0	0.0	B.& M.

* Ferro Titanium Alloy Added

Table 5 - Sheet 12

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
Open Hearth - LACKAWANNA STEEL COMPANY - Continued												
1912	90	ARA-B	.59	.72	9,886	1	1	-	-	2	2.0	Erie
	90	ASCE	.62	.75	2,504	8	1	-	6	15	59.9	P.& R.
	90	Dudley	.60	.73	2,500	-	-	-	-	0	0.0	Rutland.
	90	G.N.	.62	.75	38,130	13	-	3	-	16	4.2	G.N.
	100	ARA-A	.63	.76	5,785	72	4	-	-	76	131.3	L.V.
	100	Dudley	.62	.75	12,965	4	1	1	2	8	6.2	B.& A.
	100	Dudley	.62	.75	35,545	3	-	1	1	5	1.4	NYC &HR.
	100	P.S.	.62	.75	3,420	14	2	-	12	28	81.7	P.R.R.
	101	DL&W	.70	.83	14,230	4	1	1	2	8	5.6	D.L.& W.
		Totals			152,769	155	12	7	38	212	13.9	
1913	80	ARA-A	.53	.66	2,150	-	-	-	-	0	0.0	N.Y.S.&W.
	80	ASCE	.55	.68	4,400	-	-	-	-	0	0.0	L.S.& M.S
	80	Dudley	.55	.68	22,559	-	1	2	1	4	1.8	NYC& HR.
	85	ASCE	.65	.78	8,602	-	-	2	1	3	3.4	B.& M.
	90	ARA-A	.59	.72	5,000	-	-	-	3	3	6.0	C.B.& Q.
	90	ASCE	.62	.75	2,995	16	3	-	22	41	136.7	P.& R.
	90	G.N.	.62	.75	15,180	5	-	1	-	6	3.9	G.N.
	91	DL&W.	.67	.80	1,491	-	-	-	-	0	0.0	D.L.& W.
	100	ARA-A	.63	.76	1,453	-	-	-	-	0	0.0	C.R.I.&P.
	100	ARA-A	.63	.76	8,000	1	-	-	-	1	1.2	Erie
	100	ARA-A	.63	.76	8,323	93	-	1	3	97	116.5	L.V.
	100	ASCE	.62	.75	5,350	3	-	-	7	10	18.7	M.C.
	100	P.S.	.62	.75	11,094	2	-	1	2	5	4.5	P.R.R.
	101	DL&W.	.67	.80	11,780	-	-	-	-	0	0.0	D.L.& W.
	105	Dudley	.62	.75	8,585	-	-	-	-	0	0.0	B.& A.
	105	Dudley	.62	.75	42,884	3	1	11	-	15	3.5	NYC& HR.
		Totals			159,846	123	5	18	39	185	11.6	
1914	85	ASCE	.63	.76	5,000	-	-	-	-	0	0.0	Me.C.
	90	ARA-A	.59	.72	3,000	-	-	-	-	0	0.0	C.B.& Q.
	90	ASCE	.67	.80	3,009	-	-	-	-	0	0.0	P.& R.
	91	DL&W.	.64	.77	3,660	-	-	-	-	0	0.0	D.L.& W.
	100	ARA-A	.63	.76	4,056	-	-	-	-	0	0.0	L.V.
	100	P.S.	.62	.75	3,338	-	-	-	-	0	0.0	P.R.R.
	101	DL&W.	.64	.77	4,431	-	-	-	-	0	0.0	D.L.& W.
	105	Dudley	.62	.75	5,070	-	-	-	-	0	0.0	B.& A.
	105	Dudley	.62	.75	30,908	1	-	-	-	1	0.3	NYC& HR.
		Totals			62,472	1	-	-	-	1	0.2	
Open Hearth - MARYLAND STEEL COMPANY												
1910	80	ASCE	.62	.79	7,430	2	1	-	1	4	5.4	NYNH& H.
	85	ASCE	.55	.68	9,000	9	4	-	12	25	27.7	A.C.L.
	85	ASCE	.59	.72	4,800	5	5	18	1	29	60.4	B.& M.
	85	P.S.	.62	.75	1,596	6	2	-	-	8	50.1	P.R.R.
	90	ARA-B	.65	.80	3,437	81	2	2	51	136	395.3	B.& O.
	100	ARA-A	.62	.75	2,019	1	-	-	2	3	14.8	C.of N.J.
	100	P.S.	.62	.75	1,248	14	3	-	8	25	200.3	P.R.R.
		Totals			29,530	118	17	20	75	230	77.8	
1911	85	ASCE	.55	.68	11,000	1	4	2	1	8	7.3	A.C.L.
	85	ASCE	.59	.72	13,300	1	-	4	6	11	8.3	B.& M.
	85	P.S.	.62	.75	1,750	3	5	-	4	12	68.6	P.R.R.
	90	ARA-B	.65	.80	3,839	9	1	-	12	22	57.3	B.& O.
	100	ARA-B	.70	.80	2,967	16	2	-	13	31	104.3	B.& O.
	100	ARA-B	.62	.75	3,000	9	1	-	20	30	100.0	C.& O.
	100	ARA-B	.62	.75	6,216	27	3	-	4	34	54.7	N.& W.
	100	NYNH.	.62	.75	8,500	8	1	6	10	25	29.4	B.& M.
	100	P.S.	.62	.75	1,590	2	-	-	5	7	44.0	P.R.R.
		Totals			52,162	76	17	12	75	180	34.5	
1912	85	ASCE	.55	.68	4,650	-	-	-	-	0	0.0	A.C.L.
	85	ASCE	.40	.50	3,370	-	-	-	1	1	3.0	Southern
	100	P.S.	.62	.75	1,477	2	1	-	-	3	20.3	P.R.R.
		Totals			9,497	2	1	-	1	4	4.2	
1913	80	ASCE	.58	.71	3,446	-	-	-	-	0	0.0	NYNH& H.
	85	ASCE	.55	.68	5,950	-	-	-	-	0	0.0	A.C.L.
	85	ASCE	.62	.75	2,011	1	-	-	-	1	4.9	N.& W.
	85	ASCE	.40	.50	6,289	1	-	-	-	1	1.6	Southern
	100	ARA-B	.63	.76	10,152	31	2	1	24	58	57.1	B.& O.
	100	ARA-B	.62	.75	5,622	1	-	-	-	1	1.8	N.& W.
	100	P.S.	.62	.75	7,055	9	5	2	3	19	26.9	P.R.R.
		Totals			40,525	43	7	3	27	80	19.7	

Table 5 - Sheet 13

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
1914	80	ASCE	.53	.66	2,169	-	-	-	-	0	0.0	NYNH& H.
	85	ASCE	.55	.68	17,900	-	-	-	-	0	0.0	A.C.L.
	100	P.S.	.62	.75	18,619	1	1	1	-	3	1.6	P.R.R.
		Totals			38,688	1	1	1	-	3	0.8	
Open Hearth - PENNSYLVANIA STEEL COMPANY												
1909	80	ASCE	. -	-	2,999	-	5	1	4	10	33.3	C.N.E.
	85	ASCE	.62	.75	6,000	6	4	-	-	10	16.6	N.& W.
	85	P.S.	.62	.75	6,242	16	12	1	7	36	57.7	P.R.R.
	90	ASCE	.70	.85	2,500	3	1	-	7	11	44.0	P.& R.
	90	G.N.	.59	.72	2,838	33	6	-	4	43	151.5	G.N.
	100	ARA-A	.70	.85	1,513	2	1	-	4	7	46.3	C.of N.J.
	100	ASCE	. -	-	4,177	-	4	-	1	5	11.9	L.I.
	100	NYNH&H	.70	.90	4,405	3	5	-	4	12	27.3	NYNH& H.
	100	P&R.	.70	.85	2,500	42	3	-	2	47	188.0	P.& R.
	100	P.S.	-	-	2,441	2	15	-	1	18	73.8	Cumb.V.
	100	P.S.	.62	.75	6,294	32	30	-	32	94	149.3	P.R.R.
		Totals			41,909	139	86	2	66	293	69.9	
1910	75	ASCE	.52	.65	6,233	3	1	23	72	99	158.8	B.& M.
	80	ASCE	.70	.85	4,070	-	45	-	6	51	125.3	NYNH& H.
	85	ASCE	.62	.75	13,500	12	3	-	12	27	20.0	N.& W.
	85	P.S.	.62	.75	5,444	1	8	1	6	16	29.4	P.R.R.
	90	ASCE	.70	.85	3,564	2	-	-	1	3	8.4	P.& R.
	100	ARA-A	.70	.85	2,403	9	-	-	8	17	70.7	C.ofN.J.
	100	NYNH&H	.70	.85	5,432	2	67	-	7	76	139.9	NYNH& H.
	100	P.&R.	.70	.85	10,000	12	8	1	11	32	32.0	P.& R.
	100	P.S.	. -	-	1,977	4	-	-	-	4	20.0	Cum.V.
	100	P.S.	.62	.75	11;540	94	23	1	58	176	152.5	P.R.R.
		Totals			64,163	139	155	26	181	501	78.1	
1911	80	ASCE	.70	.85	1,620	-	8	2	-	10	61.7	NYNH& H.
	90	ASCE	.70	.85	3,500	13	2	1	43	59	168.5	P.& R.
	100	ARA-A	.70	.85	1,649	2	-	1	7	10	60.6	C.of N.J.
	100	NYNH&H	.70	.85	4,916	-	6	4	8	18	36.6	NYNH& H.
	100	P.&R.	.70	.85	6,500	5	1	-	4	10	15.3	P.& R.
	100	P.S.	. -	-	1,038	-	-	-	-	0	0.0	Cumb.V.
	100	P.S.	.62	.75	3,865	9	1	2	9	21	54.3	P.R.R.
	101	DL&W.	.70	.83	1,788	-	1	-	1	2	11.2	D.L.&W.
		Totals			24,876	29	19	10	72	130	52.3	
1912	72	N.P.	.52	.65	1,757	-	-	-	-	0	0.0	N.P.
	85	ASCE	. -	-	5,990	-	2	-	-	2	3.3	A.C.L.
	85	ASCE	.62	.75	4,485	-	2	-	2	4	8.9	N.& W.
	90	ASCE	.67	.80	6,504	3	1	-	10	14	21.5	P.& R.
	90	G.N.	.59	.72	24,148	4	1	2	19	26	10.8	G.N.
	100	ARA-A	.70	.85	6,373	-	-	-	-	0	0.0	C.of N.J.
	100	ARA-B	-	-	1,000	-	-	-	-	0	0.0	C.& O.
	100	ARA-B	.62	.75	2,175	1	-	-	-	1	4.6	N.& W.
	100	ARA-B	.62	.75	2,048	-	-	-	4	4	19.5	N.P.
	100	P.&R.	.67	.80	9,951	7	1	-	7	15	15.0	P.& R.
	100	P.S.	-	-	2,071	1	-	-	-	1	5.0	Cumb.V.
	100	P.S.	.62	.75	4,941	10	-	-	2	12	24.3	P.R.R.
	101	DL&W.	.62	.75	2,202	-	-	-	-	0	0.0	D.L.& W.
		Totals			73,645	26	7	2	44	79	10.7	
1913	72	N.P.	.52	.65	2,984	-	-	-	-	0	0.0	N.P.
	80	ASCE	. -	-	1,005	-	-	-	-	0	0.0	C.N.E.
	80	ASCE	.58	.71	1,265	-	-	-	-	0	0.0	NYNH& H.
	85	ASCE	.55	.68	1,010	-	-	-	-	0	0.0	A.C.L.
	90	ARA-B	.59	.72	10,442	-	-	-	-	0	0.0	N.P.
	90	ARA-B	.62	.75	1,045	-	-	3	4	7	67.0	N.P.
	90	G.N.	.59	.72	4,882	3	1	3	3	10	20.5	G.N.
	100	ARA-A	.70	.85	3,882	3	-	-	-	3	7.7	C.of N.J.
	100	ARA-A	.63	.76	10,306	12	-	2	-	14	13.6	L.V.
	100	ARA-B	.62	.75	1,904	-	-	-	3	3	15.8	N.P.
	100	NYNH	.63	.76	3,550	-	-	1	-	1	2.8	B.& M.
	100	NYNH&H	.65	.78	10,920	-	4	1	1	6	5.5	NYNH& H.
	100	P.&R.	.67	.80	18,988	3	-	-	1	4	2.1	P.& R.
	100	P.S.	-	-	1,536	-	-	-	-	0	0.0	Cumb.V.
	100	P.S.	.62	.75	7,757	5	-	-	-	5	6.4	P.R.R.
	101	DL&W.	-	-	7,980	1	-	-	3	4	5.0	DL& W.
		Totals			89,466	27	5	10	15	57	6.3	

Table 5 - Sheet 14

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
Open Hearth - PENNSYLVANIA STEEL COMPANY - Continued												
1914	75	B.&M.	.53	.63	1,920	-	-	-	-	0	0.0	B.& M.
	85	ASCE	.63	.76	1,490	-	-	-	-	0	0.0	B.& M.
	90	ARA-B	.59	.72	3,192	-	-	-	-	0	0.0	N.P.
	90	ASCE	.67	.80	1,003	-	-	-	-	0	0.0	P.& R.
	90	G.N.	.59	.72	1,505	-	-	-	1	1	6.6	G.N.
	100	NYNH.	.63	.76	1,572	-	-	-	-	0	0.0	B.& M.
	100	NYNH&H	.63	.76	4,480	-	-	-	-	0	0.0	NYNH& H.
	100	P.&R.	.67	.80	5,526	-	-	-	-	0	0.0	P.& R.
	100	P.S.	.62	.75	4,834	1	-	-	-	1	2.1	P.R.R.
	101	DL&W.	. -	-	4,376	-	1	-	2	3	6.9	D.L.& W.
		Totals			29,898	1	1	-	3	5	1.6	
Open Hearth - TENNESSEE COAL, IRON & RAILROAD COMPANY												
1909	75	ASCE	.52	.65	5,366	2	6	12	5	25	46.6	Southern
	80	ASCE	.59	.72	9,100	2	-	2	1	5	5.5	C. of G.
	80	ASCE	.59	.72	8,035	18	-	1	2	21	26.1	Southern
	85	ASCE	.55	.68	10,000	-	-	-	2	2	2.0	A.C.L.
	85	ASCE	.59	.72	5,013	24	-	-	2	26	51.9	C.C.& O.
	85	ASCE	. -	-	3,682	1	3	-	2	6	16.3	M.& O.
	85	ASCE	.59	.72	28,396	358	5	2	34	399	140.5	Southern
	90	ARA-A	.63	.76	4,950	5	-	-	1	6	12.1	G.H.&S.A.
	90	ARA-A	.63	.76	2,111	3	-	-	-	3	14.2	T.& N.O.
	90	C.S.	.62	.75	3,400	15	-	-	1	16	47.0	C. of G.
		Totals			80,053	428	14	17	50	509	63.8	
1910	80	ASCE	.59	.72	3,000	1	1	-	1	3	10.0	C. of G.
	80	ASCE	.55	.68	24,655	55	7	16	12	90	36.5	L.& N.
	85	ASCE	.55	.68	15,000	-	1	-	-	1	0.7	A.C.L.
	85	ASCE	-	-	7,051	2	1	-	4	7	9.9	M.& O.
	85	ASCE	.59	.72	24,635	166	15	20	32	233	94.7	Southern
	85	ASCE	.59	.72	8,353	31	3	-	6	40	47.8	StL& SF.
	90	ARA-A	.58	.71	1,000	8	-	-	-	8	80.0	C. of G.
	90	ARA-A	.63	.76	10,074	12	-	-	-	12	11.9	G.H.&S.A.
	90	ARA-A	.63	.76	4,216	9	-	-	-	9	21.4	H.& T. C.
	90	ARA-A	.63	.76	3,552	3	-	3	1	7	19.7	M.L.&T&S.
	90	ARA-A	-	-	16,725	22	3	1	3	29	17.3	S.P.
	90	ARA-A	.63	.76	5,379	2	-	-	-	2	3.7	T.& N.O.
		Totals			123,640	311	31	40	59	441	35.7	
1911	75	C.S.	.55	.68	2,218	-	-	-	-	0	0.0	H.& T.C.
	75	C.S.	.55	.68	2,800	-	-	-	-	0	0.0	M.L.&T.&S
	80	ASCE	.58	.71	7,000	-	-	-	-	0	0.0	C. of G.
	85	ASCE	.55	.68	15,000	1	1	-	-	2	1.3	A.C.L.
	85	ASCE	. -	-	2,477	1	-	-	2	3	12.1	M.& O.
	85	ASCE	.59	.72	31,829	69	5	7	16	97	30.5	Southern
	85	ASCE	.59	.72	6,602	9	1	-	9	19	28.7	StL& SF.
	90	ARA-A	.58	.71	3,000	8	-	-	1	9	30.0	C. of G.
	90	ARA-A	.63	.76	3,117	3	-	-	-	3	9.6	H.&T.C.
	90	ARA-A	.63	.76	1,000	1	-	-	1	2	20.0	M.L.&T&S.
	90	ARA-A	.63	.76	8,999	20	6	2	3	31	34.5	I.C.
	90	ARA-A	-	-	1,415	1	-	-	-	1	7.1	S.P.
	90	ARA-A	.63	.76	3,373	-	-	-	-	0	0.0	T.& N.O.
		Totals			88,830	113	13	9	32	167	18.8	
1912	80	ASCE	.58	.71	1,800	3	-	1	3	7	38.9	C. of G.
	80	ASCE	.55	.68	10,266	6	2	-	4	12	11.7	L.& N.
	85	ASCE	.55	.68	11,980	2	1	-	4	7	5.8	A.C.L.
	85	ASCE	.59	.72	8,423	7	-	-	7	14	16.6	StL& SF.
	85	ASCE	.59	.72	22,024	45	2	10	8	65	29.5	Southern
	90	ARA-A	.58	.71	2,000	1	1	1	-	3	15.0	C. of G.
	90	ARA-A	.63	.76	1,727	2	-	-	-	2	11.5	G.H.&S.A.
	90	ARA-A	.63	.76	16,903	26	2	71	51	150	88.7	I.C.
	90	ARA-A	-	-	1,191	-	-	-	1	1	8.4	S.P.
	90	ARA-B	.60	.73	31,465	19	8	1	5	33	10.5	L.& N.
	90	ASCE	.59	.72	13,000	3	-	-	10	13	10.0	StL& SF.
	90	S.F.	.63	.76	8,733	5	-	-	-	5	5.7	A.T.&S.F.
		Totals			129,512	119	16	84	93	312	24.1	
1913	75	C.S.	.55	.68	5,020	-	-	-	-	0	0.0	G.H.& S.A
	80	ASCE	.58	.71	5,300	2	-	-	-	2	3.8	C. of G.
	80	ASCE	.53	.66	9,251	1	-	-	1	2	2.1	L.& N.
	85	ASCE	.55	.68	14,940	-	-	-	-	0	0.0	A.C.L.
	85	ASCE	. -	-	1,228	-	-	-	-	0	0.0	M.& O.
	85	ASCE	.59	.72	25,814	15	1	2	2	20	7.7	Southern

Table 5 - Sheet 15

Total Rail Failures From Date Rolled to October 31st, 1914.

Year Rolled	Lbs. Per Yard	Sect'n	Spec. Carbon		Tons Laid	Total Failures To Date					Failures Per 10 M Tons	Railroad
			Min	Max		Head	Web	Base	Brkn	Total		
Open Hearth - TENNESSEE COAL, IRON & RAILROAD COMPANY - Continued												
1913	90	ARA-A	.58	.71	2,200	1	-	-	-	1	4.5	C. of G.
	90	ARA-A	.63	.76	7,179	-	-	-	-	0	0.0	G.H.&S.A.
	90	ARA-A	.63	.76	10,947	-	-	-	-	0	0.0	H.& T.C.
	90	ARA-A	.63	.76	37,159	9	3	2	3	17	4.6	I.C.
	90	ARA-A	.63	.76	4,848	-	-	-	-	0	0.0	ML&T&S.
	90	ARA-A	.63	.76	7,067	-	-	-	-	0	0.0	T.& N.O.
	90	ARA-B	.63	.76	56,719	17	11	2	6	36	6.3	L.& N.
	90	ASCE	.62	.75	7,725	2	1	-	-	3	3.9	St.L.&S.F.
	Totals				195,397	47	16	6	12	81	4.1	
1914	80	ASCE	.53	.66	7,027	-	-	-	-	0	0.0	L.& N.
	85	ASCE	.55	.68	15,750	-	-	-	-	0	0.0	A.C.L.
	85	ASCE	. -	-	1,800	1	-	-	-	1	5.5	M.& O.
	85	ASCE	.59	.72	22,429	5	-	-	-	5	2.2	Southern
	90	ARA-A	.63	.76	27,388	2	-	-	1	3	1.1	I.C.
	90	ARA-B	.63	.76	80,914	6	1	1	3	11	1.4	L.& N.
	90	ASCE	.62	.75	17,600	-	-	-	1	1	0.6	St.L.&SF.
	Totals				172,908	14	1	1	5	21	1.2	
Special Open Hearth - PENNSYLVANIA STEEL COMPANY												
1910	135	Spcl.	.90	1.10	818	81	1	-	-	82	1002.4	C. of N.J.
	135	Spcl.	.90	1.00	1,581	17	-	-	1	18	113.8	C. of N.J.
	135	Spcl.	.90	1.05	2,887	2	-	-	1	3	10.4	C. of N.J.

Appendix C.

SEGREGATION AND SPONGINESS IN LADLE TEST INGOTS.

By Robert W. Hunt & Co.

A recent order for the inspection of open-hearth steel rails was of such a character as to demand a check for the manufacturer's chemical analysis of each heat represented, and the results of our analyses differed so widely from those reported by the mill that it was finally deemed advisable to make some investigation of matters pertaining to ladle test ingots, and principally to the possibilities of their segregation and soundness. Appreciating the importance of the subject, we herewith present to the Rail Committee some of the facts recorded with a view of enabling them to extend the investigation if they should see fit and to take such steps as are practical to afford relief from present difficulties.

What has been known to exist for a long time became apparent at the outset of our investigation, and was, simply, that ladle test ingots were subject to unsoundness and segregation exactly as are all large ingots, the only difference being one of degree. Obviously as long as this condition exists, it is manifestly impossible to expect analyses of the same test ingot by different chemists to agree within the limits of possible chemical error unless drillings for the samples are taken with special care and mixed and divided so as to insure both chemists working on identical lots. But of much greater importance is the fact that when the ladle test ingot is segregated and unsound, the drillings taken from it may not be representative of the steel or heat as a whole, and the reported results are therefore misleading and inaccurate. Thus a heat of steel can be reported as .60% for carbon, while as a matter of fact, it was actually .75%, and vice versa, it might be reported as .75% and really be .60%. These figures are not exaggerations but are the differences reported by two chemists on drillings from the same test ingot.

This subject is not a new one and but recently a committee of the United States Steel Corporation has made a considerable study of ladle test ingots which has resulted in prescribing certain conditions for the guidance of their mills; and the American Society for Testing Materials has a committee, at the present time, co-operating with the Government Bureau of Standards in an investigation relating to ladle test ingots.

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Notwithstanding such steps as have been taken we feel that certain fundamental facts are already established, and if the consistent adoption

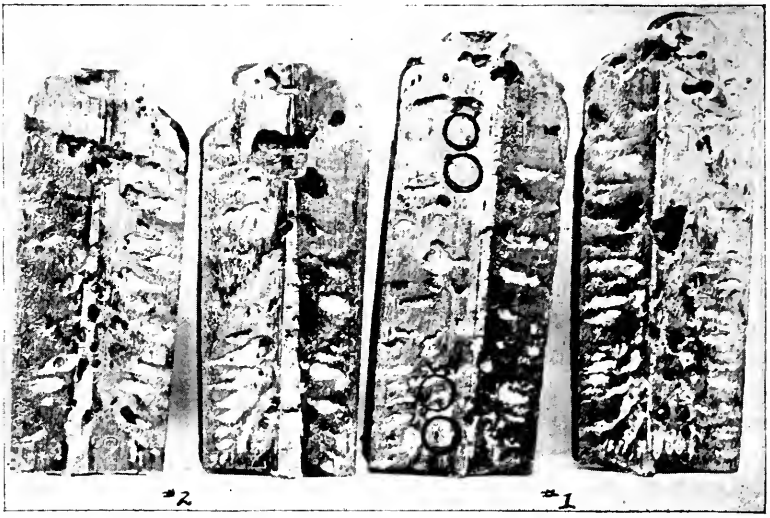

Fig. 1—Samples of Ladle Test Ingots of Steel as Poured.

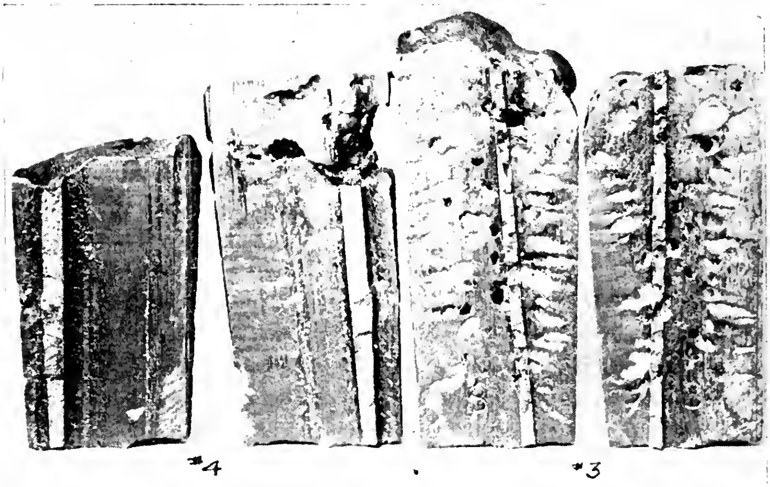

Fig. 2—Samples of Ladle Test Ingots. No. 3 Was Taken of the Steel as Poured and No. 4 Had Ferro-Silicon Added to It.

of practice based on these facts could be attained by immediate action a great benefit would be accomplished.

At the mill at which we were engaged, as mentioned above, the ladle test ingot mold was about 2½ inches square at the top, 2 inches square at the bottom and 5 inches high. Depending on the amount of steel poured into it and the extent of its boiling, or raising up of the top, the resulting ingots varied in height from 3 to 6 inches, and when they were drilled, in order to obtain the sample for analysis, many cavities were encountered. In some instances it became necessary to take drillings from two different locations on the same ingot and in such cases the chemical results varied by as much as .15% carbon (by combustion). The character of these ingots when split open is as shown by Figs. 1 and 2 and some chemical results on sample drillings from them are given below, although the difference in these cases happens to be small.

These samples of ladle test ingots were taken from the same heat of open-hearth rail steel and split open to show the interior structure.

No. 1 was taken from the second large ingot cast.

No. 2 was taken from the sixth large ingot cast.

No. 3 was taken from the thirteenth (and last) large ingot cast.

No. 4 was taken from the thirteenth large ingot cast but had ferro-silicon added to it as it was being cast.

Analysis on drilling from:	C	P	Mn	S	Si
Mill ladle test ingot	.71	.012	.81	.030	.079
Inside top of No. 1 (as indicated by circles)	.71	.021	..	...	...
Inside bottom of No. 1 (as indicated by circles)	.659	.018	..	...	...
Outside top of No. 1	.64	.016	..	...	...
Outside bottom of No. 1	.637	.017	..	...	...
Outside bottom of No. 2	.63	.018	..	...	...
Outside bottom of No. 3	.636	.018	..	...	...
Outside bottom of No. 4	.64	.019	..	...	.42

Obviously the metal near the outside of the ingots differed from that near the inside and the location of the drillings with respect to the height particularly, also gave different results. It will be noted with interest that the degree of porosity is apparently somewhat greater in the ingot from the first part of the heat than that from the last part of the heat, and further, that the addition of the deoxidizing agent, ferro-silicon, experimentally in one case, made that ingot absolutely sound for most of its height.

Nearly every rail mill has had a style of ladle test ingot of its own and the shapes and dimensions of those in vogue about two years ago are shown in Fig. 3. Some of these have been changed since that time and Figs. 4, 5, 6 and 7 show a collection of various ingots representing rail steel that have been lately cast and split open in order to show their interior condition. The ingots have been split in the center and the half section showing unsoundness and piping is shown together with the outside half elevation. The illustrations are about one-third full size. It

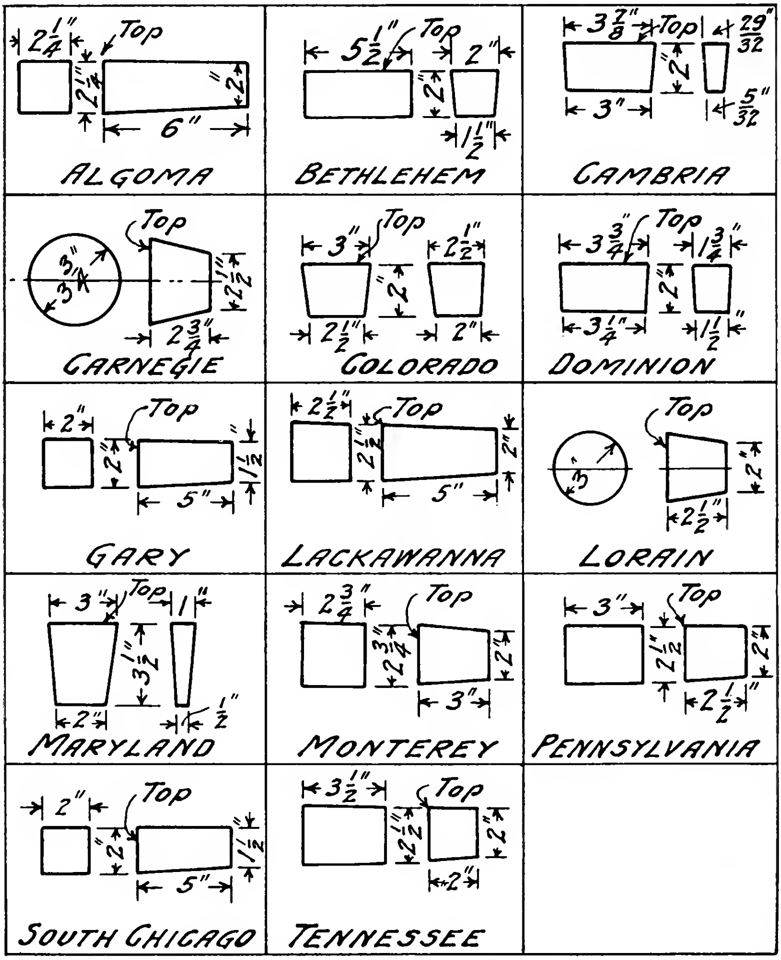

Fig. 3—Diagrams of Various Ladle Test Ingots.

will be observed that many are very unsound and no doubt in such cases segregated. Those that are sound, except for the pipe, have had aluminum added and with the result that a quiet setting steel free from blow holes has been obtained.

Soundness, viz.: freedom from blow holes, etc., is a very important feature for ladle test ingots to possess. In the first place, the more unsound one is the more it is inclined to be segregated, and secondly, in drilling steel that is full of blow holes, minute particles break off from the sides of the holes and render the chemical determination for carbon by combustion methods more difficult of accuracy than when thin flake-like drillings are furnished.

FIG. 4—SAMPLES OF LADLE TEST INGOTS.

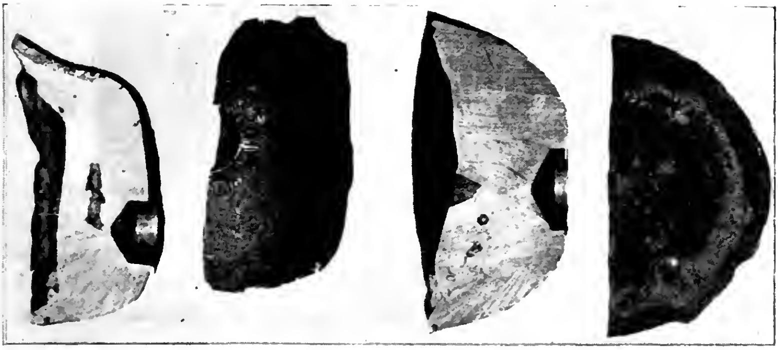

FIG. 5—SAMPLES OF LADLE TEST INGOTS.

From the results shown in Figs. 4, 5, 6 and 7, it is quite evident that the soundness of the test ingot is not predicated by its shape. At the same time it is logical to regard a thin slab like shape as preferable, because of its tendency to chill quickly and thus solidfy with a minimum degree of segregation. The disadvantage of this shape of test ingot lays principally in the difficulty of obtaining sufficient drillings to provide for the requisite number of analyses.

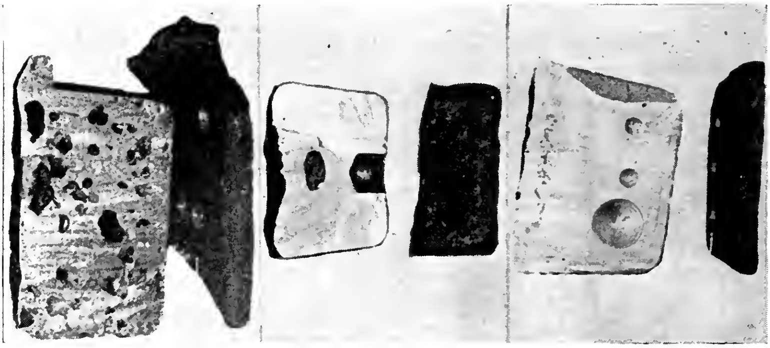

Fig. 6—Samples of Ladle Test Ingots.

Fig. 7—Samples of Ladle Test Ingots.

The addition of a deoxidizing agent to insure a sound setting steel and a ladle test ingot free from blow holes is more or less common practice at some mills, and commercially pure aluminum in the form of pellets is admirably adapted for this purpose. Fig. 8 shows two ladle test ingots (about one-third size) cast in similar molds of as nearly identical steel as it is possible to obtain from the stream filling a single large mold. In one case (sample A) no aluminum was used, with the result that the ingot was spongy, boiled badly in the mold and showed considerable segregation on analyses of different samples from the exterior and the interior. In the other cases (sample B) the addition of a little aluminum made the metal set absolutely sound, excepting for the inevitable pipe, while analyses of drillings from corresponding locations as in the first case indicated that the segregation had been materially reduced and without appreciable influence on the amount of carbon present.

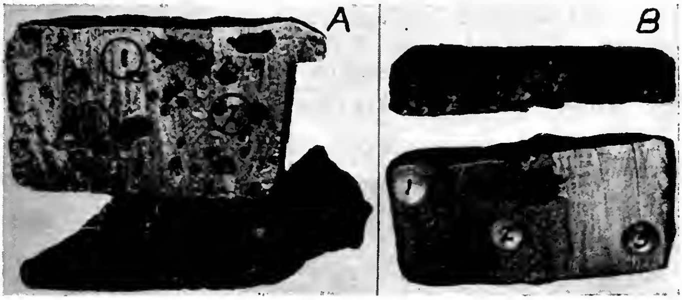

Fig. 8—Two Ladle Test Ingots of Same Steel, A as Poured and B With Aluminum.

Both ingots were drilled at the locations shown, from the outside in and also on the inside. Thus there were six sets of drillings in each case. Results for carbon (by combustion) are:

	Location			
Ingot	No. 1	No. 2	No. 3	Average
Without aluminum—outside	.692	.663	.708	.683
Without aluminum—inside	.640	.686	.72	.682
With aluminum—outside	.667	.715	.695	.692
With aluminum—inside	.70	.686	.70	.695

	With aluminum	Without aluminum
Greatest difference outside samples	.048	.045
Greatest difference inside samples	.014	.08
Greatest difference all samples	.048	.08

From the above it would appear that aluminum acted toward retarding segregation by causing the metal to set solid and it does not appreciably raise the carbon by so doing.

The efficacy of aluminum additions is further shown by reference to Fig. 9, which illustrates three ladle test ingots (about one-third size) to which aluminum was added at the time of pouring. The types of ladle test ingots there given are slow cooling because of their shapes and dimensions and much reason exists therefore, for anticipating spongy and segregated metal. Yet in every instance the steel, from the three widely separated mills represented and which ordinarily make what may be termed a low silicon or raising steel, has been made to set sound and clean by using aluminum. Careful analyses of these ingots on samples taken at various locations fails to detect any segregation beyond the limits of chemical error.

Below are given results for carbon (by combustion) on drillings taken as shown; No. 3 in each case being from the outside in as the ingot would ordinarily be drilled, and Nos. 1 and 2 being on the inside in order to show segregation, if any:

	No. 1	No. 2	No. 3
Ingot A	.634	.61	.607
Ingot B	.706	.728	.71
Ingot C	.572	.563	.574

From the three analyses made on each ingot it is clear that little, if any, segregation exists in either case.

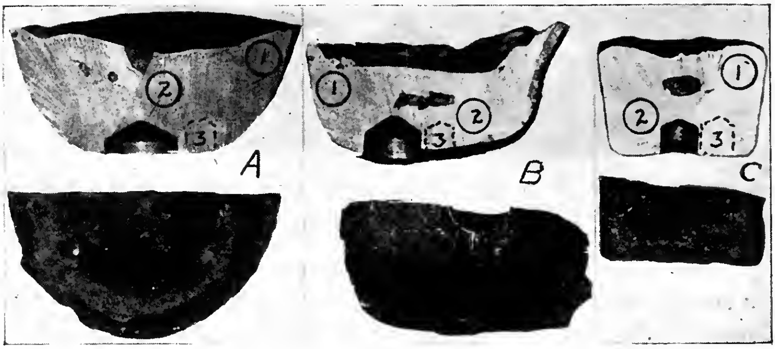

FIG. 9—LADLE TEST INGOTS TO WHICH ALUMINUM HAD BEEN ADDED.

Based on the experience of the past, therefore, we feel constrained to recommend such additions to rail specifications as will provide:

First. A standard shape and size for ladle test ingots with directions as to the size of drill and location of the borings on which the analysis is made.

Second. The addition of aluminum, preferably in the dipper, when necessary to insure a sound setting steel in the ladle test ingot with freedom from blow holes.

In conclusion, we submit that the location of the test ingot in the heat with respect to the regular ingots cast, is also deserving of consideration, as is also the precise method of making the analysis for the various chemical elements; but as these matters must of necessity require much time and study, we feel that they can be best left to development by the Testing Materials Society. The above mentioned recommendations, we feel, are more pertinent to present conditions and warrant early consideration.

Appendix D.

INFLUENCE ON RAILS OF METHOD OF BLOOMING

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report covers tests concerning the influence on the rails, of the manner in which the bloom is rolled, and particularly with reference to the transverse ductility of the bottom of the base of the rail. Blooms were rolled from ingots with varying amounts of reduction between turns. Some ingots were given light reductions, or squeezes, and turned so as to bring the other two sides in contact with the rolls, and other ingots were given successively greater reductions between turns. Also some of the rails were rolled so that what was the top side of the ingot as it first entered the blooming rolls, formed the head of the rail and other rails were rolled so that the top side of the ingot formed the web of the rail. The rails were tested by means of drop tests, tension tests, transverse tests of the base, and polishing of cross-sections. The work was done at Ensley, Ala., at the works of the Tennessee Coal, Iron and Railroad Co., who kindly furnished all the material and facilities for the investigation.

MANUFACTURE.

The steel used was open-hearth steel, made by the triplex process. In this process most of the blast furnace metal used was blown in bessemer converters, transferred to an open-hearth furnace, where most of the phosphorus was removed (the ore used being very high in phosphorus) and then transferred to another open-hearth furnace, where the process of refinement was completed. The heat was number 83,301, made April 3, 1915, and the mill record of the material used in making it was as shown in Table 1.

TABLE 1—MATERIALS USED IN HEAT.

Charge—	Purified Metal	138,300 lbs.
	Blown Metal	47,900 lbs.
	Ingot Butts	27,700 lbs.
	B. B. & S. Crops	27,100 lbs.
	Total charge	241,000 lbs.
Additions—	Hard Ore	2,700 lbs.
	Burnt Lime	7,800 lbs.
	Ferro-manganese	2,800 lbs.
	Ferro-silicon	500 lbs.
	Aluminum	10 lbs.
	Coke	900 lbs.

Rail Report No. 50, June, 1915.

Part of the ferro-manganese was added to the furnace and the rest to the ladle. The coke and most of the ferro-silicon were added to the ladle. The aluminum and a small part of ferro-silicon were added to the molds while pouring the steel. The steel was poured into ingots 24x24 inches at the bottom, about 69 inches high, and averaging 9,461 pounds each. The heat weighed 223,200 pounds and made 23 ingots and a 45-inch butt. The ladle analysis of the steel was as follows: Carbon, .66 percent.; phosphorus, .031 percent.; sulphur, .035 percent.; manganese, .78 percent.

BLOOMS.

Sixteen of the ingots were selected for the special blooming. In order to be able to identify the several sides of the ingot and to be able to follow them while making the bloom, a marker was put into the top of the ingot, immediately after casting, consisting of a steel rod about 1⅛ inches diameter by 15 inches long, held partly immersed in the steel near the middle of one side of the ingot till set.

The blooms were made in a two-high variable draft blooming mill, having passes 24 inches, 11 inches and 8 inches between collars. The blooming rolls are shown in Figure 1. The ingots were nominally 24x24 inches at the bottom end and about 1½ inches less each way at the top end. They were rolled into blooms about 8x8 inches, from which they were shaped into rails. The blooms were made from the ingots with reductions between turning, varying from 1 inch to 10 inches in the early stages of the blooming. With 1-inch reductions, the ingot was first given a reduction or squeeze of 1 inch, bringing it down to 23 inches. It was turned and the other side reduced to 23 inches. It was again turned and the 1-inch reductions continued, turning after each, until a size 20x20 inches was reached, after which it was reduced to 11x11 inches with 3-inch reductions. The bloom was transferred to the 11-inch pass, brought to 11x8 inches, transferred to the 8-inch pass and finished to 8x8 inches With 2-inch reductions, the bloom was made in the same way, except that down to 20x20 inches the reductions were 2 inches instead of 1. With 3-inch reductions between turns, the ingot was first reduced 1½ inches and then brought back without turning and reduced 1½ inches more. It was turned and the blooming continued with 3-inch reductions in two passes each between turns. The full reduction of 3 inches was not made in one pass for fear that the rolls would not stand it. With 4-inch reductions, the bloom was made to as small a size as possible, with reductions of 4 inches between turns in two passes each. The same principle

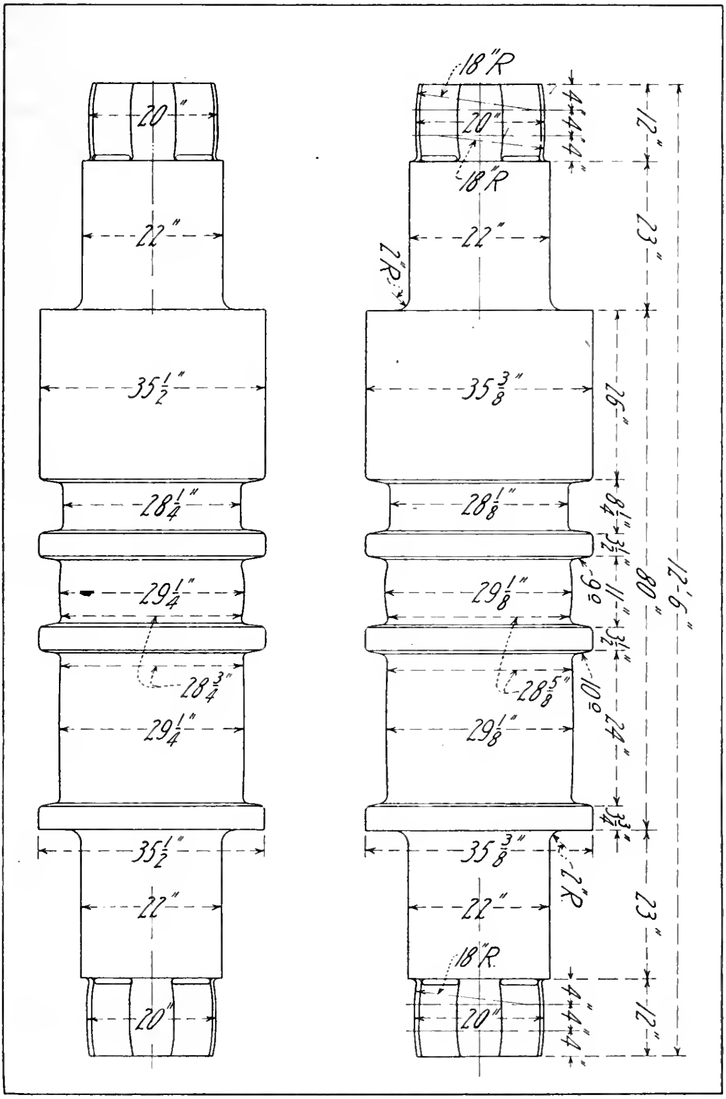

Fig. 1—Blooming Rolls.

was carried out with reductions between turns of 6, 8 and 10 inches. In addition blooms were made according to the regular method in use at Ensley, consisting of reducing one side to 20 inches in the 24-inch pass and turning, reducing in the 24-inch pass to 11 inches and turning, reducing the other side to 11 inches in the 11-inch pass and turning, reducing in the 11-inch pass to 8 inches and turning and finally reducing the other side to 8 inches in the 8-inch pass, using ordinarily a total of 15 passes. For each of the eight conditions of rolling, two blooms were made, one of which was rolled so that what was the top side of the ingot as it first entered the rolls, was finally rolled into the head of the rail, and the other of which was rolled so that the top side of the ingot was rolled into the right side or right web of the rail. Ingots 1 to 8 inclusive were rolled "top in top" and ingots 9 to 16 inclusive were rolled "top in web." The schedule for rolling the ingots into blooms was as follows:

Ingots 1 and 9. 1-inch reductions to 20x20, turning after each pass for 8 passes. 3-inch reductions in two passes each to 11x11, turning after each 3-inch reduction, making 12 passes more. Move to 11-inch pass, reduce one side to 8 inches in two passes and turn. Move to 8-inch pass and finish to 8x8 in two passes. Total, 24 passes.

Ingots 2 and 10. 2-inch reductions to 20x20, turning after each pass for 4 passes. 3-inch reductions in two passes each to 11x11, turning after each 3-inch reduction, making 12 passes more. Finish as before. Total, 20 passes.

Ingots 3 and 11. 3-inch reductions, two passes each, turning after each 3-inch reduction to 15x15, making 12 passes. Then 4-inch reduction each way, two passes each, turning after each 4-inch reduction to 11x11, making 4 passes more. Finish as before. Total, 20 passes.

Ingots 4 and 12. 4-inch reductions, two passes each, turning after each 4-inch reduction to 16x16, making 8 passes. Then 5-inch reduction each way, two passes each, turning after each 5-inch reduction to 11x11. Finish as before. Total, 16 passes.

Ingots 5 and 13. 6-inch reductions, 4 passes each, turning after each 6-inch reduction to 18x18, making 8 passes. Then make a 7-inch reduction each way, 4 passes each, turning after each 7-inch reduction to 11x11. Finish as before. Total, 20 passes.

Ingots 6 and 14. 8-inch reductions, 4 passes each, turning after each 8-inch reduction to 16x16, making 8 passes. Then a 5-inch reduction each way, two passes each, turning after each 5-inch reduction to 11x11. Finish as before. Total, 16 passes.

Ingots 7 and 15. 10-inch reductions, 5 passes each, turning after each 10-inch reduction to 14x14, making 10 passes. Then a 3-inch reduction each way, two passes each, turning after each reduction to 11x11. Finish as before. Total, 18 passes.

Ingots 8 and 16. Regular practice. Reduce to 24x20 in 2 passes and turn. Reduce to 20x11 in 6 passes and turn. Transfer to 11-inch passes, reduce to 11x11 in 4 passes and turn. Reduce to 11x8 in 2 passes and turn. Transfer to 8-inch pass and finish to 8x8 in 1 pass. Total, 15 passes.

In the above schedule no account was taken of the side spread in rolling, which was considerable in some cases, particularly in the regular practice. On entering the blooming rolls, the ingots were "fairly hot," although pyrometer readings were not taken.

RAILS.

From the 8x8 bloom the steel was made into rail in nine shaping passes direct without reheating the bloom. Diagrams of these passes are shown in Figures 2 and 3. The preceding shape from which a bar was formed is shown in dotted line on each diagram. The areas of the shaping passes and their percentages of reduction from the previous shape are shown in Table 2.

TABLE 2—SHAPING PASSES.

Pass Number	Area sq. in.	Reduction Percent
1	48.60	19.00
2	35.68	26.56
3	26.28	27.22
4	19.92	24.20
5	17.30	13.15
6	12.64	26.94
7	10.28	18.67
8	9.00	12.45
9	8.55	5.00

After the bloom was made it was cut into three parts, each part making two or three rails, with a total of seven or eight rails from the ingot. The top rail of the third part, which was the E or F rail, was set aside for testing. The rails were of the 85 lb. A. S. C. E. section. From each rail ten pieces were cut and numbered consecutively from one to ten from the top end and used for tests as follows:

No. 1—5 ft. for drop test with head in tension.
No. 2—5 ft. for drop test with base in tension.
Nos. 3 and 4—1½ ft. each for tensile tests.
Nos. 5 to 10 incl.—2 ft. each, for transverse test of base and polishing of cross section.

DROP TESTS.

Two drop tests were made of each rail, one with the head in tension and the other with the base in tension. The tup was 2,000 lbs., the height of drop was 20 ft., the centers of the supports were 3 ft. apart and the

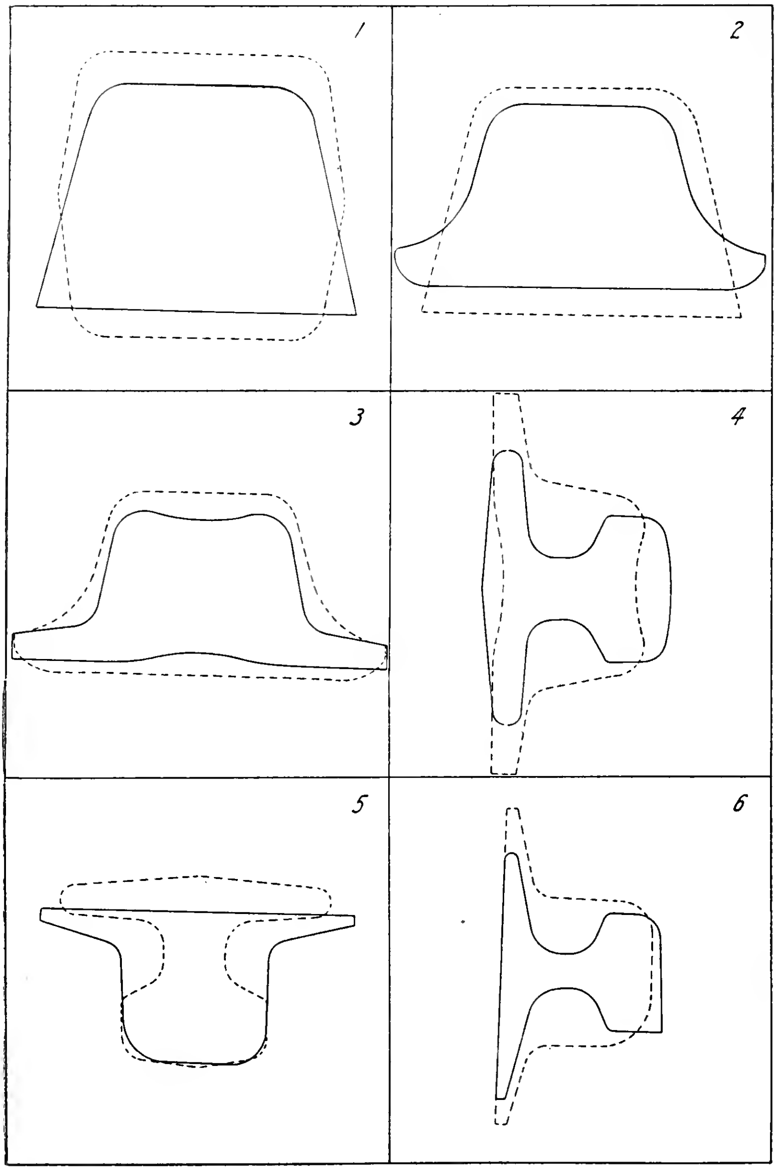

Fig. 2—Shaping Passes 1 to 6 Inclusive.

anvil was 20,000 lbs., spring supported. The striking face of the tup and the bearing surfaces of the supports each had a radius of 5 in. The deflection or set under the first blow was measured in a distance of 3 ft. of the side that was below in testing. Gage marks 1 in. apart were put lengthwise on the side in tension, about the middle of the piece tested,

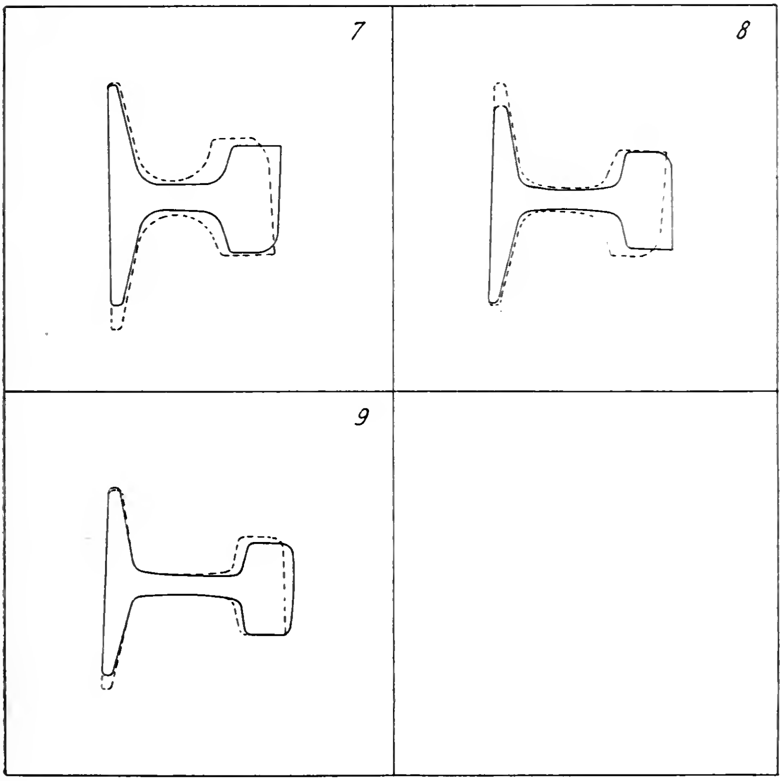

Fig. 3—Shaping Passes 7, 8 and 9.

for a distance of 6 in., and the increase in length of the space which stretched most at breaking was taken as the measure of ductility. The results of the tests are shown in Table 3. All the specimens tested with the head in tension, broke as tension breaks about half way between supports. Of the sixteen specimens tested with the base in tension, fourteen broke near the middle as tension breaks and two specimens (Nos. 6-2 and 15-2) broke a short distance inside of one support, splitting at the support through a seam about .05 inch deep.

It will be noted from the average figures that the rails rolled "top in top" gave about the same results as those rolled "top in web." That is, the drop test results averaged about the same for rails rolled so that what was the top side of the ingot, as it first entered the blooming rolls, was rolled as the top of the head of the rail, as for rails rolled so that the top side of the ingot formed the side or web of the rail.

TABLE 3—DROP TESTS.

Initial Reductions Inches	Specimen Number	Part in Tension	Deflection 1st Blow Inches	No. of Blows	Elong. Percent
TOP IN TOP.					
1	1-1	Head	1.78	3	23
2	2-1	"	1.69	3	19
3	3-1	"	1.70	3	24
4	4-1	"	1.69	2	18
6	5-1	"	1.69	2	17
8	6-1	"	1.70	2	16
10	7-1	"	1.71	3	20
Regular	8-1	"	1.75	3	20
	Average		1.71	2.6	19.6
1	1-2	Base	1.77	4	23
2	2-2	"	1.68	3	17
3	3-2	"	1.76	2	12
4	4-2	"	1.75	3	15
6	5-2	"	1.73	3	17
8	6-2	"	1.71	2	7
10	7-2	"	1.67	3	15
Regular	8-2	"	1.75	3	17
	Average		1.73	2.9	15.4
TOP IN WEB.					
1	9-1	Head	1.74	2	19
2	10-1	"	1.78	3	20
3	11-1	"	1.73	2	17
4	12-1	"	1.73	2	16
6	13-1	"	1.72	2	16
8	14-1	"	1.72	3	20
10	15-1	"	1.71	3	21
Regular	16-1	"	1.74	2	16
	Average		1.73	2.4	18.1
1	9-2	Base	1.74	3	15
2	10-2	"	1.73	3	23
3	11-2	"	1.75	3	20
4	12-2	"	1.75	3	22
6	13-2	"	1.73	2	12
8	14-2	"	1.71	3	16
10	15-2	"	...	1	6
Regular	16-2	"	1.69	2	12
	Average		1.73	2.5	15.8

In Figure 4 the elongation results are plotted in relation to the initial reduction in making the bloom from the ingot. It will be noted that with the base in tension there was in general a decrease in ductility as the initial reduction increased. There was, however, considerable irregularity in the results and it would take a much more extensive set of tests to determine whether this relationship could be expressed as a law. With the head in tension the ductility was about the same for the different rates of reduction.

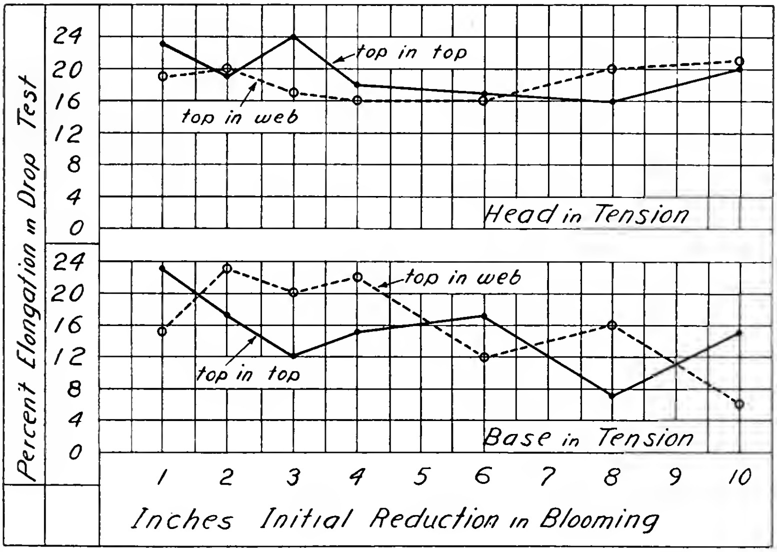

FIG. 4—ELONGATION IN DROP TEST AS RELATED TO REDUCTION IN BLOOMING.

TRANSVERSE TESTS OF BASE.

Transverse tests of the base were made of five pieces from each rail, each piece being 2 ft. long. The method of test was to support the rail on two supports placed opposite each other near the edges of the flanges under the middle of its length. The supports were 6 in. long and were intended to be placed ½ in. in from the sides of the flanges, which would have made the distance between supports 1 in. less than the width of the base, or 4$\frac{3}{16}$ in. Instead, the distance between supports was made 4 in. by mistake. The load was applied in the test machine to the head of the rail at the middle. The general arrangement is shown in Figure 5.

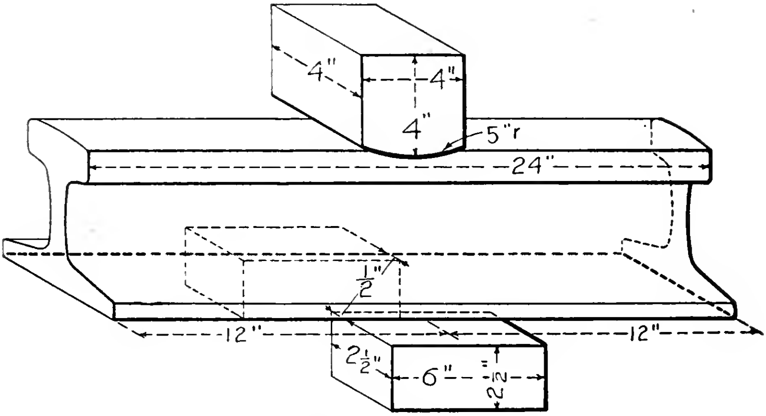

Fig. 5—Method of Making Transverse Test of Base.

The load was measured that it took to break the rail. The transverse elongation was measured by putting prick punch marks 1 in. apart crosswise on the bottom of the base and at the middle of the length of the piece tested. The greatest extension after breaking, in any one of the spaces, was taken as the measure of the transverse ductility. The results of the transverse tests are given in Table 4.

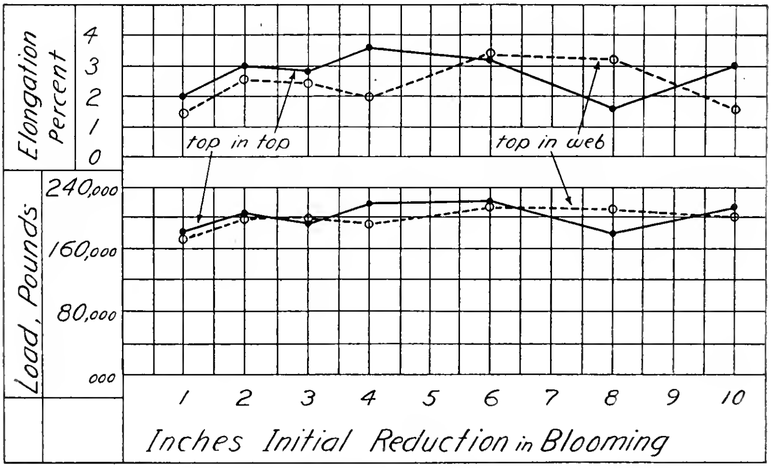

Fig. 6—Results of Transverse Tests of Base as Related to Reduction in Blooming.

TABLE 4—TRANSVERSE TESTS OF BASE.

Initial Reduct. Ins.	Top in Top				Top in Web			
	No.	Load lbs.	Elong. Per cent	Depth Seam Ins.	No.	Load lbs.	Elong. cent Per	Depth Seam Ins.
1	1-5	186,500	2	Slight	9-5	176,100	1	.03
	1-6	174,800	2	Slight	9-6	160,200	1	.03
	1-7	177,200	2	...	9-7	178,700	2	.03
	1-8	198,800	2	...	9-8	184,300	2	.03
	1-9	172,800	2	Slight	9-9	159,000	1	.03
	Av.	182,020	2.0		Av.	171,660	1.4	
2	2-5	213,700	3	...	10-5	191,200	2	.03
	2-6	195,500	3	...	10-6	203,200	3	Small
	2-7	211,300	3	...	10-7	202,900	3	Small
	2-8	191,200	2	...	10-8	205,700	3	Small
	2-9	214,000	4	...	10-9	185,900	2	Small
	Av.	205,140	3.0		Av.	197,780	2.6	
3	3-5	205,000	4	...	11-5	200,900	2	Small
	3-6	192,000	2	...	11-6	211,100	3	...
	3-7	182,600	3	...	11-7	189,900	2	...
	3-8	180,500	2	Slight	11-8	185,100	2	Slight
	3-9	203,000	3	...	11-9	208,000	3	Slight
	Av.	192,620	2.8		Av.	199,000	2.4	
4	4-5	202,500	3	...	12-5	191,300	2	Small
	4-6	229,300	5	...	12-6	194,900	2	.03
	4-7	221,200	4	...	12-7	189,700	2	.03
	4-8	217,800	3	...	12-8	173,900	2	.04
	4-9	216,100	3	...	12-9	201,700	2	.03
	Av.	217,380	3.6		Av.	190,300	2.0	
6	5-5	225,700	3	...	13-5	206,200	2	...
	5-6	205,700	2	...	13-6	221,000	3	...
	5-7	217,800	3	...	13-7	221,100	4	...
	5-8	225,800	4	...	13-8	205,800	3	Slight
	5-9	230,300	4	...	13-9	219,300	5	...
	Av.	221,060	3.2		Av.	214,680	3.4	
8	6-5	166,700	1	.03	14-5	209,400	3	Small
	6-6	173,500	1	.04	14-6	175,600	2	Slight
	6-7	185,300	2	.04	14-7	232,300	4	...
	6-8	194,300	2	Slight	14-8	218,400	3	...
	6-9	186,100	2	.02	14-9	214,400	4	...
	Av.	181,180	1.6		Av.	210,020	3.2	
10	7-5	214,100	3	...	15-5	184,700	2	Slight
	7-6	207,700	2	...	15-6	179,800	2	...
	7-7	206,000	3	...	15-7	210,300	3	...
	7-8	217,500	4	...	15-8	220,700	3	...
	7-9	210,900	3	...	15-9	206,400	3	Slight
	Av.	211,240	3.0		Av.	200,380	2.6	
Regular	8-5	195,300	3	Small	16-5	229,500	4	...
	8-6	207,700	3	...	16-6	231,400	4	...
	8-7	215,500	4	...	16-7	209,700	2	.02
	8-8	208,700	3	...	16-8	207,700	2	...
	8-9	197,700	2	Slight	16-9	192,700	2	Small
	Av.	204,980	3.0		Av.	214,200	2.8	
	Gen. Av.	201,953	2.8		Gen. Av.	199,753	2.6	

It will be noted that the general average results, showing breaking load and transverse ductility, of all the rails rolled top in top were about the same as the general average results of the rails rolled top in web. The average results of the five tests of each bar are plotted in Figure 6 in relation to the initial reductions in making the bloom from the ingot. Here again it will be noted that there seems not to have been any special relation between the amount of reduction and the transverse properties of the base. From an inspection of the table it will be noted that the low results in breaking load and transverse elongation were in the samples showing seams. This investigation was not, however, made so much with reference to the formation of seams, especially deep seams, but more with reference to the transverse ductility.

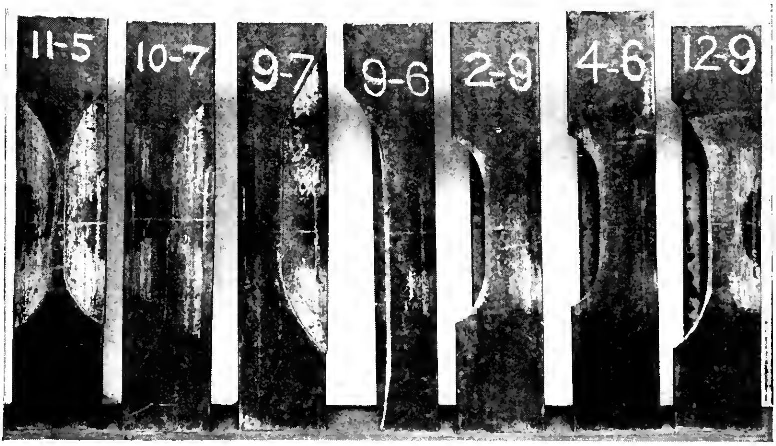

FIG. 7—TYPES OF FRACTURE IN TRANSVERSE TEST OF BASE.

In this connection it is interesting to compare the transverse ductility of the bottom of the base with the longitudinal ductility. The method of measurement was the same, but the longitudinal stretch was produced in the drop test, while the transverse stretch was obtained more slowly in the test machine. The transverse ductility averaged 2.7 percent. and the longitudinal ductility averaged 15.6 percent. Part of the problem of improvement of rails consists of increasing the transverse ductility of the base and particularly of eliminating the cases of very low transverse ductility, although the lot of rails in hand compares favorably with the average run of rails.

Samples of typical fractures in the transverse test of the base are shown in Figure 7. Some samples it will be noted tended to split along "cleavage" lines, while in other samples a curved piece of the flange tore out, indicating an absence of a marked cleavage condition.

TENSILE TESTS.

Tensile tests were made from two pieces of each rail and from three locations in the section of each piece, making six tensile tests from each rail. The pieces were cut from the section as shown in Figure 8.

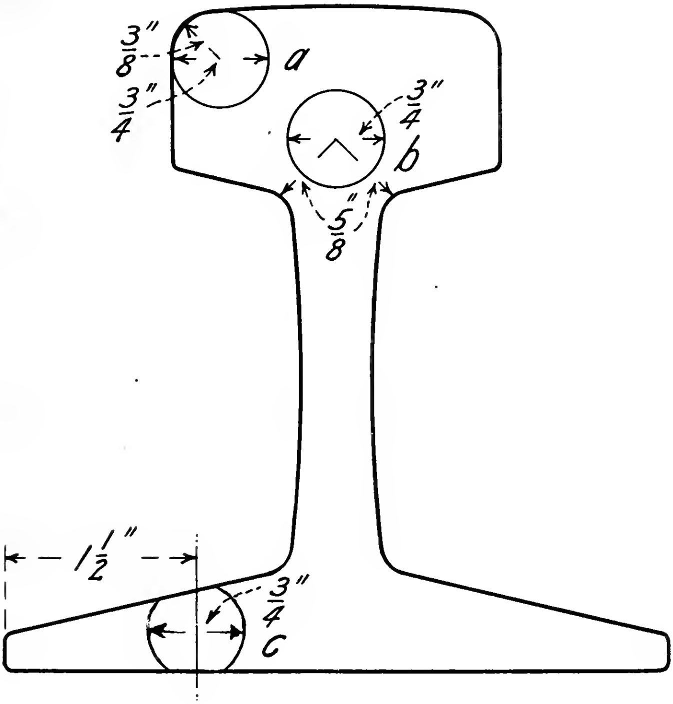

FIG. 8—LOCATIONS OF TENSILE TEST PIECES.

The samples from the corner of the head and the flange were from the brand or bottom side of the rail, that is, the side that was below in passing through the finishing rolls. The test pieces were 12 in. long, ¾ in. diameter at the ends and turned to ½ in. diameter for a gage length of 2 in. at the middle. The tests were made in a 300,000-pound Riehle test machine. The yield point was determined by means of a Berry strain gage and was taken as the load at which a considerable acceleration occurred in the speed of the dial hand. The detail results are shown in tables 5 to 8, inclusive, and the average results are collected for more convenient comparison in tables 9 to 13, inclusive. The average results in the tensile tests are plotted in Figure 9 in relation to the reduction in blooming. The rails rolled "top in top" gave about the same results as those rolled "top in web" and the curves show the average results of the two rolling conditions. It will be noted that the tensile results of the rails were also about the same for the various methods of blooming as used in making these rails.

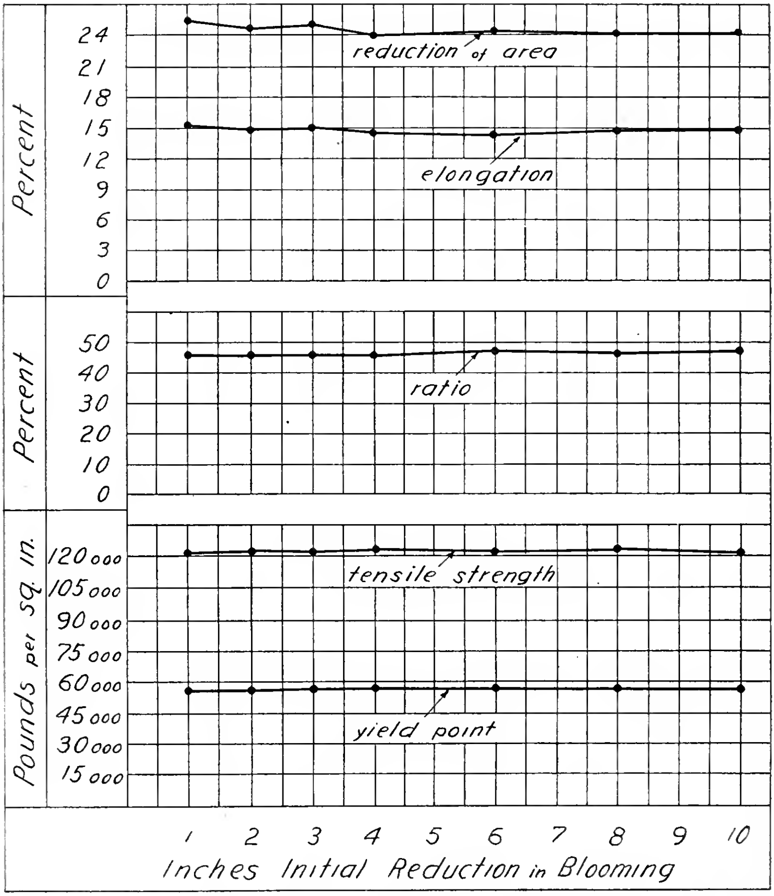

FIG. 9—RESULTS OF TENSILE TESTS AS RELATED TO REDUCTION IN BLOOMING.

In this connection it is interesting to compare the results from the three positions in the rail section and for this purpose the general average results are given below:

TABLE 5—TENSILE TESTS, BARS 1, 2, 3 AND 4.

Initial Reduction Ins.	No.	Yld. Pnt. Lbs. Per Sq. In.	Tens. Str. Lbs. Per Sq. In.	Ratio	Elong. Percent	Red. Area Percent
1	1-3 a	......	118,000	....	16.0	26.1
	b	50,200	111,600	45.0	16.0	27.8
	c	59,300	121,800	48.7	16.0	26.8
1	1-4 a	52,600	119,900	43.9	16.0	27.8
	b	49,700	111,700	44.6	15.0	28.1
	c	55,200	121,000	45.6	16.5	26.1
1	1- a	52,600	118,950	44.0	16.0	27.0
	b	49,950	111,650	44.8	15.5	28.0
	c	57,250	121,400	47.2	16.3	26.5
	Av.	53,267	117,333	45.3	15.9	27.2
2	2-3 a	56,100	125,200	44.8	13.5	22.3
	b	51,900	117,000	44.4	15.0	21.8
	c	61,600	126,100	48.8	15.5	24.4
2	2-4 a	54,300	123,100	44.1	14.5	23.2
	b	53,000	117,700	45.1	15.0	23.3
	c	58,300	126,000	46.3	15.5	26.8
2	2- a	55,200	124,150	44.4	14.0	22.8
	b	52,450	117,350	44.7	15.0	22.6
	c	59,950	126,050	47.5	15.5	25.6
	Av.	55,867	122,517	45.6	14.8	23.7
3	3-3 a	58,400	122,500	47.7	15.5	24.7
	b	53,500	116,700	45.9	15.5	23.6
	c	56,600	125,000	45.3	15.0	25.7
3	3-4 a	55,000	122,000	45.1	13.5	21.5
	b	52,800	116,100	45.4	15.5	23.3
	c	59,900	125,000	47.9	13.5	25.4
3	3- a	56,700	122,250	46.3	14.5	22.8
	b	53,150	116,400	45.6	15.5	23.5
	c	58,250	125,000	46.6	14.3	25.6
	Av.	56,033	121,217	46.2	14.8	24.0
4	4-3 a	55,200	123,700	44.7	14.0	23.9
	b	53,200	119,000	44.7	14.5	22.6
	c	57,900	126,500	45.8	13.5	25.7
4	4-4 a	55,400	121,900	45.5	13.5	24.0
	b	55,700	117,100	47.6	13.5	21.9
	c	59,400	125,600	47.3	16.0	25.8
4	4- a	55,300	122,800	45.0	13.8	24.0
	b	54,450	118,050	46.1	14.0	22.3
	c	58,650	126,050	46.5	14.8	25.8
	Av.	56,133	122,300	45.9	14.2	24.0

TABLE 6—TENSILE TESTS, BARS 5, 6, 7 AND 8.

Initial Reduction, Inches	No.	Yield Point, Lbs. per Sq. In.	Tens. Str., Lbs. per Sq. In.	Ratio	Elong. Percent	Red. Area, Percent
6	5-3 a	58,600	123,300	47.5	13.5	23.3
	b	55,200	117,900	46.8	14.5	24.0
	c	59,800	126,100	47.4	14.5	25.4
6	5-4 a	56,300	121,800	46.2	13.5	24.4
	b	55,200	113,000	48.8	14.5	24.4
	c	61,700	126,000	49.0	14.0	25.4
6	5- a	57,450	122,550	46.9	13.5	23.9
	b	55,200	115,450	47.8	14.5	24.2
	c	60,750	126,050	48.2	14.3	25.4
	Average	57,800	121,350	47.6	14.1	24.5
8	6-3 a	59,300	122,800	48.3	14.5	24.9
	b	58,000	126,000	46.0	15.0	24.0
	c	59,000	126,900	46.5	15.0	27.0
8	6-4 a	55,400	123,500	44.9	13.0	20.5
	b	53,500	115,300	46.3	14.5	25.4
	c	59,100	126,800	46.6	14.5	27.1
8	6- a	57,350	123,150	46.5	13.8	22.7
	b	55,750	120,650	46.2	14.8	24.7
	c	59,050	126,850	46.6	14.8	27.1
	Average	57,350	123,550	46.4	14.5	24.8
10	7-3 a	58,900	122,400	48.1	15.0	25.4
	b	51,600	115,400	44.7	15.5	24.3
	c	60,600	124,000	48.9	16.0	26.7
10	7-4 a	57,400	121,800	47.1	13.5	24.3
	b	53,600	115,300	46.5	15.0	24.7
	c	59,800	124,900	47.9	15.0	25.7
10	7- a	58,150	122,100	47.6	14.3	24.9
	b	52,600	115,350	45.6	15.3	24.5
	c	60,200	124,450	48.3	15.5	26.2
	Average	56,983	120,633	47.2	15.0	25.2
Regular	8-3 a	59,600	123,300	48.3	15.0	22.6
	b	54,000	115,200	46.9	15.5	24.8
	c	62,400	126,000	49.5	15.0	24.7
Regular	8-4 a	56,800	125,600	45.2	13.5	22.6
	b	54,000	115,200	46.9	15.0	24.7
	c	60,400	126,900	47.6	15.0	25.4
Regular	8- a	58,200	124,450	46.8	14.3	22.6
	b	54,000	115,200	46.9	15.3	24.8
	c	61,400	126,450	48.5	15.0	25.1
	Average	57,867	122,033	47.4	14.9	24.2

TABLE 7—TENSILE TESTS, BARS 9, 10, 11 AND 12.

Initial Reduction, Inches	No.	Yield Point, Lbs. per Sq. In.	Tens. Str., Lbs. per Sq. In.	Ratio	Elong., Percent	Red. Area, Percent
1	9-3 a	56,500	124,900	45.3	13.5	22.6
	b	53,500	117,000	45.7	15.5	25.0
	c	64,700	129,800	49.8	13.5	24.0
1	9-4 a	58,900	123,200	47.8	15.5	22.1
	b	52,900	116,000	45.6	16.0	24.7
	c	62,500	127,500	49.1	15.5	25.5
1	9- a	57,700	124,050	46.5	14.5	22.4
	b	53,200	116,500	45.7	15.8	24.9
	c	63,600	128,650	49.5	14.5	24.8
	Average	58,167	123,067	47.2	14.9	24.0
2	10-3 a	56,600	120,900	46.9	14.0	23.0
	b	54,300	116,300	46.6	13.5	24.7
	c	61,700	126,100	48.9	15.5	26.1
2	10-4 a	58,400	121,500	48.0	15.5	24.7
	b	54,100	117,000	46.2	15.0	24.9
	c	60,000	126,200	47.6	14.0	24.7
2	10- a	57,500	121,200	47.5	14.8	23.9
	b	54,200	116,650	46.4	14.3	24.8
	c	60,850	126,150	48.2	14.8	26.9
	Average	57,517	121,333	47.4	14.6	25.2
3	11-3 a	55,800	122,100	45.6	15.0	25.1
	b	52,200	115,200	45.3	16.0	25.4
	c	58,400	126,000	46.3	15.0	26.4
3	11-4 a	58,400	125,800	46.4	15.0	26.1
	b	53,500	116,300	46.0	16.0	25.8
	c	62,700	128,700	48.8	14.0	26.4
3	11- a	57,100	123,950	46.0	15.0	25.6
	b	52,850	115,750	45.6	16.0	25.6
	c	60,550	127,350	47.6	14.5	26.4
	Average	56,833	122,350	46.4	15.2	25.9
4	12-3 a	55,600	125,200	44.4	14.0	23.3
	b	54,400	118,700	45.9	15.0	22.6
	c	59,000	128,000	46.1	13.5	24.7
4	12-4 a	56,500	126,300	44.8	13.5	22.6
	b	56,100	117,400	47.8	15.5	23.9
	c	59,000	126,100	46.8	15.0	25.4
4	12- a	56,050	125,750	44.6	13.8	23.0
	b	55,250	118,050	46.8	15.3	23.3
	c	59,000	127,050	46.4	14.3	24.1
	Average	56,767	123,617	45.9	14.5	23.5

TABLE 8—TENSILE TESTS, BARS 13, 14, 15 AND 16.

Initial Reduction, Inches	No.	Yield Point, Lbs. per Sq. In.	Tens. Str., Lbs. per Sq. In.	Ratio	Elong., Percent	Red. Area, Percent
6	13-3 a	58,000	123,800	46.8	14.0	24.7
	b	54,400	116,200	46.8	15.0	24.6
	c	60,700	125,800	48.3	15.0	24.7
6	13-4 a	61,000	126,000	48.4	11.0*	23.0
	b	53,700	117,200	45.8	14.5	24.0
	c	62,900	129,800	48.5	14.0	24.7
6	13- a	59,500	124,900	47.6	14.0	23.9
	b	54,050	116,700	46.3	14.8	24.3
	c	61,800	127,800	48.4	14.5	24.7
	Average	58,450	123,133	47.4	14.4	24.3
8	14-3 a	53,500	122,200	43.8	15.0	23.9
	b	53,700	118,000	45.5	14.0	22.2
	c	59,900	126,200	47.5	15.5	24.5
8	14-4 a	58,400	123,700	47.2	15.0	23.7
	b	55,600	117,800	47.2	14.0	22.6
	c	60,300	127,500	47.3	14.5	24.6
8	14- a	55,950	122,950	45.5	15.0	23.8
	b	54,650	117,900	46.4	14.0	22.4
	c	60,100	126,850	47.4	15.0	24.6
	Average	56,900	122,567	46.4	14.7	23.6
10	15-3 a	56,300	123,200	45.7	14.0	23.7
	b	53,600	118,500	45.2	15.0	23.8
	c	60,100	126,300	47.6	15.5	24.4
10	15-4 a	59,100	123,000	48.0	15.5	23.3
	b	53,400	117,000	45.6	14.5	23.7
	c	59,900	125,600	47.7	14.5	25.4
10	15- a	57,700	123,100	46.8	14.8	23.5
	b	53,500	117,750	45.4	14.8	23.8
	c	60,000	125,950	47.7	15.0	24.9
	Average	57,067	122,267	46.6	14.9	24.1
Regular	16-3 a	57,200	121,700	47.0	15.0	23.3
	b	56,100	120,500	46.5	15.0	23.6
	c	64,500	126,800	50.8	15.0	24.0
Regular	16-4 a	57,300	124,900	45.8	15.5	22.6
	b	54,900	121,100	45.3	13.5	22.1
	c	61,300	126,900	48.3	15.5	26.4
Regular	16- a	57,250	123,300	46.4	15.3	23.0
	b	55,500	120,800	45.9	14.3	22.9
	c	62,900	126,850	49.6	15.3	25.2
	Average	58,550	123,650	47.3	15.0	23.7

*Sample 13-4a broke about ½ inch from gage mark. Elongation not used in calculating average.

TABLE 9—AVERAGE YIELD POINTS.

Rolling Condition	Initial Reduction, Inches	Bar No.	Position in Section			
			A	B	C	Average
Top in Top	1	1	52,600	49,950	57,250	53,267
	2	2	55,200	52,450	59,950	55,867
	3	3	56,700	53,150	58,250	56,033
	4	4	55,300	54,450	58,650	56,133
	6	5	57,450	55,200	60,750	57,800
	8	6	57,350	55,750	59,050	57,350
	10	7	58,150	52,600	60,200	56,983
	Regular	8	58,200	54,000	61,400	57,867
		Average	56,369	53,444	59,438	56,417
Top in Web	1	9	57,700	53,200	63,600	58,167
	2	10	57,500	54,200	60,850	57,517
	3	11	57,100	52,850	60,550	56,833
	4	12	56,050	55,250	59,000	56,767
	6	13	59,500	54,050	61,800	58,450
	8	14	55,950	54,650	60,100	56,900
	10	15	57,700	53,500	60,000	57,067
	Regular	16	57,250	55,500	62,900	58,550
		Average	57,344	54,150	61,350	57,615
		Gen. Av.	56,857	53,797	60,394	57,016

TABLE 10—AVERAGE TENSILE STRENGTHS.

Rolling Condition	Initial Reduction, Inches	Bar No.	Position in Section			
			A	B	C	Average
Top in Top	1	1	118,950	111,650	121,400	117,333
	2	2	124,150	117,350	126,050	122,517
	3	3	122,250	116,400	125,000	121,217
	4	4	122,800	118,050	126,050	122,300
	6	5	122,550	115,450	126,050	121,350
	8	6	123,150	120,650	126,850	123,550
	10	7	122,100	115,350	124,450	120,633
	Regular	8	124,450	115,200	126,450	122,033
		Average	122,550	116,263	125,288	121,367
Top in Web	1	9	124,050	116,500	128,650	123,067
	2	10	121,200	116,650	126,150	121.333
	3	11	123,950	115,750	127,350	122,350
	4	12	125,750	118,050	127,050	123,617
	6	13	124,900	116,700	127,800	123,133
	8	14	122,950	117,900	126,850	122,567
	10	15	123,100	117,750	125,950	122,267
	Regular	16	123,300	120,800	126,850	123,650
		Average	123,650	117,513	127,081	122,748
		Gen. Av.	123,100	116,888	126,185	122,058

TABLE 11—AVERAGE RATIOS OF YIELD POINT TO TENSILE STRENGTH.

Rolling Condition	Initial Reduction, Inches	Bar No.	Position in Section			
			A	B	C	Average
Top in Top	1	1	44.0	44.8	47.2	45.3
	2	2	44.4	44.7	47.5	45.6
	3	3	46.3	45.6	46.6	46.2
	4	4	45.0	46.1	46.5	45.9
	6	5	46.9	47.8	48.2	47.6
	8	6	46.5	46.2	46.6	46.4
	10	7	47.6	45.6	48.3	47.2
	Regular	8	46.8	46.9	48.5	47.4
		Average	45.9	46.0	47.4	46.4
Top in Web	1	9	46.5	45.7	49.5	47.2
	2	10	47.5	46.4	48.2	47.4
	3	11	46.0	45.6	47.6	46.4
	4	12	44.6	46.8	46.4	45.9
	6	13	47.6	46.3	48.4	47.4
	8	14	45.5	46.4	47.4	46.4
	10	15	46.8	45.4	47.7	46.6
	Regular	16	46.4	45.9	49.6	47.3
		Average	46.4	46.1	48.1	46.9
		Gen. Av.	46.2	46.1	47.8	46.7

TABLE 12—AVERAGE ELONGATIONS, PERCENT IN 2 INCHES

Rolling Condition	Initial Reduction, Inches	Bar No.	Position in Section			
			A	B	C	Average
Top in Top	1	1	16.0	15.5	16.3	15.9
	2	2	14.0	15.0	15.5	14.8
	3	3	14.5	15.5	14.3	14.8
	4	4	13.8	14.4	14.8	14.2
	6	5	13.5	14.5	14.3	14.1
	8	6	13.8	14.8	14.8	14.5
	10	7	14.3	15.3	15.5	15.0
	Regular	8	14.3	15.3	15.0	14.9
		Average	14.3	15.0	15.1	14.8
Top in Web	1	9	14.5	15.8	14.5	14.9
	2	10	14.8	14.3	14.8	14.6
	3	11	15.0	16.0	14.5	15.2
	4	12	13.8	15.3	14.3	14.5
	6	13	14.0	14.8	14.5	14.4
	8	14	15.0	14.0	15.0	14.7
	10	15	14.8	14.8	15.0	14.9
	Regular	16	15.3	14.3	15.3	15.0
		Average	14.7	14.9	14.7	14.8
		Gen. Av.	14.5	15.0	14.9	14.8

TABLE 13—AVERAGE REDUCTIONS OF AREA, PERCENT.

Rolling Condition	Initial Reduction, Inches	Bar No.	Position in Section			
			A	B	C	Average
Top in Top	1	1	27.0	28.0	26.5	27.2
	2	2	22.8	22.6	25.6	23.7
	3	3	22.8	23.5	25.6	24.0
	4	4	24.0	22.3	25.8	24.0
	6	5	23.9	24.2	25.4	24.5
	8	6	22.7	24.7	27.1	24.8
	10	7	24.9	24.5	26.2	25.2
	Regular	8	22.6	24.8	25.1	24.2
		Average	23.8	24.3	25.9	24.7
Top in Web	1	9	22.4	24.9	24.8	24.0
	2	10	23.9	24.8	26.9	25.2
	3	11	25.6	25.6	26.4	25.9
	4	12	23.0	23.3	24.1	23.5
	6	13	23.9	24.3	24.7	24.3
	8	14	23.8	22.4	24.6	23.6
	10	15	23.5	23.8	24.9	24.1
	Regular	16	23.0	22.9	25.2	23.7
		Average	23.6	24.0	25.2	24.3
		Gen. Av.	23.7	24.2	25.6	24.5

	SECTION POSITION			
	A	B	C	Av.
Yield point, lbs. per sq. in.	56,857	53,797	60,394	57,016
Tensile strength, lbs. per sq. in.	123,100	116,888	126,185	122,058
Ratio, yield point to tensile strength	46.2	46.1	47.8	46.7
Elongation in 2 in., percent	14.5	15.0	14.9	14.8
Reduction of area, percent	23.7	24.2	25.6	24.5

The A samples from the corner of the head and the C samples from the flange, would be of about the same chemical composition, but the C samples showed somewhat higher yield point and tensile strength with a little greater ductility. The rails tested were from the lower part of the ingot and the B samples would therefore be somewhat lower in the hardening elements carbon and phosphorus. These samples showed slightly more ductility than the A samples and also considerably lower yield point and tensile strength.

POLISHED SECTIONS.

From the end of each piece used for transverse test of the base, a cross section of the head was cut. This made five pieces from each of the 16 rail bars, or a total of 80 cross-sections. These were polished with emery, etched with copper-ammonium chloride solution until the deposited copper could be wiped off easily and finally polished with tripoli. The purpose of this examination was to disclose any small cracks or fissures that might exist in the interior of the head. No internal cracks were found in any of the samples.

SUMMARY.

1. An investigation was made concerning the influence on the rails, of the manner in which the bloom is rolled and particularly with reference to the transverse ductility of the bottom of the base of the rail. Blooms were rolled from ingots with varying amounts of reduction between turns. Some ingots were given light reductions or squeezes and turned so as to bring the other two sides in contact with the rolls, and other ingots were given successively greater reductions between turns. Also some of the rails were rolled so that what was the top side of the ingot as it first entered the blooming rolls, formed the head of the rail and other rails were rolled so that the top side of the ingot fomed the web of the rail.

2. The work was done at Ensley, Ala., at the works of the Tennessee Coal, Iron and Railroad Co., who kindly furnished all the material and facilities for the investigation.

3. The rails were made by the open-hearth process and were tested by means of drop tests, tension tests, transverse tests of the base, and polishing of cross-sections.

4. Sixteen ingots were selected for special blooming. Eight were rolled "top in top," that is, with the top side of the ingot as it first entered the blooming rolls, rolled into the head of the rail, and the other eight were rolled "top in web," that is, with the top side of the ingot rolled into the web of the rail. The amounts of reduction between turning were varied in the early part of the blooming and were, respectively, 1 in., 2 in., 3 in., 4 in., 6 in., 8 in., 10 in., and regular practice, two ingots being rolled for each of the eight rolling conditions. From the standpoint of the construction of the mill, it was considered not advisable to reduce the ingot more than 2 inches in one pass and the reductions between turning of 3 inches or more were therefore produced in two or more passes.

5. In the drop test, the rails rolled top in top gave about the same results as those rolled top in web. With the head in tension the ductility in the drop test was about the same for the different rates of reduction. With the base in tension there was a general decrease in ductility as the rate of initial reduction in blooming increased, but there was considerable irregularity in the results and it would take a much more extensive set of tests to be able to state this as a law.

6. Transverse tests of the base were made by placing the rail on two supports, 6 in. long, placed opposite each other near the edges of

the flanges, and applying the load to the head of the rail at the middle. The general average results showing breaking load and transverse ductility of the rails rolled top in top were about the same as those of the rails rolled top in web. The transverse results were also about the same for the various rates of reduction in blooming.

7. The longitudinal ductility of the base in the drop test averaged 15.6 percent. and the transverse ductility of the base in the transverse test averaged 2.7 percent.

8. The thought is expressed that part of the problem of improvement of rails consists of increasing the transverse ductility of the base and particularly of eliminating the cases of very low transverse ductility.

9. In the tensile tests the rails rolled top in top gave about the same results as those rolled top in web. The tensile results were also about the same for the various rates of reduction.

10. Incidentally to the main theme of the investigation, a comparison was made of the tensile results from three locations in the rail section, namely, the upper corner of the head, the interior of the head and the flange. For a given tensile strength, the ductility was greatest in the flange, next in the corner of the head and least in the interior of the head.

11. Cross-sections were cut from the head of the rails, polished with emery, etched with copper-ammonium chloride solution and finally polished with tripoli. No internal cracks were found in any of the samples examined.

12. In conclusion, the general results may be summarized as follows: The rails rolled "top in top" gave about the same results as those rolled "top in web," in the drop tests, transverse tests of the base and tensile tests. The results were also about the same for the various rates of reduction in making the bloom, except that in the drop tests with the base in tension there was a general decrease in ductility as the rate of initial reduction increased, but there was considerable irregularity in the results and it would take a much more extensive set of tests to be able to state this as a law. This work had reference particularly to the transverse ductility of the base, and not specially to the production of seams due to the tearing open of the sides of the bloom in rolling.

Appendix E.

AMERICAN RAIL MILL PRACTICE.

In June, 1915, the Rail Committee of the American Railway Engineering Association appointed a Sub-Committee on Rail Mill Practice, consisting of C. S. Churchill, Chairman, E. B. Ashby, A. S. Baldwin, J. R. Onderdonk and M. H. Wickhorst (the latter acting as secretary), to visit the several rail mills and report upon the methods in use in manufacturing rails. The purpose of the visits was to obtain information concerning the present state of the art and concerning developments and improvements in recent years in the art of making rails and particularly those which had to do with the quality of the rails. A brief general description is given of the several rail plants and afterward is given a comparison of practices, divided into the different stages in the manufacture of rails, such as ore supply, open-hearth practice, methods of rolling, etc. The various analyses and other numerical information were kindly furnished by the several companies.

DESCRIPTION OF RAIL PLANT OF THE ALGOMA STEEL CORPORATION.

A visit was made on August 6 and 7, 1915, to the rail plant of the Algoma Steel Corporation by Messrs. A. S. Baldwin and M. H. Wickhorst, members of the Sub-Committee on Mill Practice, accompanied by Messrs. A. L. Davis, J. H. Gibboney, R. W. Hunt and C. W. Genet. The plant is located at Sault Ste. Marie, Ontario, Canada, on the banks of the St. Mary's River connecting Lake Superior with Lake Michigan. The iron ores and limestone are obtained from the Lake Superior district and the coal supply is obtained from West Virginia, all from properties belonging to the Algoma company.

Ore.

Most of the ore used comes from the Magpie and Helen mines on the Canadian side of Lake Superior, owned by the Algoma company. Some other ores are also used, notably Albany ore. Representative analyses of these ores are shown below. The analysis of the Magpie is the season average.

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*Report 51, November, 1915.

	Magpie Dried 212°	Helen As Received	Helen Dried 212°	Albany As Received	Albany Dried 212°
Moisture	....	7.81	.....	11.17	.....
Iron	50.26	49.63	53.83	51.25	57.70
Silica	9.89	8.01	8.69	5.20	5.86
Phosphorus	.015	.082	.089	.053	.060
Sulphur	.31	.29	.32	.....	.....
Alumina	1.36	3.34	3.62	1.30	1.46
Lime	7.40	nil	nil	.19	.21
Magnesia	7.53	nil	nil	.12	.14
Manganese	2.77	.60	.17	.53	.60

Coal.

The coal is obtained from the Cammelton and Pocahontas mines. West Virginia and the season averages for 1914 are shown in the following analyses:

	Cammelton.	Pocahontas.
Moisture	2.56	3.00
Vol. Comb. Matter	35.80	17.56
Fixed Carbon	57.02	76.13
Ash	7.18	6.31
Phosphorus	.022	.009
Sulphur	1.16	.83

In the above analyses, the constituents, except the moisture, are percentages of the dry coal.

Coke.

The coke is made from a mixture of 35 parts Pocohontas coal and 65 parts Cammelton coal, in two batteries, each of 55 Koppers by-product coke ovens. The plant has a capacity of 1,000 tons of coke per 24 hours and the yield is ten tons of coke per 13¾ tons of coal. A representative analysis of the coke is given below:

Moisture		3.69
Vol. Comb. Matter		2.30
Fixed Carbon		86.41
Silica	3.72	
Alumina and iron oxide	6.68	
Lime	.62	
Phosphorus	0.018	
Ash		11.29
Sulphur		.80

Limestone.

The limestone used for fluxing in the blast and open-hearth furnaces is quarried at Fiborn, Michigan, and a representative analysis is as follows:

Silica	.78
Iron oxide and alumina	.48
Lime	54.16
Magnesia	.72
Phosphorus	.0015
Sulphur	.084

Blast Furnaces.

There are three blast furnaces, two with a capacity of 7,500 tons of pig iron a month each, and the other with a capacity of 13,500 tons per month, or a total monthly capacity of 28,500 tons. The metal has about the following composition:

Si	P	S	Mn	C
.85	.13	.04	1.00	3.80

Steel Making.

Steel is made by both the Bessemer and open-hearth processes, and it is expected to also use the duplex process in the future. From the blast furnaces the liquid metal is conveyed to the mixers, of which there are two, one 150 tons capacity for the Bessemer plant and one of 250 tons capacity for the open-hearth plant. The Bessemer plant consists of two converters each of 5 tons capacity. The open-hearth plant consists of 7 furnaces, 3 of 40 tons capacity and 4 of 80 tons capacity, or a total capacity of about 25,000 tons per month.

The method of making the open-hearth steel is to charge in the order named: lime, ore, scrap (mostly rail and bloom butts) and liquid metal. The metal is worked down to .45 or .55 per cent. carbon and recarbonized with hard coal added to the ladle. Should the carbon go lower than this while reducing the phosphorus, some liquid blast furnace metal is added to the hearth, as recarbonizer. About one-fourth of the ferro-manganese is added to the furnace and the rest to the ladle. The ferro-silicon is added to the ladle. No additions have been made to the mold, but experiments are being made with reference to mold additions of aluminum.

Two sizes of ingot mold have been used, 18x19 and 19x23, but it is intended to make the 19x23 mold the usual one for rail ingots.

Mill.

There are 5 sets of soaking pits with a total capacity of 96 ingots. The blooming mill is a two-high 35-inch reversing mill, driven by a 4,000 h.p. direct connected motor, or a 50x60-inch twin reversing steam engine. The 19x23 ingots are bloomed to 8x8 inches in 19 passes. The bloom ends are cropped off and the bloom cut into two parts, with a steam driven, gear-connected shear. The blooms then go to reheating furnaces, of which there are three, holding 16 blooms each, or a total reheating capacity of 48 blooms. The blooms are shaped into rail in 11 passes and the total number of passes from the large ingot to the finished rail is 30. The rail-shaping mill consists of three three-high stands. The first and second roughers are each 23½x48 inches and with four passes each. The finishing stand is 28x58 inches with three passes. The rails are sawed to length singly. There are two hots beds under cover each 106 ft. long, or a total hot bed length of 212 ft. There are five straightening presses. The loading of the rails onto cars is done by skids.

Fracture Test from Every Ingot.

One matter of special interest at the present time is the nick and break test of the top rail crop from every ingot as called for in the specifications of the Illinois Central Railroad, for whom the Algoma company was rolling rails. These specifications require that a test be made from each ingot and that the fracture be free from defect such as pipe and free from the fine crystalline structure in the interior indicating segregation. In order to break the rail ends expeditiously, a bulldozer was fitted with a holder that a rail could be slid into from the side, and with a ram fitted to press on the side of the rail and break it. For convenience the rail was nicked hot on the flange and after it had reached a black heat it was dipped into water to cool it quickly. Somewhat later Mr. Baldwin expects to furnish the Rail Committee the results under this system of inspection.

DESCRIPTION OF RAIL PLANT OF THE BETHLEHEM STEEL COMPANY.

A visit was made on July 14, 1915, to the rail plant of the Bethlehem Steel Company by Messrs. C. S. Churchill, E. B. Ashby and M. H. Wickhorst, members of the Sub-Committee on Mill Practice, accompanied by Messrs. J. H. Gibboney and J. A. Colby.

The rail plant is part of the Saucon Plant of the Bethlehem Steel Company, located at South Bethlehem, Pa. The ores are obtained from Cuba, Sweden and Chili, and the coal supply for coke production and for gas producers is obtained from West Virginia. The steel for rails is made by the basic open-hearth process.

Ore.

Average analyses of the several ores are as follows:

	Cuban	Swedish	Chilean
Iron	56.00	66.00	67.00
Manganese	.30	.10	.20
Phosphorus	.03	.20	.025
Sulphur	.30	.01	.01
Silica	12.00	2.00	1.50

Coal.

The coal supply for metallurgical processes comes from West Virginia. For coke making Davis and Thomas coals are used and for the gas producers which supply the open-hearth furnaces, Westmoreland coal is used. The average analyses of these coals are about as follows:

	Westmoreland	Davis	Thomas
Volatile matter	36.00	23.00	23.00
Fixed carbon	57.00	69.00	67.00
Ash	7.00	8.00	10.00
Sulphur	1.00	1.00	1.00

Coke.

The coke for the blast furnaces is made in by-product coke ovens and its analysis averages about as follows:

Moisture	3.50
Volatile matter	1.50
Fixed carbon	84 00
Ash	11.00
Sulphur	.80
Phosphorus	.03

Blast Furnaces.

The blast furnaces are located at the Lehigh plant and the liquid metal is hauled about 2½ to 3 miles to mixers at the Saucon plant, where the rails are made. The blast furnace metal delivered to the rail plant has about the following composition:

C	Si	S	P	Mn
3.5	1.00	.04	.50	.60

Steel Making.

The blast furnace metal is poured into mixers, of which there are three, having capacities of 250 tons, 450 tons and 1,000 tons, respectively. The open-hearth plant has 16 furnaces of about 75 tons capacity each, or a monthly open-hearth capacity of about 75,000 tons. This plant furnishes steel for two mills, the rail mill and the structural mill. In making the steel, the furnace is charged with lime, ore, scrap steel and liquid mixer iron in the order mentioned. The carbon is worked down to about .10 per cent. and the metal is recarbonized by adding liquid iron to the furnace. The recarbonizing iron has about the following composition:

C	Si	S	P	Mn
3.5	1.00	.04	.05	.60

Most of the ferro-manganese is also added to the furnace, but a portion (about 500 pounds) is added to the ladle. The ferro-silicon is added to the ladle while pouring the steel from the furnace. The average time of a heat in the furnace is about 10½ hours.

The steel is poured into molds measuring 19 by 23 inches at the bottom and the ingots weigh about 8,000 pounds each. While pouring the ingots, aluminum is added equivalent to about 1½ oz. of aluminum per ton of steel. After stripping, the ingots go to the soaking pits, of which there are 44, each holding 4 ingots, or a total of 176 ingots.

Rail Mill.

The ingots are bloomed in 15 passes to 8 by 8 inches in a 40-inch, variable draft, reversible mill, driven by a steam engine, twin tandem compound 40-in. by 66-in. by 54-in. The blooming mill supplies both the rail and structural mills. The blooms are cropped in an 800-ton shear, and cut into two parts, each part ordinarily making three rails. The blooms are then taken by a transfer crane to a reheating furnace which holds about 60 blooms, and in which the blooms remain about one hour. The bloom then goes through a 28-inch roughing mill, two-high, driven by a reversing steam engine. The bar is given five passes in this stand. It then goes through a 28-inch, three-high mill and given five more passes. Finally the bar passes through a 28-inch, two-high finishing mill. The two latter stands are driven by the same engine. The stand of roughing rolls is driven by a 32-in. by 56-in. by 50-in. twin tandem compound steam engine with a maximum speed of 125 r.p.m. The intermediate and finishing stands are driven by a 44-in. by 76-in. by 60-in. cross compound steam engine, 85 r.p.m. The total number of passes from the ingot to the rail is 26, of which 15 are in the blooming mill and 11 to shape the rail. The rails are sawed singly. The monthly capacity of the rail mill is about 24,000 tons. There are 6 hot beds about 70 feet long each, or a total hot-bed capacity of 420 feet, all well covered and protected from the weather. There are six gag presses. The rails are loaded with a magnetic crane.

Changes in Practice.

A number of changes have been made in recent years, the main object of which was to obtain more uniformity of conditions of manufacture, and thus more uniformity of the finished rails. In the open-hearth, it was formerly the practice to "catch the carbon coming down," but the present method is to work out almost all the carbon and then recarbonize by adding liquid blast furnace iron to the bath before tapping, thus securing better mixing and more uniform composition. In pouring the ingots attention is being given to the most suitable use of aluminum. The effort is to use sufficient aluminum to have the ingots set quietly and thus reduce the segregation, but not enough to cause very deep piping. The amount used is about 1½ ounces per ton of steel. Since February, 1914, the blooms have been run from the blooming mill through a heating furnace. The blooms are thus started in at the rail mill at a more uniform temperature and probably also at a little higher temperature.

DESCRIPTION OF RAIL PLANT OF THE CAMBRIA STEEL CO.

A visit was made on August 25, 1915, to the rail plant of the Cambria Steel Company by Messrs. C. S. Churchill, W. E. F. Armstrong (representing Mr. J. R. Onderdonk) and M. H. Wickhorst, members of the Sub-Committee on Mill Practice, accompanied by Messrs. J. H. Gibboney and J. A. Colby. The works of the Cambria Steel Company are located at Johnstown, Pa. The rail mill is located at the Cambria plant, but most of the open-hearth steel and blooms are made at the Franklin plant, about three miles distant. The iron ore is obtained from the Lake Superior district; the coal for coke making is obtained partly near Johnstown from Cambria Steel Company mines and is partly Pittsburgh coal; the coke is partly made at Johnstown in by-product ovens and partly bought as bee-hive coke from the Connellsville, W. Va., district; the limestone is Pennsylvania limestone.

Ore.

Representative analyses of the Lake Superior ores used are given below:

	Beaver		Harper	
	As Received.	Dried 212° F.	As Received	Dried 212° F.
Iron	54.20	62.12	56.91	60.41
Phosphorus	.068	.078	.088	.093
Silica	2.98	3.42	5.14	5.46
Manganese	.21	.24	.11	.12
Alumina	2.02	2.32	1.69	1.80
Lime	.10	.12	1.45	1.54
Magnesia	.16	.19	2.43	2.58
Sulphur	.009	.010	.015	.016
Moisture	12.74	.....	5.80	.....

Coal.

Below are given representative analyses of the Franklin coal, obtained near Johnstown, as washed and dried at 212° F., and of the Pittsburgh coal, dried at 212° F.:

	Franklin.	Pittsburgh.
Volatile Matter	18.58	33.09
Fixed Carbon	74.25	58.75
Ash	7.17	8.16
Sulphur	1.17	1.21
Phosphorus	.016	.015

Coke.

The coke made at Johnstown gives about the following analysis:

Volatile matter	.82
Fixed carbon	89.14
Ash	10.04
Sulphur	.83

Phosphorus	.023
Silica	4.56
Iron oxide	2.02
Alumina	3.00
Lime	.05
Magnesia	.32

Limestone.

A representative analysis of the Pennsylvania limestone used, dried at 212° F., is given below:

Calcium carbonate	91.25
Magnesium carbonate	.11
Silica	3.24
Alumina	.90
Phosphorus	.008

Blast Furnaces.

Most of the open-hearth steel for rails is made at the Franklin plant. This has 8 blast furnaces with a capacity of 500 tons per day each, or a total capacity of about 100,000 tons of iron per month. The metal as delivered to the open-hearth plant, shows about the following analysis:

Si	Mn	P	S
.90	1.75	.15	.04

Steel Making.

The open-hearth plant at Franklin has 20 furnaces, 17 of 80 tons capacity and 3 of 100 tons capacity. There is a 300-ton mixer and it is contemplated to change this to a 1,000-ton mixer. The furnaces are charged with lime, ore, scrap steel and liquid iron, the usual charge being about 60 per cent iron and 40 per cent scrap steel. The bath is worked down to about .30 per cent. carbon and the metal is recarbonized by adding liquid iron to the furnace. While tapping the furnace, ferro-manganese (80 per cent.) and ferro-silicon are added to the ladle. Aluminum is added to the molds when needed to quiet the steel. The ingots are 20½x23 inches at the bottom and weigh about 7,000 pounds. The Franklin plant has two sets of soaking pits, one for the blooming mill and one for the slabbing mill. Each set consists of 8 pits, each pit holding 16 of the 20½x23-inch ingots, or a total capacity of 128 ingots for each mill.

Rail Making.

The blooming is done at the Franklin plant in a 40-inch, 2-high, variable draft, reversible mill, steam driven. The ingots are bloomed to 9x10 inches in 15 passes. The blooms are then shipped to the Cambria plant for rolling into rail. They are first charged into a continuous bloom-heating furnace 50 ft. long, the cold blooms being fed at one end and the hot blooms being drawn out at the other end. They are pushed through by electric power. From the continuous furnace the blooms go into a Siemen's reheating furnace for a further "wash" heat. Some of the steel for rails is made into ingots and blooms at the Cambria plant, and these generally go from the bloomer direct into the Siemen's reheating furnaces. There are 5 Siemen's furnaces, holding 15 blooms each, or a total capacity of 75 blooms. The bloom is made into rail in 12 shaping passes. There are three stands, the roughing with 7 passes, the middle roughing with 3 passes and the finishing with 2 passes. This makes a total of 27 passes from the ingot to the rail. There are 4 hot beds, two under cover. There are 6 straightening presses. The loading of the rails is done with magnet cranes.

Changes in Practice.

A number of changes have been made in recent years; a continuous reheating furnace has been installed for the preliminary reheating of cold blooms; magnet cranes have been installed for loading rails; the hot beds, which were uncovered, have been half covered, and it is expected to cover the entire bed. A matter of considerable interest as an effort to eliminate segregation from the rails, is the work which has been done with the sink-head process of making ingots as recently described before the American Iron and Steel Institute by E. F. Kenney, Metallurgical Engineer of the Cambria Steel Co. Although not yet incorporated into regular mill practice, a considerable number of rails have been made from such ingots, which confine the pipe and segregation close to the top of the ingot, and allow rails to be made free from these defects while using a usual top discard of 10 per cent.

DESCRIPTION OF RAIL PLANT OF THE CARNEGIE STEEL COMPANY.

A visit was made on August 24, 1915, to the rail plant of the Carnegie Steel Company by Messrs. C. S. Churchill and M. H. Wickhorst, members of the Sub-Committee on Mill Practice, accompanied by Messrs. J. H. Gibboney and J. A. Colby. The plant is located at Braddock, Pa., and is known as the Edgar Thompson Works of the Carnegie Steel Company. The ores are from the Mesaba Range of the Lake Superior District. The coke for the blast furnaces is from the Connellsville district of West Virginia and the coal for the open-hearth furnaces is from the Pittsburgh district.

Ore.

Mesaba ores are used for making the basic pig iron and representative analyses of the several ores used are given below:

	SiO_2	Iron	Mn	P	Al_2O_3	CaO	MgO	S
Group 1........	6.89	59.29	.66	.046	1.85	.50	.55	.165
Group 2........	5.95	60.60	.69	.051	2.02	.50	.58	.055
Group 3........	6.24	57.02	1.12	.081	2.98	.46	.58	.055
Group 4........	9.21	54.88	.98	.104	2.78	.44	.65	.165
Group 7........	12.08	53.61	.78	.082	3.00	.58	.58	.055
Group 10........	12.75	56.50	.57	.040	2.10	.44	.53	.041

Coke.

A representative analysis of the Connellsville coke used is given below:

Volatile matter	1.00
Fixed carbon	88.60
Ash	10.40
Sulphur	.84
Silica	5.96
Iron	.92
Alumina	3.20
Phosphorus	.013
Lime	.12
Magnesia	.11

Coal.

A representative analysis of the Pittsburgh coal used for the open-hearth producers is given below:

Volatile matter	29.00
Fixed carbon	63.20
Ash	7.80
Sulphur	.95
Phosphorus	.010

Limestone.

The limestone for the blast and open-hearth furnaces is obtained in the neighborhood of Pittsburgh and a representative analysis is as follows:

Calcium oxide	49.70
Magnesium oxide	4.39
Iron and aluminum oxides	1.60
Silica	1.60
Sulphur	.11
Phosphorus	.007

Blast Furnaces.

There are 11 blast furnaces with a capacity of 150,000 tons of iron per month, and they furnish iron for both the Bessemer and open-hearth plants. A representative analysis of the basic iron furnished for the open-hearth mixer is as follows:

C	Si	S	P	Mn
3.5 to 4.0	1.5	.035	.20	1.60

Steel Making.

The liquid iron is brought to the open-hearth plant and poured into a 500-ton mixer. There are 14 open-hearth furnaces of 100 tons capacity per charge, with a total capacity of 70,000 tons of steel per month. The method of operation is to charge lime, ore, scrap steel and liquid iron and work the carbon almost all out of the metal. The metal is then recarbonized and the manganese also added at the same time, by adding to the furnace a mixture of liquid iron and spiegel. If more silicon is needed than furnished by the recarbonizer it is added as ferro-silicon to the ladle while tapping the furnace. Aluminum is added to the molds while pouring the steel into them. The amount used is about ten pounds aluminum for a 105-ton heat, or about 1½ ounces per ton of steel. With high silicon heats the aluminum may be omitted as unnecessary to keep the steel quiet in the molds. The recarbonizing metal is a mixture of blast furnace iron and spiegel, which latter is melted in a cupola previous to mixture with the liquid iron, which is done in a special mixer for the recarbonizing metal. The recarbonizer has about the following analysis:

C	Mn	Si
4.25	5.00	1.25

The composition of the spiegel is about as follows: Mn., 19.00 per cent.; Si., 1.00 per cent. The molds are 23½ inches square at the bottom and the ingots are made about 70 inches high.

Rail Mill.

There are 21 soaking pits holding 10 ingots each, or a total capacity of 210 ingots. The first part of the blooming is done in a set of two stands of two-high rolls driven by a steam engine running 70 rev. per min. and geared down to drive the rolls 4.4 rev. per min. The ingot goes through a pass in each stand, is returned by means of turntables and return rolls to the first stand and makes another pass in each stand. This makes four passes and reduces the ingot to a bloom 15x17 inches. It then goes to the third blooming stand. This is three-high, gives the bloom seven passes and reduces it to 10x10 inches. After making a top discard of about 25 per cent., the bloom is cut into three or four parts of two rail lengths each. The blooms then go to the reheating furnaces, of which there are four, holding nine blooms each, or a total capacity of 36 blooms.

The bloom is shaped into rail in 13 passes, distributed among three stands. The roughing stand has 7 passes, the intermediate stand has 5 passes and the finishing stand 1 pass. The total number of passes from the ingot to the rail is 24. The rails are sawed two at a time. They are loaded with magnet cranes.

Changes in Practice.

The Edgar Thomson Works have been in process of reconstruction for several years and the work is now largely completed. These works originally made only Bessemer steel, and when the call came for open-hearth rails, the blooms were obtained from the Homestead Works of the Carnegie Steel Co. The Edgar Thomson Works now have a large, well-appointed open-hearth plant, and one matter of special interest and importance as regards the quality and uniformity of the rail output is the method of making the additions of carbon, manganese and silicon. These are added in liquid form to the furnace, thus insuring quick reaction and a thorough mixture of the metal in the ladle before pouring the ingots. The loading yard has been rebuilt and is supplied with magnet cranes. The blooming mill is new and the rail shaping mill is now being rebuilt. It is also the practice with heavy rails to make a discard of 30 per cent. from the top of the ingot.

DESCRIPTION OF RAIL PLANT OF THE COLORADO FUEL & IRON COMPANY.

A visit was made on September 7, 1915, to the rail plant of the Colorado Fuel & Iron Company by Messrs. H. J. Boughton, A. L. Davis, J. H. Gibboney and M. H. Wickhorst. The steel works of the company, including the rail plant, are located at Pueblo, Colo., and are known as the Minnequa Works. Most of the iron ore is obtained from Sunrise, Wyo., but some is obtained from Oro Grande, N. M. The coal is obtained from the Trinidad district of Colorado, and the coke is made in that territory previous to shipment to Pueblo. The limestone and dolomite are obtained in Colorado, near Pueblo.

Ore.

Representative analyses of the iron ores are given below, showing the dry ores:

	Sunrise, Wyo.	Oro Grande, N. M.
Iron	56.20	58.50
Phosphorus	.076	.033
Silica	10.00	7.50
Manganese	.17	trace
Iron protoxide	....	4.00
Manganese oxide	.22	trace
Alumina	3.78	.....
Lime	.95	2.70
Magnesia	.13	.29
Copper	.08	.....
Sulphur	.041	.315
Loss on ignition	2.20	4.45

Coke.

The coke for the blast furnaces is made in bee-hive ovens from Trinidad coal and shipped to Pueblo. Representative analyses of the cokes used are given below:

Kind	Fixed Carbon	Volatile Matter	Ash	Sulphur	Phos.	Moist.
Segundo	80.78	.85	18.02	.548	.116	.35
Sopris	78.80	1.50	19.35	.580	.006	.35
Tabasco	80.97	1.65	17.13	.712	.004	.25

Limestone.

The limestone and dolomite are obtained in Colorado and below are given representative analyses:

	Limestones			Dolomite
	Howard	Special Howard	San Carlos	Canon City
Phosphorus	.006	.013	.037	.012
Silica	1.68	1.30	4.80	1.74
Iron peroxide	.24	1.12	.99	.67

Alumina	.26	.73	1.10	1.10
Lime	54.38	54.38	52.70	30.95
Magnesia ...	trace	trace	trace	20.21
Sulphur	.028	.031	.041	.033

Blast Furnaces.

There are six blast furnaces each of 350 tons capacity per 24 hours. A representative analysis of the blast furnace metal delivered to the open-hearth plant is as follows:

Si	S	P	Mn	C	Cu
1.52	.025	.174	.30	4.10	.20

Steel Making.

The open-hearth plant has fifteen furnaces of 65 tons capacity, or a total monthly capacity of 45,000 tons. The hot metal from the blast furnaces is charged into a 200-ton mixer. The operation of the furnace is to charge lime, scrap steel and either hot metal from the mixer or cold pig iron or both. When hot metal is used, mill scale is also charged with the lime and scrap steel, to aid in oxidizing the metalloids. The carbon is worked down to below .10 per cent. and the metal is recarbonized by adding liquid iron to the furnace. The manganese and silicon are added as cold spiegel partly to the furnace and partly to the ladle while tapping the furnace. The spiegel is made at Pueblo from Leadville, Colo., ore, and has about the following analysis: Mn, 35 per cent.; Si, 2.0 per cent.; P, .15 per cent. Aluminum is added to the molds while pouring the steel, equivalent to about 1 oz. per ton of steel and after pouring the ingots they are capped with an iron plate to insure a flat top and prevent the steel from rising. The molds are 20x22 inches at the bottom. There are six soaking pits, four holes each, and each hole holding six ingots, or a total capacity of 144 ingots.

Rail Mill.

The ingots are bloomed in 13 passes to 8x8 inches, in a 38-inch reversing mill, steam driven, with adjustable top roll. The grooves in the rolls are, respectively, 19, 13¼, 10 and 8 inches between collars. The blooms are sheared with hydraulic shears. They are direct rolled into rail without reheating in 10 shaping passes. The shaping rolls are in two stands, five passes in the roughing rolls and five in the finishing rolls. Another stand is, however, being installed in which to give the rail its final pass, and this will then reduce the number of passes in the second stand to four. The total number of passes from ingot to rail is 23. The rails are sawed singly. There are three hotbeds, each 100 ft. long, or a total hotbed length of 300 ft., all under cover. There are 7 straightening presses and 14 drill presses. The loading is done on skids.

DESCRIPTION OF RAIL PLANT OF THE ILLINOIS STEEL COMPANY, GARY WORKS.

A visit was made on September 9, 1915, to the rail plant of the Gary Works of the Illinois Steel Company by Messrs. A. S. Baldwin and M. H. Wickhorst, members of the Sub-Committee on Mill Practice, accompanied by Messrs. W. J. Boughton, A. L. Davis, J. H. Gibboney and H. B. MacFarland. The plant is located at Gary, Ind., at the south end of Lake Michigan. The iron ores are obtained from the Lake Superior district, the coal supply is obtained from West Virginia and Kentucky, the coke is made at Gary and the limestone supply is obtained from Michigan and Illinois.

Ore.

The ore is from the Mesaba range of the Lake Superior district, and below is given a representative analysis of the ore dried at 100° C. The moisture in the natural ore is about 12 per cent.:

Iron	57.5
Silica	7.0
Lime	0.7
Magnesia	0.4
Alumina	2.1
Sulphur	.022
Phosphorus	.10
Loss on ignition	7.5

Coal.

The coal used for making coke is partly Pocahontas, West Virginia, coal and partly Elkhorn, Ky., coal, and representative analyses of the dried coals are given below:

	Pocahontas	Elkhorn
Volatile	16.5	35.0
Fixed carbon	77.0	57.5
Ash	6.5	7.5
Sulphur	0.5	0.6
Phosphorus	trace	.012

Coke.

The coke is made at Gary in 8 batteries of Koppers by-product ovens of 70 ovens each, or a total of 560 ovens. The coal used consists of 30 per cent. Pocahontas and 70 per cent. Elkhorn coal, and a representative analysis of the dry coke obtained is as follows:

Volatile	1.25
Fixed carbon	91.00
Ash	7.75
Sulphur	0.60
Phosphorus	.01

Limestone.

The supply of limestone is obtained from Calcite, Mich., and from Fairmont, Ill., and representative analyses are as follows:

	Fairmont	Calcite
Calcium carbonate	95.6	98.25
Magnesium carbonate	.8	.55
Silica	2.0	.75
Iron oxide	1.0	.15
Alumina	0.6	.30

last Furnaces.

Gary has eight blast furnaces of about 400 tons capacity per 24 hours each. The metal supplied to the open-hearth plant for rail steel shows about the following analysis:

C	Mn	P	S	Si
4.2	1.5	.2	.035	1.2

Steel Making.

Gary has four open-hearth plants with a total of 42 open-hearth furnaces, each of 100 tons capacity. Plants 3 and 4 furnish rail steel. Plant No. 3 has one 300-ton mixer and plant No. 4 has two 300-ton mixers. The steel is made by charging lime, ore and scrap steel to the furnace, heating for about two hours and then charging liquid iron from the mixer. The carbon is then worked down to about .2 per cent. and the metal recarbonized by adding liquid iron to the furnace. Ferro-manganese (80 per cent.) and ferro-silicon (50 per cent.) are added to the ladle while tapping the furnace. No additions are made to the mold. The molds are 20x24 inches at the bottom. For the rail mill there are 12 soaking pits, 4 holes each, each hole holding 4 ingots, or a total capacity of 192 ingots.

Rail Mill.

The ingots are bloomed to 7½x8 inches in 9 passes. The ingot first goes through four two-high tandem blooming rolls, making one pass in each. Then the bloom is given five passes in a three-high blooming mill. The bloom is shaped into rail without reheating in nine passes, making a total of 18 passes from the ingot to the rail. There are six hot-beds, each 100 ft. long, or a total hot-bed length of 600 ft., all under cover. There are 16 straightening presses. The rails are loaded with magnet cranes.

DESCRIPTION OF RAIL PLANT OF THE LACKAWANNA STEEL COMPANY.

A visit was made on September 23. 1915, to the rail plant of the Lackawanna Steel Company by Messrs. J. A. Colby, J. H. Gibboney and M. H. Wickhorst. The steel works of the company are located at Buffalo, N. Y., on the shore of Lake Erie. The ore is obtained from the Lake Superior district, the coal from Pennsylvania and the limestone from New York.

Ore.

The principal ore supply is from the Mesaba range of the Lake Superior district and the following is an average analysis of the dried ore:

Iron	57.0
Silica	6.5
Calcium oxide	1.0
Aluminum oxide	2.0
Phosphorus	.15
Sulphur	.02

Coal.

Part of the coal for making coke is mined at Ellsworth, Pa., and the following is an average analysis of it:

Volatile matter	33
Fixed carbon	57
Ash	8
Moisture	2

Coke.

Some of the coke is made from Ellsworth coal in bee-hive ovens at Ellsworth and some is made at Buffalo in a plant of 700 Otto-Hoffman by-product coke ovens from a mixture of about 75 per cent. Ellsworth coal and 25 per cent. other coals, mixed so as to give about 27 per cent volatile. The bee-hive coke constitutes about 40 per cent of the coke used in the blast furnaces. These cokes show about the following analyses of dried samples:

	Ellsworth Bee-Hive	By-Product
Volatile matter	1.0	1.5
Fixed carbon	89.5	90.0
Ash	9.5	8.5

Limestone.

The limestone is obtained from Pekin, N. Y., and the following is an average analysis of it:

Calcium carbonate	95.0
Magnesium carbonate	2.8
Silica	1.0
Aluminum oxide	1.0
Iron oxide	0.2

Blast Furnaces.

There are 7 blast furnaces, 5 of 500 tons capacity per 24 hours and 2 of 200 tons capacity. The iron shows about the following analysis:

Carbon	3.75
Silicon	1.25
Manganese	.90
Phosphorus	.30
Sulphur	.05

Steel Making.

The steel for rails is made about 50 per cent by the straight open-hearth process and about 50 per cent by the duplex process. There is a Bessemer plant with four 12-ton converters and two open-hearth plants. One open-hearth plant has 14 furnaces, 7 80-ton and 7 100-ton. The new plant has 6 open-hearth furnaces, 4 100-ton stationary and 2 250-ton tilting furnaces. The old open-hearth plant makes straight open-hearth steel. It has a 600-ton mixer. The new open-hearth plant is located next to the Bessemer plant and makes largely duplex steel. The Bessemer plant in conjunction with the new open-hearth has two 300-ton mixers. In making duplex steel the metal is first blown in a Bessemer converter, transferred to an open-hearth furnace, which has been charged with limestone, some liquid iron added and the carbon worked down to about .2 per cent. The furnace is tapped and the metal recarbonized by adding liquid spiegel to the ladle while tapping the furnace. This also adds the needed manganese and silicon. When needed to quiet the steel, aluminum is added to the molds. The spiegel is melted in a cupola and contains about 10 per cent. manganese and 1.5 per cent. silicon. The molds are 19x19 inches at the bottom and the ingots average about 4,500 pounds. There are 28 soaking pits, holding 6 ingots per pit, or a total capacity of 168 ingots.

Rail Mill.

The ingot is rolled in 6 passes to a bloom 8x8 inches. It first receives one pass in each of two stands of tandem rolls and then four passes in a two-high reversing mill. The bloom is rolled into rail in 9 shaping passes divided among 3 stands, having, respectively, 4, 4 and 1 pass. The total number of passes from the ingot to the rail is 15. One important feature of the rolling at this plant is the introduction between the first and second stands of shaping rolls, of a "deseamer," which is a machine recently devised for milling the hot bar on the head and base to remove most of the defects in the surface. The rails are sawed singly. There are four hot-beds, two of them 147 ft. long and two 129½ ft. long, or a total hot-bed length of 553 ft., all under cover. There are 13 straightening presses. The rails are loaded with magnet cranes.

Changes in Practice.

A number of improvements and changes have been made in recent years. An additional open-hearth plant has been built and the duplex method has been instituted for about 50 per cent. of the rail steel made. Eight soaking pits have been added. The hot-beds have been covered over and magnet cranes have been installed. The most notable improvement from the standpoint of rail quality has been the installation of a "deseamer," an invention designed in the first place to remove the seams from the base of the rail and afterward extended to do likewise with the head.

DESCRIPTION OF RAIL PLANT OF THE MARYLAND STEEL COMPANY.

A visit was made on September 24, 1915, to the works of the Maryland Steel Company by Messrs. J. A. Colby, J. H. Gibboney and M. H. Wickhorst. These works are located at Sparrow's Point, Md., on the Chesapeake Bay, accessible to ocean vessels. The ores are obtained from Cuba, the coal is obtained from Pennsylvania, the limestone from West Virginia, and the dolomite, which is also used in the blast furnaces, is obtained from Pennsylvania.

The ore supply consists of about two-thirds Mayari ore from the northern part of Cuba and about one-third Daiquiri ore from the southern part of Cuba. The natural Mayari ore contains about 30 per cent. of moisture and previous to shipment from Cuba it is dried and nodulized. Representative analyses of the ores as received at Sparrow's Point are as follows:

	Mayari	Daiquiri
Iron	54.98	58.00
Silica	3.45	10.70
Aluminum oxide	14.00	1.08
Sulphur	.11	.52
Phosphorus	.02	.025
Manganese	.85	.24
Moisture	2.70	1.56
Copper	trace	.20
Chromium	2.03	
Nickel	.90	
Carbon	.19	
Titanium oxide	.60	
Vanadium	trace	

The carbon in the Mayari ore comes from the coal used for nodulizing.

Coal.

The coal for making coke is 75 per cent. from Clearfield and Indiana Counties, Pennsylvania, and 25 per cent. from Washington County, Pennsylvania. Representative analyses of the dry coals are as follows:

	Clearfield and Indiana Counties	Washington County
Volatile matter	25	33
Fixed carbon	65	58
Ash	10	9
Sulphur	1.25	1.1
Phosphorus	.015	.01
Moisture in natural coal	3.0	2.5

Coke.

The coke is made at Sparrow's Point in a plant of 120 Koffers by-product ovens, from a mixture of the above coals. The yield of dry coke is about 67 per cent. of the dry coal and the capacity is about 1,450 gross tons of coke per day. The moisture in the coke is about eight per cent., and below is given a representative analysis of the dry coke:

Volatile matter	1.5
Fixed carbon	86.0
Ash	12.5
Sulphur	1.1
Phosphorus	.012

Limestone and Dolomite.

In the blast furnaces about 50 per cent. limestone and 50 per cent. dolomite are used. The limestone is from Martinsburg, W. Va., and the dolomite is from Bainbridge, Pa. Representative analyses are given below:

	Limestone	Dolomite
Calcium carbonate	93.50	53.13
Magnesium carbonate	2.00	42.00
Silica	2.00	2.25
Aluminum oxide	.45	.55
Iron oxide	.40	.60
Sulphur	trace	trace
Phosphorus	trace	trace

Blast Furnaces.

There are four blast furnaces with a capacity of 450 tons per day each, or a total monthly capacity of 54,000 tons. The iron delivered to the mixers shows about the following analysis:

Carbon	4.25
Silicon	.85
Phosphorus	.05
Sulphur	.025
Manganese	.90
Chromium	2.00
Nickel	1.90
Titanium	.10
Copper	.10

Steel Making.

The steel for rails is made mostly by the duplex process, in which the steel making is started in a Bessemer converter and finished by the open-hearth process. The Bessemer plant has three 18-ton converters, four iron cupolas and one 1,000-ton mixer. The open-hearth plant has five tilting furnaces of 50 tons capacity each and one 140-ton mixer, used mostly for recarbonizing metal. The open-hearth furnace is charged with limestone, roll scale and "transfer" metal (that is, partly blown metal from the Bessemer), containing about one per cent. carbon. The carbon is worked down to about .2 per cent and the furnace is tapped, the metal being recarbonized by adding spiegelized liquid iron to the ladle while tapping the furnace and before the slag starts to come. The spiegel is obtained from the New Jersey Zinc Company, and its average analysis is given below, together with the average analysis of the spiegelized recarbonizing mixture:

	Mn	P	Si	C
Spiegel	20.0	.06	.9	5.0
Recarbonizer	12.5	.06	1.5	4.5

Aluminum is added to the molds when needed to quiet the steel. The ingots are 21x23 inches at the bottom and weigh about 6,500 pounds. There are 12 soaking pits holding six ingots each, or a total of 72 ingots. The minimum time in the soaking pits is one hour and thirty-five minutes.

Rail Mill.

The ingots are bloomed to 8x8 inches in fifteen passes in a 36-inch variable draft reversing mill, steam driven. In addition to the top and bottom crops, the bloom is sheared into two parts, the top part ordinarily making three rails and the bottom part making two rails, when of 100-lb. section. The bloom is shaped into rail in eleven passes, making 26 passes from the ingot to the rail. There are three stands, the roughing stand having six passes, the intermediate stand four passes and the finishing stand one pass. The rails are sawed to length singly. There are six hot-beds, each 56 ft. long, or a total length of 336 ft., all under cover. There are eight straightening presses and fourteen drill presses. The rails are loaded with magnet cranes.

Changes in Practice.

During recent years a number of changes have been made. The ore supply was formerly obtained from Spain and is now obtained from Cuba. The blast furnaces have been rebuilt, including improvements in methods of charging, and a 1,000-ton mixer has been installed. An open-hearth plant has been built. Two soaking pits have been added. Magnet cranes have been installed. A bloom heating furnace has been built, but has not yet been put into operation.

DESCRIPTION OF RAIL PLANT OF THE PENNSYLVANIA STEEL COMPANY.

A visit was made on September 25, 1915, to the works of the Pennsylvania Steel Company by Messrs. J. A. Colby, J. H. Gibboney and M. H. Wickhorst. These works are located at Steelton, Pa., a few miles distant from Harrisburg. The ore supply at present is partly from Cuba and partly from the Lake Superior district. Normally the ore would come mostly from Cuba, but under present war conditions, there is difficulty in getting satisfactory shipment of a sufficient supply of Cuban ore. The coal for making coke and the limestone are obtained in Pennsylvania.

Ore.

A number of ores are used, but the supply consists mostly of Mayari. Cuba, and Lake Superior ores from the Beaver and Harper mines. Representative analyses of these are given below. The Mayari analysis is of the nodulized ore as received and the other analyses represent the dried ore. Beaver ore as received contains about 8 per cent. moisture and the Harper ore about 2 per cent.:

	Mayari	Beaver	Harper
Iron	54.98	61.0	57.0
Silica	3.45	4.0	6.0
Aluminum oxide	14.00	2.0	0.5
Sulphur	.11	....	....
Phosphorus	.02	.09	.08
Manganese	.85	.3	.25
Chromium	2.03		
Nickel	.90		
Carbon	.19		
Moisture	2.70		
Titanium oxide	.60		
Vanadium	trace		
Copper	trace		

Coal.

The coal for making coke is obtained from the Penn-Mary mine at Heilwood, Indiana County, Pennsylvania. The coal is washed before making coke of it and below are given representative analyses of the dried coal, natural and washed:

	Washed	Natural
Volatile matter	28	26.5
Fixed carbon	64	62.0
Ash	8	11.5
Sulphur	1.25	2.0

Coke.

The coke is made in a plant of 120 Semet-Solvay by-product coke ovens with a capacity of 1,100 tons per day. A representative analysis of the dry coke is as follows:

Volatile matter	1.00
Fixed carbon	89.25
Ash	9.75
Sulphur	1.00

Limestone.

The limestone is obtained from a quarry at Steelton and the following is a representative analysis of it:

Calcium carbonate	78.06
Magnesium carbonate	15.39
Silica	5.94
Iron oxide	.72
Aluminum oxide	.64

Blast Furnaces.

There are six blast furnaces at Steelton, five of 350 tons per day capacity and one of 500 tons capacity. A representative analysis of the iron from the blast furnaces is as follows:

Carbon	3.50
Silicon	1.30
Manganese	.65
Sulphur	.03
Phosphorus	.13
Chromium	.17
Nickel	.13
Copper	.06

Steel Making.

Steel is made by both the straight open-hearth and duplex processes. There are two Bessemer converters of 25 tons capacity each, six stationary open-hearth furnaces of 90 tons capacity each, two tilting open-hearth furnaces of 200 tons capacity each and two mixers, one of 400 tons capacity and one of 800 tons capacity. In making duplex steel, the open-hearth furnace is charged with limestone and Bessemer metal that has been blown to about .10 per cent. carbon, mixer metal is added to bring the carbon in the bath to about .30 per cent. and the metal then worked down to about .10 per cent. carbon. The furnace is tapped and liquid mixer metal is added to the ladle at the same time, to recarbonize. Ferro-manganese and ferro-silicon in cold form are also added to the ladle. Aluminum is added to the molds. The ingots as now made for the new rail mill are 20x24 inches at the bottom, but were formerly 18x18 inches. There are four soaking pits of four holes each, holding four ingots per hole, or a total capacity of 64 ingots. The minimum time in the pits is 2½ hours.

Rail Mill.

The mill for rolling rails is entirely new, including soaking pits, blooming mill, reheating furnaces, rail mill and finishing department. The ingots are rolled into 8x8 blooms in 19 passes in a two-high variable draft reversing mill. In addition to the top and bottom crops, the bloom is cut into parts of two rail lengths each. The blooms then go through reheating furnaces, of which there are three, eight doors each, holding two blooms per door, or a total capacity of 48 blooms. The blooms are shaped into rails in ten passes divided among three stands. This gives a total of 29 passes from the ingot to the rail. The first or roughing stand is a two-high 35-inch mill with five passes; the second, or intermediate stand, is a three-high, 28-inch mill with three passes; and the third or finishing stand is a three-high, 28-inch mill with two passes. The rails are sawed to length singly. There are four hot-beds, each 84 ft. long, or a total length of 336 ft., all under cover. There are four gag presses and eight drill presses. The rails are loaded with magnet cranes.

Changes in Practice.

Additions have been made to the open-hearth plant and an entirely new rail mill has recently been built, including soaking pits, blooming mill, reheating furnaces, rail mill, finishing department and loading yard. This mill rolls both girder and tee rails.

DESCRIPTION OF RAIL PLANT OF THE TENNESSEE COAL, IRON AND RAILROAD COMPANY.

A visit was made on July 1, 1915, to the plant of the Tennessee Coal, Iron & Railroad Company, by Messrs. Chas. S. Churchill and M. H. Wickhorst, members of the Sub-Committee on Mill Practice, accompanied by Mr. J. H. Gibboney.

The rail plant and mill of the Tennessee Coal, Iron & Railroad Company is located at Ensley, Ala., a few miles from Birmingham, Ala. The various main raw materials, such as ore, coal, dolomite and limestone, are obtained in the neighborhood of Ensley from properties also belonging to the same company. The mill rolls open-hearth rails made by the duplex or triplex process, that is, the steel making is started in a Bessemer furnace and the refining finished in an open-hearth furnace in the duplex process, or in the triplex process the metal is passed serially through two open-hearth furnaces.

Ore.

The iron ore used is obtained from Red Mountain, and the following are given as representative analyses of the ore from the several mines:

	Muscoda (No. 1)	Fossil (No. 8)	Ishkooda (No. 13)
Iron	33.93	35.44	36.51
Silica	10.68	16.04	17.28
Alumina	3.33	3.17	2.91
Lime	19.82	16.24	13.63
Manganese	.15	.14	.17
Phosphorus	.30	.33	.37
Water	.30	.52	.38

Coal.

The coal is obtained from the Warrier field and below are given representative analyses. A number of partings in the seams makes it necessary to wash the coal in order to obtain low ash cokes:

	Unwashed Coal				Washed Coal			
	Ash	Vol.	Sul.	Fix. Car.	Ash	Vol.	Sul.	Fix. Car.
Pratt	8.27	30.10	1.53	61.60	5.29	30.80	1.28	63.90
Blue Creek	15.76	23.97	.86	60.27	7.93	25.61	.79	66.46

Coke.

The coke is made in by-product coke ovens and the following are representative analyses of Pratt and Blue Creek by-product cokes:

	Fix. C.	Ash	Sul.	Phos.	Moist.
Pratt	89.98	8.88	1.16	.045	4.73
Blue Creek	88.22	10.83	.65	.050	....

Flux.

The flux used is mostly dolomite, obtained by open quarry methods and a representative analysis is as follows:

Silica	Alumina	Lime	Magnesia	Iron
.55	.41	31.48	20.11	.10

Blast Furnaces.

Ensley has a group of six blast furnaces, each with a capacity of about 400 tons of iron per 24 hours. Their annual capacity is about 780,000 tons.

Steel Making.

The liquid metal from the blast furnace is poured into a large reservoir or mixer, of which there are two, one of 600 tons capacity and the other of 250 tons capacity. The composition of the mixer metal runs about as follows:

C	Si	S	P	Mn
3.8	.91	.041	.81	.40

In making steel by the duplex process, the iron is first blown in 20-ton converters. The converter performs the usual Bessemer function of eliminating partially or completely the silicon, manganese and carbon. Phosphorus and sulphur are removed later in the open-hearth. The iron is either full blown, in which all the silicon, manganese and carbon are eliminated, or "high blown," in which the silicon and manganese have been eliminated, but a portion of the carbon remains.

The open-hearth plant consists of eight tilting furnaces, each of 100 tons capacity. They measure 45 feet from port to port and are 16 feet wide. They are first charged with cold stock, consisting of calcined lime, ore, scale and scrap in the order named. When making rail steel it is the practice to charge three "soft" or "full blown" converter heats and two "high blown" heats, the latter containing about 3.00 per cent. carbon. A rather violent reaction or "kick" characterizes the addition of the first high carbon heat; the second addition produces a milder reaction. After the bath has again become normal, tests are taken for phosphorus and carbon, and if these are satisfactory, the full heat is quickly poured into a 100-ton ladle. The carbon in the steel as poured from the furnace is ordinarily down to about .50 per cent. and it is brought up to the desired amount by additions of coke to the ladle while pouring the steel from the furnace. The ferro-manganese used is added partly to the furnace and partly to the ladle. The ferro-silicon is added mostly to the ladle and partly to the individual molds while pouring the steel into them. In addition, aluminum is also generally added to the molds, equivalent to about 1½ oz. of aluminum per ton of steel. The ingots are 24x24 inches at the bottom and average about 9,500 pounds. The open-hearth plant has an annual capacity of about 750,000 tons.

Recently the triplex process has been developed at Ensley and a part of the steel is being made by it. In this process the refining is started in one furnace and finished in another.

The phosphorus is reduced in the primary furnace from about .8 per cent. down to .1 per cent. and a high phosphorus slag is obtained as a by-product, which is sold for fertilizer. The steel is then transferred to the finishing furnace and the reduction of phosphorus completed down to the required amount. One finishing furnace is able to refine the output of about three primary furnaces. The analyses made preliminary to tapping the heat are made in a small laboratory adjacent to the open-hearth floor.

Rail Mill.

The plant for rolling rails consists of a 44-in. blooming mill, a 34-in. roughing mill and a 27-in. finishing mill. The blooming mill is two-high, with variable draft and driven by a 55x56 in., direct connected, reversing Mesta engine. The rolls have three passes, respectively 24-in., 11-in. and 8-in., between collars. The ingots are 24x24-in. and are rolled into 8x8-in. blooms in 15 passes. After making the usual top crop of about 10 per cent., the bloom is cut into three parts, each part making two or three rails. The roughing mill is two-high and driven by a 55x56-in., direct connected, reversing Mesta engine. These rolls give the bar four passes. The finishing mill is three-high, consists of three stands and finishes the bar in five passes. The total number of passes from ingot to rail is 24. The rails are sawed with gang saws, there being four saws. The rails are loaded with a magnetic crane.

IRON ORES.

The sources of the iron ores used and the average percentages of the main constituents in the dry ores are shown in table 1.

TABLE 1.—IRON ORES.

Mill	Source	Fe	SiO_2	CaO MgO	P
Algoma	Can. Magpie	50	9.9	15.0	.015
	Can. Helen	54	8.7	nil	.09
	Minn.-Albany	58	5.9	0.3	.06
Bethlehem	Cuba	56	12.0	......	.03
	Sweden	66	2.0	......	.20
	Chili	67	1.5	......	.025
Cambria	Minn.-Beaver	62	3.4	0.3	.08
	Mich.-Harper	60	5.5	4.1	.09
Carnegie	Minn.-Mesaba	57	9.0	1.1	.08
Colorado	Wyoming-Sunrise	56	10.9	1.1	.08
	N. M.-Oro Grande	58	7.5	3.0	.03
Ill.-Gary	Minn.-Mesaba	58	7.0	1.1	.10
Lackawanna	Minn.-Mesaba	57	6.5	1.0	.15
Maryland	Cuba-Mayari	55	3.5	...	.02
	Cuba-Daiquiri	58	10.7	...	.025
Pennsylvania	Cuba-Mayari	55	3.5	...	.02
	Minn.-Beaver	61	4.0	...	.09
	Mich.-Harper	57	6.0	......	.08
Tennessee	Alabama	35	15.0	16.0	.40

It is interesting to note the wide geographic distribution of the sources of ore supply, including the United States and Canada, Cuba, South American and Sweden, the source of supply being determined largely by the transportation facilities. The largest tonnage is from the Lake Superior district, this supplying the mills of the Algoma, Illinois, Lackawanna, Carnegie and Cambria companies. Under present war conditions and unsatisfactory shipping facilities, the Pennsylvania company is also obtaining part of its supply from the same source. Most of the lake ore now available is high in phosphorus and therefore not available for making Bessemer steel rails, and this was an important factor in the large displacement of Bessemer rails by open-hearth rails. The Cuban and South American ores are low in phosphorus and the Mayari ore from Cuba also contains considerable nickel and chromium. The Alabama ores have a low percentage of iron and are also very high in phosphorus. In fact, this phosphorus is now being saved as a valuable by-product in the form of a high phosphorus slag and sold as fertilizer.

Of course, economic conditions require that the most available supplies of raw materials, such as ore, coal and limestone, be used, but it is probable that care in obtaining uniformity of stock and production conditions will have a favorable influence toward good quality in the rails and there is a general tendency to give considerable attention to this matter.

COALS.

The sources of most of the coal supplies used for coke making and average analyses of the dry coals are given in table 2.

TABLE 2.—COALS.

Mill	Source	Vol.	Fix. Carb.	Ash.	S
Algoma	W. Va.-Cammelton	35.8	57.0	7.2	1.2
	W. Va.-Pocahontas	17.6	76.1	6.3	.8
Bethlehem	W. Va.-Davis	23.0	69.0	8.0	1.0
	W. Va.-Thomas	23.0	67.0	10.0	1.0
Cambria	Pa.-Franklin	18.6	74.2	7.2	1.2
	Pa.-Pittsburgh	33.0	58.8	8.2	1.2
Illinois-Gary	W. Va.-Pocahontas	16.5	77.0	6.5	0.5
	Ky.-Elkhorn	35.0	57.5	7.5	0.6
Lackawanna	Pa.-Ellsworth	34.0	58.0	8.0	....
Maryland	Pa.-Clearfield	25.0	65.0	10.0	1.3
	Pa.-Washington Co	33.0	58.0	9.0	1.1
Pennsylvania	Pa.-Heilwood—Washed	28.0	64.0	8.0	1.3
	Pa.-Heilwood—Nat	26.5	62.0	11.5	2.0
Tennessee	Ala.-Pratt—Washed	30.8	63.9	5.3	1.3
	Ala.-Pratt—Nat	30.1	61.6	8.3	1.5
	Ala.-Blue Creek—Washed	25.6	66.5	7.9	0.8
	Ala.-Blue Creek—Nat	24.0	60.3	15.7	0.9

COKES.

The kinds of cokes used and the ash and sulphur contents of the dry cokes are listed in table 3:

TABLE 3.—COKES.

Mill	Kind	Ash	Sulphur
Algoma	By-Product	11.3	0.8
Bethlehem	By-Product	11.4	0.8
Cambria	By-Product	10.0	0.8
Carnegie	Bee-hive	10.4	0.8
Colorado	Bee-hive	18.0	0.6
Ill.-Gary	By-Product	7.8	0.6
Lackawanna	By-Product	8.5	....
Lackawanna	Bee-hive	9.5	....
Maryland	By-Product	12.5	1.1
Pennsylvania	By-Product	9.8	1.0
Tennessee	By-Product—Pratt	8.9	1.2
	By-Product—Blue Creek	10.8	0.7

It will be noted that the coke is very largely made in by-product ovens, which allow the recovery of the gas, ammonia and tar.

LIMESTONES.

A list of the limestones and dolomites used as fluxes in the blast furnaces and the percentages of the main constituents are given in table 4.

TABLE 4.—LIMESTONES.

Mill	Source	$CaCO_3$	$MgCO_3$	SiO_2
Algoma	Mich.-Fiborn	96.0	1.6	0.8
Cambria	Pennsylvania	91.3	0.1	3.2
Carnegie	Pa.-Pittsburgh	88.8	9.2	1.6
Colorado	Colorado	97.3	trace	2.0
Ill.-Gary	Mich.-Calcite	95.6	0.8	2.0
	Ill.-Fairmont	98.3	0.5	0.8
Lackawanna	N. Y.-Pekin	95.0	2.8	1.0
Maryland	W. Va.-Martinsburg	93.5	2.0	2.0
	Pa.-Bainbridge	53.1	42.0	2.3
Pennsylvania	Pa.-Steelton	79.0	15.4	5.9
Tennessee	Alabama	56.2	42.3	0.6

It will be noted that most of the blast furnace fluxes are limestones high in lime, but several of them are high magnesia dolomites.

BLAST FURNACES.

The number of the blast furnaces, their daily capacity in gross tons of iron, and the percentages of some of the constituents in the iron, are given in table 5.

TABLE 5.—BLAST FURNACES.

Mill	Number Furnaces	Daily Capacity	P	S	Mn	Si
Algoma	3	750	.13	.04	1.00	.85
Bethlehem	....	....	.50	.04	.60	1.00
Cambria, Franklin	8	3,300	.15	.04	1.75	.90
Carnegie	11	5,000	.20	.04	1.60	1.50
Colorado	6	2,100	.18	.03	.30	1.50
Ill.-Gary	8	3,200	.20	.04	1.50	1.20
Lackawanna	7	3,100	.30	.05	.90	1.25
Maryland	4	1,800	.05	.03	.90	.85
Pennsylvania	6	2,250	.13	.03	.65	1.30
Tennessee	6	2,400	.80	.04	.40	.90

In addition to the elements shown, the metal at the Colorado mill contains a small amount of copper and at the Maryland and Pennsylvania mills, the metal contains nickel and chromium. The Tennessee metal is very high in phosphorus and the company has started to recover it and make it available for fertilizer.

STEEL MAKING.

Table 6 is given showing the main steel making equipment at the several rail plants. In addition to the Bessemer equipment shown, some of the plants have Bessemer converters which are not used for making rail steel, or make only a small tonnage of it.

TABLE 6.—FURNACES.

Mill	Process	Mixers	Bes. Furnaces	O. H. Furnaces
Algoma	Bes.-O. H.-Dupl	2- 150 T	2- 5 T	3- 40 T
		1- 250 T		4- 80 T
Bethlehem	O. H.	1- 250 T		16- 75 T
		1- 450 T		
		1-1000 T		
Cambria, Franklin	O. H.	1- 300 T		17- 80 T
				3-100 T
Carnegie	O. H.	1- 500 T		14-100 T
Colorado	O. H.	1- 200 T		15- 65 T
Ill.-Gary	O. H.			42-100 T
Lackawanna	O. H.-Dupl	2- 300 T	4-12 T	7- 80 T
		1- 600 T		11-100 T
				2-250 T
Maryland	Duplex	1- 140 T	3-18 T	5- 50 T
		1-1000 T		
Pennsylvania	O. H.-Duplex	1- 400 T	2-25 T	6- 90 T
		1- 800 T		2-200 T
Tennessee	Dupl.-Tripl	1- 250 T	2-20 T	8-100 T
		1- 600 T		

While the proper sorting and uniformity of the stock of the raw materials exert a favorable influence on the quality of the rails, the big factors that influence quality begin with the making of the steel and particularly the method of recarbonizing and adding manganese and the care used in doing so. Some of the features of the steel making at the several mills are listed in table 7.

It will be noted that at most of the mills the carbon is mostly worked out in making the steel and then brought up to the desired amount by means of pig iron or spiegel (which is an iron high in manganese as well as carbon). Two of the mills "catch the carbon coming down;" that is, the furnace is tapped when the carbon in the bath gets down to the desired amount or slightly below and the deficiency is made up by adding coal or coke to the ladle while tapping the furnace. This method was formerly more extensively used, but it seems that the carbon aimed at in the steel is secured with less certainty. The recarbonizer is added at some mills to the ladle while tapping the furnace and at other mills it is added to the furnace before tapping. The latter method probably is more

TABLE 7.—ADDITIONS.

Mill	How Recarbonized	How Mn and Si Added	Al added to mold
Algoma	C worked to .5. H. Coal added to ladle	Cold Fe Mn part to furnace, part to ladle. Cold Fe Si to ladle	Expermenting
Bethlehem	C worked to .1. Liquid iron added to furnace	Cold Fe Mn, part to furnace, part to ladle. Cold Fe Si to ladle	Yes
Cambria	C worked to .3. Liquid iron added to furnace	Cold Fe Mn and Fe Si added to ladle	Yes
Carnegie	C worked to .1. Liquid spiegelized iron to furnace adds C Mn and Si	Liquid speigelized iron to furnace	Yes
Colorado	C worked to .1. Liquid iron added to furnace	Cold spiegel part to furnace, part to ladle	Yes
Ill.-Gary	C worked to .2. Liquid iron added to furnace	Cold Fe Mn and Fe Si added to ladle	No
Lackawanna	C worked to .2. Liquid spiegelized iron to ladle adds C Mn and Si	Liquid spiegelized iron to ladle	Yes
Maryland	C worked to .2. Liquid spiegelized iron to ladle adds C, Mn and Si	Liquid spiegelized iron added to ladle	Yes
Pennsylvania	C worked to .1. Liquid iron added to ladle	Cold Fe Mn and Fe Si added to ladle	Yes
Tennessee	C worked to .5. Coke added to ladle	Fe Mn part to furnace, part to ladle. Fe Si mostly to ladle, part to molds	Yes

certain in securing uniform mixture, although there probably is also more loss of silicon by absorption into the slag.

In adding manganese the most general practice is to add it to the ladle as cold 80 per cent. ferro-manganese while tapping the furnace, although some of it is sometimes added to the furnace before tapping, using the larger lumps this way to insure thorough melting and mixing with the steel. Some plants add the manganese as liquid spiegelized iron to the ladle while tapping the furnace, which thus adds the carbon, manganese and silicon at the same time. Probably the practice that is most effective in obtaining thorough mixture of all the ingredients before tapping the steel from the ladle is that at the Carnegie rail plant, where liquid spiegelized iron is added to the furnace before tapping into the ladle.

Aluminum is rather generally used as a mold addition in amounts of one to two ounces per ton of steel. Some plants use it regularly and others aim to omit its use when the steel sets quiet in the mold without it. Gary uses no aluminum in rail steel, depending upon sufficient silicon to obtain quiet setting steel. This plant also has a rule not to use ingots with "horny tops" for rails.

ROLLING.

Some of the features concerning the ingots and blooms are listed in table 8.

It will be noted that most of the mills have two-high reversing rolls with adjustable top roll, thus affording variable draft in blooming. Such rolls have considerable flexibility, but have not, however, a high tonnage

TABLE 8.—INGOTS AND BLOOMS.

Mill	Size Ingots	Soaking Pits-Capac. Ingots	Blooming Rolls	Blooming Passes	Size Bloom
Algoma	19x23	96	1-2 high revers.	19	8x8
Bethlehem	19x23	175	1-2 high revers.	15	8x8
Cambria-Franklin	20½x23	128	1-2 high revers.	15	9x10
Carnegie	23½x23½	210	2-2 high		
			1-3 high	11	10x10
Colorado	20x22	144	1-2 high revers.	13	8x8
Ill.-Gary	20x24	192	4-2 high	9	7½x8
			1-3 high		
Lackawanna	19x19	168	2-2 high	6	8x8
			1-2 high revers.		
Maryland	21x23	72	1-2 high revers.	15	8x8
Pennsylvania	20x24	64	1-2 high revers.	19	8x8
Tennessee	24x24	144	1-2 high revers.	15	8x8

capacity, due to the necessity for reversing the direction of the rolls after each pass. Three of the mills divide the blooming among several stands with fixed passes. Observation seems also to indicate a greater tendency to tearing of the sides of the bloom at these mills, although this is a matter for more critical investigation before definite conclusions are warranted.

Some of the features concerning the rails are listed in table 9.

TABLE 9.—RAILS.

Mill	Reheater Capacity Blooms	Shaping passes	Total Passes	How Sawed	Hot-bed Feet	Straightng Presses	Loading
Algoma	48	11	30	Singly	212	5	Skids
Bethlehem	60	11	26	Singly	420	6	Magnets
Cambria	75	12	27			6	Magnets
Carnegie	36	13	24	Twos			Magnets
Colorado	None	10	23	Singly	300	7	Skids
Ill.-Gary	None	9	18	Gang	600	16	Magnets
Lackawanna	None	9	15	Singly	553	13	Magnets
Maryland	None	11	26	Singly	336	8	Magnets
Pennsylvania	48	10	29	Singly	336	8	Magnets
Tennessee	None	9	24	Gang			Magnets

It will be noted that at half the mills the rails are direct-rolled from the heat of the ingot, while at the other mills the blooms are reheated, being given a "wash" heat. The Tennessee plant has a bloom reheating furnace, that can be used for heating up cold blooms when necessary, but is not used in the regular rolling of rails. The Maryland plant has installed a bloom reheating furnace, but it has not yet been put into use. Most of the mills saw the rails singly from the hot bar. This method is, of course, slower than where two or more rails are cut from the bar at one time, but the rails can probably be cut closer to the length aimed at when sawed singly. One very noteworthy feature in rolling rails is the device gotten up and used by the Lackawanna Steel Company for hot milling the bar, while partly shaped into rail and before finishing. The top of the head and the bottom of the base are milled or scraped, so as to remove most of the surface flaws and seams from the tread and base of the rail.

CHANGES IN PRACTICE.

Extensive changes have been made among the rail mills during recent years. The rail plants of the Carnegie and Pennsylvania steel companies have been mostly rebuilt and important changes have been made at some of the other plants. Some of the features of interest along this line are noted below. One feature of interest is that there has been considerable improvement in testing equipment and in the amount of investigative work being done by the mills.

At the Algoma Steel Co. a matter of special interest is the nick and break test of a piece of rail from each ingot and the examination of the fracture for both pipe and segregation.

The Bethlehem Steel Co. have made a number of changes largely directed to securing more uniformity in the conditions of manufacture. Large mixers have been installed; in making the steel the practice was to "catch the carbon coming down," while now the metal is recarbonized by means of liquid iron added to the furnace; the practice has been instituted of reheating the blooms.

At the Cambria Steel Co. a feature of special interest is the sinkhead process of casting ingots by which the segregation is obtained close to the top of the ingot and cut off with the ordinary top crop, and which process has been used in some rollings of rail.

At the Carnegie Steel Co. a new open-hearth plant has been built and almost all of the rest of the rail plant has been rebuilt.

The feature of special interest at the Lackawanna Steel Co. is the deseamer or hot miller described above.

The Pennsylvania Steel Co. have made changes and additions to their steel-making plant and the rail mill is entirely new.

MILL PRACTICE AND RAIL FAILURES.

The rail mills are making considerable efforts to avoid sending out rails liable to give failures and the statistics of rail failures presented in Report 48 indicate that these efforts are being attended with some success, even though it seems to be true that conditions of service have been growing more severe.

Most of the failures of rails can be divided into three types of failures, as follows:

1. Crushed and split heads.
2. Broken rails and broken bases.
3. Transverse or internal fissures.

The first type of failure, crushed and split heads (vertical longitudinal interior cracks) are mostly the result of segregation, or a concentration of carbon, phosphorus and sulphur in the upper and interior part of the ingot, attended generally with a condition of sponginess in the interior, and a condition of softness in the outer portions of the section, in the upper part of the ingot. The "peaning" or "ironing" action of the rolling wheels causes a side spread of the top part of the head. The outer metal has practically always sufficient ductility to stand this side spread, but if the interior metal has not, it develops a crack, which keeps growing until a split head results. Of course, the more severe the service, the more rapidly does the failure result, but in the absence of defestive internal metal the effect of severe service is to simply distort the shape of the rail head, and make bad riding track. It is necessary, therefore, to obtain metal free from excessive segregation and one method of doing this is to discard the top fourth or more of the ingot. This is now the practice of the Carnegie Steel Co. in making all heavy section rails. This method requires that the top part of the ingot be rolled into other material, or that the bloom butts be remelted. Another method is to use the sink-head process of casting ingots, which is being developed in several modifications and which collects most of the segregated material into the top ten per cent. of the ingot. This method has been used to a small extent by the Cambria Steel Co. It seems that the general method is a very commendable one, although it also seems to have not yet been developed to a point commercially practicable for the manufacture of rails in large quantities. Our investigations, as well as other work, have shown that ingots that are lively in the mold when setting are attended with considerable interior segregation. Such ingots set with raised or "horny" tops, and as this appearance is evidence of considerable segregation, strong efforts should be made to avoid using ingots with raised tops. The skillful use of silicon, aluminum or titanium makes the ingot set flat and tends to restrain the segregation, but also produces a larger pipe. It may be here remarked that attention is now also being given to more effective means of rejecting segregated rails, by means of analysis, drop test and fracture appearance. Much has been done to avoid making and to eliminate segregated rails and it seems probable that in the course of time the arts of making and inspecting rails will reach a point where failures from split heads will be mostly eliminated.

Broken rails (including square and angular breaks) and broken bases are here classed together, as in general it may be said that they both have their origin in longitudinal seams in the bottom of the base of the rail. A seam not directly under the web, when it opens up, may result in only breaking out a piece of the flange or a "crescent" break, but if near the middle of the bottom of the base, the opening up of a seam is apt to result in a break through the whole section. The bases of rails are now more generally being made thicker than formerly, and should, it would seem, be stronger against this type of failure, although the main purpose of the thickening was originally to provide more uniform temperature of the rail section when being rolled. More recently the fillet between the web and the base has been increased in some rail sections to afford additional strength against "broken" rails. From the manufacturing standpoint, the Lackawanna Steel Co. have taken vigorous action and devised a deseamer, a machine for milling the surface from the hot bar before fully formed into rail, thereby removing most of the defects from the bottom of the base of the rail. Although it may be said that seams are produced in the rolling, we are not, however, able to state definitely and concisely the factors which govern their formation, and we have here a field for extensive investigation. Besides the elimination of seams we have also the problem of increasing the transverse ductility of the bottom of the base, which is generally both low and irregular.

The type of failure known as transverse or internal fissure is one that has become prominent in the last few years with the introduction of open-hearth steel for rails. It usually shows itself as an oval-shaped crack or "simple" transverse fissure inside the head and crosswise of the length of the rail and is also of a bright silvery appearance until exposed to the air. Sometimes, however, the fissure occurs lengthwise and about parallel with the top of the head and about one-half inch down from the top. Generally, also, this latter kind has a transverse fissure running down from it, forming a "compound" internal fissure, or what Dr. P. H. Dudley has named the "coalescent" kind. Although the term "transverse fissure" first came into use, it is evidently only a species (although the most numerous) of a larger group that may be called internal fissure.

As to the cause of this type of failure, we are unable to talk with great confidence and likewise we are still uncertain as to the remedy. The failure seems evidently to be one of detail fracture under the action of repeated stresses, or, more properly, repeated strains. It is sometimes claimed that any normal rail is apt to develop this kind of fracture, but there is a little evidence indicating that the fissure starts from an original internal defect, which keeps growing under repeated alternations of stress, until failure finally results. Of course, any severe strain, as in the gag press, or by defective counterbalance or flat spots on wheels would much hasten the development of the fissure. Increasing the weight of the rail should, it would seem, strengthen the rail against this type of failure, by reducing the fiber stresses, but this whole matter is one in need of very extensive investigation.

Appendix F.

INTERNAL FISSURES IN RAILS.

The Rail Committee of the American Railway Engineering Association appointed a Sub-Committee to report on the matter of rail failures of the type known as "internal fissures," concerning particularly the state of information and investigations in progress concerning such failures. The Sub-Committee consisted of W. C. Cushing, Chairman; C. F. W. Felt and M. H. Wickhorst.

TYPES OF INTERNAL FISSURES.

The internal fissure first came prominently to notice in a report made by J. E. Howard on the Manchester, N. Y., wreck on the Lehigh Valley Railroad in 1911, and it was in this report that Mr. Howard aptly applied the term "transverse fissure." This failure usually manifests itself as an oval-shaped spot in the interior of the head, as shown in Fig. 1, representing a typical example. These spots occur in all sizes from one-fourth-inch or less in diameter to almost the full size of the section of the head. When a fracture occurs through a fissure that has not extended to the surface, the fissure appears bright and polished and we have a "silvery oval spot." When, however, previous to the complete fracture, the internal fissure has reached the surface, the spot will appear dark, due to weathering. One interesting and very constant feature noticeable in transverse fissures is the presence of a "nucleus," a crystalline or granular spot, generally somewhat central, which apparently acted as the center of growth of the fissure.

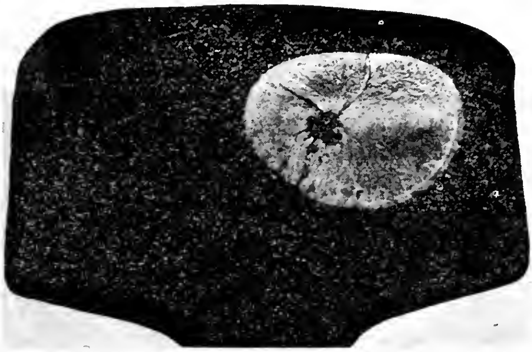

Fig. 1. Sample of Transverse Fissure.

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*Report 52, January, 1916.

Although the simple transverse fissure is the more usual form in which the internal fissure shows itself, the fissure sometimes occurs as a compound type, in which a horizontal fissure is joined by one or more transverse fissures. This is the type that Dr. P. H. Dudley has termed the "coalescent" type of interior fissure and specimens are shown in Figs. 2 and 3, showing fractures of two different rails. In this type the fissure apparently started to grow as a horizontal fissure about one-half inch below the top surface of the head and the transverse fissure then branched out from it or perhaps grew independently.

FIG. 2. SAMPLE OF COMPOUND INTERNAL FISSURE.

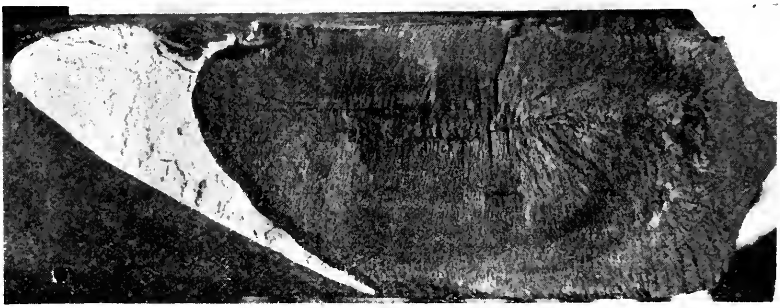

FIG. 3. SHOWING HORIZONTAL FISSURE, LOOKING DOWN ON TOP OF HEAD.

"Internal fissure" is therefore a term that may be applied to a group of failures consisting of two or three species, namely, the simple transverse fissure (which is the most numerous), the compound fissure (showing both horizontal and transverse fissures), and probably also the simple horizontal fissure. In all this discussion it is understood the type of failure known as "split head" or "piped rail" is excluded. Although this failure shows a longitudinal vertical fissure, still the term "split head" has come to be applied to it and it requires separate discussion.

BIBLIOGRAPHY.

A bibliography has been prepared so as to have for convenient reference the main articles that have appeared in the last few years concerning internal fissures in rails. The literature on the subject starts with Mr. Howard's report on the Manchester wreck on the Lehigh Valley Railroad that occurred August 25, 1911, when this type of failure first came prominently to public attention. The publications consulted were the Railway Age Gazette, Railway Review, Iron Age and Iron Trade Review. Also the Proceedings of the American Railway Engineering Association, American Society for Testing Materials, the National Association of Railway Commissioners, and some of the reports of the Interstate Commerce Commission. While not exhaustive, it is believed the bibliography given below is a fairly full representation of the literature on the subject.

The explanations of the cause for the fissures as contained in the written articles seem to differ widely, but a close study of them suggests that they are not necessarily inconsistent with each other. They probably each contain an element of truth, but a full and complete explanation probably has not yet been worked out. A characteristic and constant feature of transverse fissures is the "nucleus," a granular or crystalline spot surrounded by the smooth or polished part of the fissure. The nucleus is ordinarily from ⅛ to ¼-inch in diameter, but may be larger or smaller. The surrounding smooth part has been found in all sizes from nothing to almost the full size of the head. It seems fairly certain that the nucleus acted as a center of growth from which the fissure developed under "repeated alternations of stress" or the "wave action" under moving trains, but the origin of the nucleus seems not yet to have been fully explained, although undoubtedly it is a vital part of the problem. Several questions arise: Did the nucleus form in the track in normal material; or was there already a predisposing condition in the interior metal of the rail head, or again, was the nucleus an original fissure existing in the rail when laid in the track?

INTERNAL FISSURES IN RAILS.

BIBLIOGRAPHY.

1911.

"Interstate Commerce Commission Investigation of Lehigh Valley Accident at Manchester, N. Y." Report of the Chief Inspector of Safety Appliances of a serious accident on August 25, 1911, embodying a report by James E. Howard. The rail which caused the accident showed internal transverse fissures and other defects. The formation and development of the internal fissures is explained as "due to the use of hard steel and subjecting it to high wheel pressures" under repeated alternations of stress.

"The Broken Lehigh Valley Rail." Iron Age, Vol. 88, p. 800, October 12, 1911. From Mr. Job's testimony in coroner's inquiry concerning Lehigh Valley wreck near Manchester, N. Y., on August 25, 1911.

"Rail Failure—Lehigh Valley Wreck." Iron Trade Review, Vol. 49, p. 1108, December 21, 1911. From coroner's report of Lehigh Valley wreck at Manchester, N. Y., August 25, 1911, with references to reports by Touceda, Job and Howard. Touceda found high manganese, which may have produced "cold shortness under shock." Job attributed defects to faulty mill practice. Howard blamed heavy loads and hard steel.

1912.

"Limit of Endurance of Steel Rails Reached?" Iron Trade Review, Vol. 50, p. 353, February 8, 1912. Mr. Howard's report on Manchester wreck, with illustrations of rail.

"The Broken Lehigh Valley Rail." Railway Age Gazette, Vol. 52, p. 280, February 16, 1912. An extended and copiously illustrated abstract of a report made by J. E. Howard for the Interstate Commerce Commission, concerning accident to Lehigh Valley train at Manchester, N. Y., on August 25, 1911. An editorial on this paper occurs in the same number, p. 267.

"Wheel Loads and Transverse Fissures in Rails." By "Mechanical Engineer." Railway Age Gazette, Vol. 52, p. 468, March 15, 1912. Discussion of Mr. Howard's report on the Lehigh Valley rail.

"Broken Rail on the New Haven." Railway Age Gazette, Vol. 52. p. 1012, May 3, 1912. On February 11, 1912, the Federal Express on the New York, New Haven & Hartford Railroad was derailed by a broken rail that showed an internal transverse fissure. Some results are given of the examination of the rail by the railroad.

"Some Defective Rails and How to Avoid Them." By Robert Job. Iron Trade Review, Vol. 51, p. 504, September 12, 1912. From paper before the International Society for Testing Materials. Illustrations are given, including internal fissures, which are attributed to defective mill practice, the details of which are not otherwise discussed

"Types of Defective Rails and Some Methods Used in Detecting Them." By Robert Job. Railway Age Gazette, Vol. 53, p. 954, November 15, 1912. Paper presented at Sixth Congress of the International Association for Testing Materials, New York, September, 1912. Among other types of rail failures Mr. Job presented illustrations of transverse and compound internal fissures. Concerning them he remarked that "thorough study proved beyond question that the composition of the steel in its ordinary elements was not the cause of the failure, and also that the conditions of service were not the prime cause."

"That Broken Rail on the Lehigh Valley Railroad." Railway and Engineering Review, Vol. 51, p. 1023, November 25, 1912. Editorial comment dissenting from views expressed in Interstate Commerce Commission report.

1913.

"Investigation of Silvery Oval Spots, sometimes called 'Transverse or Internal Fissures' in Rail Heads." By W. C. Cushing, Proceedings, American Railway Engineering Association, Vol. 14, 1913, p. 413. Results of the examination of some transverse fissure rails by C. D. Young of the Altoona Laboratory of the Pennsylvania Railroad. Slag was found in the fractures and the suggestion is made that this may have started an internal fracture, which developed in service until a broken rail resulted.

"Interstate Commerce Commission Investigation of Louisville & Nashville Accident near Hay's Mill, Ala." Report by Chief Inspector of Safety Appliances, dated August 15, 1913, of accident on October 1, 1912, embodying report by J. E. Howard. "The formation and successive development of these transverse fissures, as a matter of opinion, was the direct result of overstraining loads, combined alternate repeated bending stresses and intense wheel contact stresses."

"Analysis of a Broken Rail." Railway Age Gazette, Vol. 55, p. 623, October 3, 1913. Extract from a report by J. E. Howard on rail that caused a derailment on the Louisville & Nashville Railroad near Hay's Mill, Ala., October 1, 1912. Examination showed the rail to contain a number of transverse fissures. The rail was found to be high in carbon, but of uniform chemical composition. The explanation is given that the fissures were due to repeated alternations of combined bending stresses and intense wheel contact stresses, and the origin of the fissure in the interior is explained as due to the cold rolling effect of the wheels putting the metal at the running surface in compression and thus offsetting tensile stresses near the running surfaces.

1914.

"Interstate Commerce Commission Investigation of Southern Railway Accident near Oyama, N. C." Report by Chief Inspector of Safety Appliances, dated January 7, 1914, of accident on March 31, 1913, embodying report by J. E. Howard. The same explanation of the formation of fissures is given as in the previous cases.

"Internal Transverse Cracks and Fissures in Rails." By Robert Job. Railway Age Gazette, Vol. 56, p. 266, February 6, 1914. Illustrations are given of rails showing transverse fissures, including some that occurred in Austrian rails, copied from a publication by Dormus at Vienna in 1901. Mr. Job concludes that "traffic conditions were not the prime cause of the growth of the cracks," but that the cause of the failure is to be looked for in the condition of the steel.

"Internal Transverse Fissures in Rails." By P. H. Dudley. Iron Age, Vol. 93, p. 492, February 14, 1914. From a report by Dr. Dudley, January 6, 1914, to the President of the New York Central Lines. Attributes the fissures to insufficient ductility in the rail head account conditions of manufacture, with conditions of service contributory.

"A Study of Interior Transverse Fissures in Rails." By P. H. Dudley. Railway Age Gazette, Vol. 56, p. 415, February 27, 1914. Editorial comment on p. 411. Illustrated article in which the fissure is attributed to various conditions of manufacture, and particularly to the bad effect of the gagging when straightening the rail.

"Internal Transverse Defects in Steel Rails." By Robert Job. Iron Age, Vol. 93, p. 660, March 12, 1914. From the article in the Railway Age Gazette, February 6, 1914.

"Transverse Fissures and Broken Rails." Iron Age, Vol. 93, p. 1528, June 18, 1914. From Interstate Commerce Commission report on New York, New Haven & Hartford wreck near Westerly, R. I.

"Interstate Commerce Commission Investigation of New York, New Haven & Hartford Accident near Westerly, R. I." Report by Chief Inspector of Safety Appliances, dated April 24, 1914, of accident on October 25, 1913, embodying reports by J. E. Howard, Bureau of Standards, New York, New Haven & Hartford Railroad and Wirt Tassin. Mr. Howard concluded "that the proximate cause to which the transverse fissures in broken rail No. 1 are ascribed are high wheel loads, with their attending strains, evidence of other causes not having been found."

"Fatigue of Rails." By Paul Kreuzpointner. Railway Age Gazette, Vol. 57, p. 755, October 23, 1914. A discussion of "fatigue," or detail fracture with illustrations of the difference in the appearance of such fracture in good or sound material and in defective material.

"Interstate Commerce Commission Investigation of Delaware, Lackawana & Western Accident near Alford, Pa." Report by Chief Inspector of Safety Appliances, dated December 31, 1914, of accident on October 31, 1914, embodying report by J. E. Howard. The conclusion is expressed "That the growth of transverse fissures is the result of repeated stresses, and their formation occurs in consequence of overloads applied to the rails in service."

1915.

"Study of a Rail With Internal Fissures." By M. H. Wickhorst. Proceedings, American Railway Engineering Association, Vol. 16 (1915), p. 195. Results of an examination of a rail that had failed in service due to transverse fissures. It showed numerous small cracks, mostly longitudinal, in the interior of the head.

"Internal Fissures in New Rails." By M. H. Wickhorst. Proceedings, American Railway Engineering Association, Vol. 16 (1915), p. 389. Illustrations are given of some small longitudinal cracks found in new rails.

"Interior Transverse Fissures." By P. H. Dudley. Proceedings, American Railway Engineering Association, Vol. 16 (1915), p. 1120. Illustrated discussion by Dr. Dudley, presenting part of a letter to the President of the New York Central Lines. Attention is called to the harmful effect of the gag press in the cold straightening of rails.

"The Failure of Material Under Repeated Stresses." By H. F. Moore and F. B. Seeley. American Society for Testing Materials, Vol. 15, 1915, p. 437. While not dealing specially with rails, this paper gives a full discussion of the subject of "fatigue" of metals, or fracture in detail under repeated stresses, together with a bibliography of the subject.

"Fissures in Rails." Railway Review, Vol. 56, p. 562, April 24, 1915. Editorial discussion reviewing various explanations for transverse fissures.

"Gagging Rails and Transverse Fissures." By A. W. Thompson. Railway Age Gazette, Vol. 59, p. 888, November 12, 1915. Expresses the thought that the elimination of gagging would probably not overcome the transverse fissure.

"Transverse Fissures the Result of Rail Gagging." By P. H. Dudley. Railway Age Gazette, Vol. 59, p. 1001, November 26, 1915. Exhibits two types of interior transverse fissure, the intergranular and coalescent types. The intergranular (or simple transverse) fissure is explained as due to gagging on the base in straightening and the coalescent (or compound) fissure is explained as due to gagging on the head.

National Association of Railway Commissioners, Washington, D. C. Various types of rail failures are discussed, including transverse fissures, in the reports of the Committee on Rails and Equipment for 1912 and succeeding years. This failure is described as a progressive fracture under repeated alternate stresses. The tendency seems to be to ascribe the failure mostly to high wheel loads and hard steel.

CHEMICAL AND PHYSICAL PROPERTIES.

The Altoona Laboratory of the Pennsylvania Railroad examined a great many rails that failed due to transverse fissures, the examinations including chemical and physical tests. The information was kindly given the Committee and in Table 1 is shown the chemical and physical results obtained. In these tables the tensile strength is expressed in pounds per square inch, the elongation is expressed in per cent. in two inches with specimens one-half inch in diameter, and the reduction of area is expressed in per cent. of the original area of the cross-section. For presentation in more convenient form, some of this information is shown diagrammatically in Figs. 4, 5 and 6, presenting the age, carbon, phosphorus, tensile strength and elongation of each of the samples tabulated. In showing the carbon and phosphorus, the vertical column showing the amount of the element is divided into two parts, the unshaded part representing the amount in the corner of the head and the shaded part representing the amount in the interior of the head.

A study of the tables and diagrams shows some interesting features. The age of the rails when broken, it will be noted, lies mostly between two and four years. Across the carbon diagrams are drawn two lines representing the carbon limits of the present American Railway Engineering Association specifications, namely, .62 and .75 per cent. It will be noticed that a great many of the rails show carbon above .75 per cent., although probably a great many of them were bought to specifications calling for carbon above the present American Railway Engineering Association limits.

A line is drawn across the phosphorus diagrams at .04 per cent. representing the upper limit in rail specifications, and it will be noticed that in most of the cases of open-hearth rail the phosphorus is well below this amount.

In Report 40 the relation between carbon and tensile strength was found to be expressed by the formula,

$$T = 40{,}500 + 1250\,C$$

where T equals tensile strength in lbs. per square inch and C equals carbon in .01 per cent. (See Proceedings, American Railway Engineering Association, Vol. 16, 1915, p. 175.) According to this formula the average tensile strength of .62 per cent. carbon rail steel is 118,000 lbs. per square inch and of .75 per cent. carbon rail steel is 134,250 lbs. per square inch. Two lines are drawn on the diagram to represent these tensile strengths and while most of the individual results lie between these lines, a great many lie below them. It should be explained that in preparing the tensile test piece, the head of the rail was usually split along the middle and the tensile specimen was then cut from about the center of one-half. The axis of the test specimen was thus about half-way between the side of the head and the vertical center plane of the rail, and also about half-way between the top and bottom surfaces of the rail head.

Also in Report 40 the relation between carbon and elongation was found to be expressed by the formula:

$$E = 40 - .38\,C$$

where E equals the per cent. elongation in two inches and C the carbon in .01 per cent. (See Proceedings, American Railway Engineering Association, Vol. 16, 1915, p. 176.) According to this formula, the

TABLE 1. TRANSVERSE FISSURE RAILS.

Mill	Rail No.	Sec.	Wt.	Rolled	Heat No.	Broken	Age	Analysis Corner Head					Analysis Interior Head					Tensile Results		
				Mo. Yr.		Mo. D. Yr.	Yr. Mo.	C	Mn	P	Si	S	C	Mn	P	Si	S	Tens. Str.	Elong.	Red. Area
Bethlehem	1	P. S.	85	4-09	17773	2-25-13	3-11	.72	.95	.022	.127	.023	.82	.95	.026	.132	.030	122350	2.00	2.06
	2			09	17773	3- 5-13	3-11	.77	.95	.028	.141	.029	.77	.94	.025	.136	.021	131350	3.00	7.01
	3			4-09	17773	9-15-13	4- 6	.83	.85	.017	.071	.025	.85	.86	.019	.071	.029	127090	3.00	8.16
	4			09	17773	10-31-13	4- 7	.78	.84	.019	.132	.023	.79	.82	.020	.127	.028	90350	2.50	1.63
	5			4-09	18753	1-25-14	4-10	.90	.89	.034	.060	.012	.85	.85	.021	.080	.012	142950	5.60	6.85
	6			4-09	20688	3-27-12	3- 0	.82	.63	.024	.085	.030	.80	.66	.024	.089	.026	89000	1.00	0.90
	7			09	22589	3-22-12	3- 0	.80	.80	.021	.141	.027	.79	.80	.022	.141	.024	130050	8.50	10.20
	8			4-09	23495	12-21-12	3- 9	.74	.74	.035	.100	.025	.73	.71	.029	.108	.020	126150	10.75	12.56
	9			4-09	23495	6-14-13	4- 2	.79	.73	.024	.153	.027	.80	.75	.024	.159	.027	76874	2.00	.888
	10			4-09	23495	2- 2-15	5-10	.77	.89	.027	.150	.023	.76	.88	.025	.150	.023	130650	8.00	11.25
	11		100	4-09	3513	10-27-13	4- 7	.89	.71	.014	.103	.019	.84	.71	.014	.108	.017	133050	10.76	12.35
	12			09	8803	4- 4-14	5- 0	.78	.68	.010	.127	.020	.75	.67	.007	.132	.018	123550	14.00	19.59
	13	P.R.R.	100	4-09	15715	4- 3-14	5- 0	.89	.67	.014	.118	.017	.77	.67	.014	.122	.015	127450	11.50	16.28
	14	P. S.	100	09	16740	2-29-12	2- 8	.92	.75	.012	.090	.025	.93	.75	.015	.085	.026	96430	1.00	1.30
	15		100	09	16740	4- 4-12	3- 0	.92	.74	.016	.094	.025	.82	.75	.013	.094	.021	131800	12.00	22.13
	16			09	16740	8- 3-14	3- 4	.90	.71	.010	.061	.030	.87	.72	.012	.066	.024	134900	8.75	7.63
	17			4-09	16746	4-22-12	3- 1	.63	.63	.024	.126	.016	.79	.60	.020	.136	.017	132230	9.00	10.38
	18			4-09	16745	6-20-12	3- 3	.72	.72	.012	.085	.029	.72	.74	.013	.085	.031	128650	14.00	18.20
	19			09	17787	6-25-14	5- 3	.71	.76	.036	.089	.028	.73	.76	.047	.089	.039	127950	10.50	9.57
	20			09	18745	3- 9-12	2-11	.86	.87	.027	.141	.020	.81	.87	.033	141	.018	95170	2.00	1.60
	21			4-09	18745	6- 4-12	3- 2	.87	.87	.027	.132	.020	.90	.88	.022	.132	.021	119750	3.00	2.42
	22			09	19645	8- 2-12	3- 4	.72	.78	.022	.071	.022	.70	.76	.018	.071	.021	122650	14.00	19.45
	23			4-09	19645	9- 9-12	3- 5	.88	.71	.011	.113	.021	.84	.72	.009	.113	.020	137300	10.00	11.59
	24			09	19657	9-16-12	3- 6	.80	.65	.028	.041	.024	.79	.65	.031	.041	.023	106890	4.25	6.22
	25			09	19667	2- 2-14	4- 8	.77	.67	.010	.141	.024	.74	.65	.011	.136	.021	128400	13.00	19.65
	26			6-09	19780	9-23-13	4- 4	.73	.89	.040	.150	.022	.69	.87	.043	.155	.020	89330	1.50	9.80
	27			4-09	23518	4-14-12	3- 0	.82	.74	.022	.103	.021	.81	.74	.027	.089	.020	127500	12.00	18.20
	28	P.R.R.	100	09	32653	5-16-13	4- 2	.84	.66	.015	.158	.028	.80	.67	.015	.150	.025	121480	6.00	5.30
	29	P. S.	100	10	1705	11-13-13	3-10	.72	.61	.046	.179	.036	.69	.62	.046	.179	.029	129300	13.00	19.57
	30	P.R.R.	100	10	2057	10- 2-13	3- 9	.74	.76	.029	.160	.019	.77	.75	.031	.160	.022	106000	2.00	2.69
	31	P. S.	100	10	14304	11-12-11	1-10	.81	.69	.029	.146	.031	.83	.68	.030	.141	.033	121630	10.00	12.20
	32			3-10	14307	1-26-13	2-11	.76	.64	.029	.120	.026	.67	.63	.025	.118	.028	122500	12.00	14.99
	33			11-10	16246	2- 2-12	2- 0	.83	.73	.037	.160	.023	.78	.73	.034	.160	.017	111850	2.00	3.10
	34	P.R.R.	100	2-10	16246	12- 6-11	1-10	.84	.66	.030	.160	.026	.83	.67	.031	.160	.024	114650	2.50	3.55
	35	P. S.	100	10	20110	9-10-13	3- 7	.78	.84	.035	.165	.014	.79	.84	.028	.169	.015	107250		
	36	P.R.R.	100	10	20116	4-29-13	3- 3	.80	.81	.016	136	.025	.81	.80	.018	.135	.027	129690	12.00	14 08

CORRECTION.

THE PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, April 26, 1916.

Mr. W. C. Cushing,
Chief Engineer M. of W.

Dear Sir:

Referring to American Railway Engineering Association report No. 52, to the Rail Committee, on Internal Fissures in Rails:

In Table 1, pages 8 to 10, inclusive, a number of the rails are given as P. R. R. section, rolled in 1909, or later years, whereas the rolling of the P. R. R. section rail has been stopped since 1907, with the exception of one small lot, which was used on side tracks.

I have had Mr. Coughlin's office check this list over, and find that Bethlehem rails Nos. 13, 28, 34, 36 and 44 should be P. S. instead of P. R. R. section. Although their records do not show it, Bethlehem rail No. 30 presumably should also be P. S. section, as the Bethlehem Company never rolled any P. R. R. 100-pound section.

I presume that Carnegie Rail No. 1, given as P. R. R. 85-pound section, rolled in 1909, should also be P. S. section. Possibly your records will show this.

In checking over this table Mr. Coughlin's office has found several errors, which it might be well to bring to Mr. Wickhorst's attention, viz., Bethlehem rail No. 17, carbon and manganese .85 and .83, respectively, instead of .63 and .63. Bethlehem rail No. 24, reduction of area 5.22 instead of 6.22, as given. Cambria rail No. 4, 85-pound section instead of 100, as given. Lackawanna rail No. 4, tensile strength 126550, instead of 136200, as given. Pennsylvania Steel Company rail No. 3, carbon .82 instead of .52, as given.

Yours truly,
(Signed) A. W. GIBBS,
Chairman, Rail Committee.

	37	P. S.	100	2–10	None	2– 2–12	2– 0	.80	.68	.031	.160	.024	.76	.68	.026	.155	.023	130350	7.00	8.60
	38			2–10	None	1– 2–12	1–11	.79	.57	.028	.170	.027	.80	.58	.030	.158	.030	115660	5.50	5.90
	39			2–10	None	1–16–12	2– 0	.77	.56	.037	.174	.023	.80	.57	.034	.174	.025	111560	6.50	10.40
	40			2–10	None	2– 2–12	2– 0	.81	62	.030	.177	.023	.81	.62	.030	.169	.026	117970	5.50	6.10
	41			2–10	None	1–25–12	2– 0	.79	.62	.039	.165	.021	.75	.61	.030	.165	.019	116850	4.50	6.05
	42			2–10	None	2– 2–12	2– 0	.80	.60	.029	.160	.022	.82	.60	.032	.165	.024	101980	3.00	2.60
	43			10	61797	4– 3–14	4– 0	.85	.81	.035	.108	.013	.82	.83	.036	.105	.016	136050	6.00	5.72
	44	P.R.R.	100	5–11	16948	12–16–13	2– 7	.92	.99	.023	.113	.026	.88	.99	.024	.109	.024	145050	9.50	11.76
	45	P. S.	100	11	19798	6–29–14	3– 1	.91	.82	.031	.146	.030	.90	.82	.026	.141	.030	130400	4.00	4.07
Carnegie	1	P.R.R.	85	09	8056	10–26–13	4– 0	.52	.90	.101	.030	.022	.48	.91	.094	.033	.021	114750	18.50	31.31
	2	P. S.	100	12–09	9658	1–23–14	4– 2	.55	1.00	.101	.108	.038	.54	.99	.096	.103	.035	118800	16.50	29.63
	3			10	36000	7–22–13	3– 0	.65	.69	.040	.220	.045	.72	.73	.045	.226	.045	121770	15.00	23.21
	4			11	53045	4– 8–14	3– 0	.84	.71	.035	.244	.028	.82	.71	.035	.239	.026	142950	10.00	12.57
Maryland	1*	P. S.	100	10–10	645651	8– 4–14	3–10	.50	.97	.058	.089	.051	.49	.94	.055	.094	.047	122900	17.00	33.20
	2†			10	134564	10–12–12	2	.45	.85	.065	.132	.050	.51	.83	.070	.127	.060	122800	17.00	30.06
Cambria	1	P. S.	100	5–09	5517	1–14–12	2– 0	.81	.66	.021	.108	.031	.81	.67	.020	.111	.031	123750	10.00	11.45
	2			09	8667	12–15–13	4– 6	.91	.57	.015	.141	.026	1.00	.52	.015	.146	.036	127230	7.00	7.75
	3			10	12309	3–12–14	3– 6	.80	.57	.026	.160	.022	.86	.59	.032	.155	.025	136100	9.00	11.72
	4			9–10	12761	7–30–14	3–11	.71	.64	.023	.122	.034	.77	.66	.025	.127	.037	122300	13.00	19.38
	5			11–10	20342	11–23–13	3–11	.73	.72	.029	.165	.025	.80	.72	.032	.160	.034	123190	11.50	12.41
	6			2–11	1499	9–14–12	1– 7	.75	.69	.027	.118	.024	.83	.69	.034	.122	.032	128150	13.60	17.10
	7			3–11	1551	8–11–14	3– 5	.82	.78	.026	.089	.027	.87	.78	.028	.089	.029	136300	10.00	14.06
	8			3–11	13357	6–29–14	3– 4	.87	.72	.020	.115	.024	.91	.72	.021	.108	.027	138050	10.00	11.71
	9			11	13399	6–27–14	3– 4	.68	.61	.020	.146	.014	.82	.63	.028	.150	.027	120850	7.00	7.96
	10			3–11	13534	1– 1–15	3–10	.76	.70	.022	.061	.021	.76	.71	.021	.061	.024	127650	12.00	16.62
	11			3–11	13595	5–27–12	1– 3	.83	.77	.033	.127	.022	.87	.80	.034	.122	.025	135400	9.25	10.82
	12			2–11	15335	3–19–14	3– 2	.79	.67	.029	.179	.030	.92	.71	.033	.174	.040	130600	11.00	14.77
	13			2–11	51550	7–22–14	3– 6	.77	.75	.016	.089	.031	.86	.72	.018	.085	.031	126200	13.00	18.16
	14			2–11	61524	6–29–12	1– 5	.76	.67	.025	.103	.027	.88	.69	.031	.103	.042	128200	13.25	17.20
	15			4–12	17424	3–16–14	2– 0	.81	.59	.021	.108	.016	.81	.61	.018	.103	.016	120550	13.50	17.78
	16			10–12	19678	5– 7–14	1– 7	.76	.60	.022	.056	.018	.77	.60	.023	.061	.021	124200	12.50	15.68
	17			12	19695	5–21–13	0– 8	.74	.65	.021	.080	.021	.79	.66	.022	.085	.027	90870	7.00	11.22
	18			11–12	19734	5–18–13	0– 7	.78	.73	.027	.132	.019	.77	.74	.029	.122	.019	135100	9.50	10.66
	19			11–12	20299	6–20–14	1– 8	.76	.71	.029	.071	.026	.74	.71	.029	.075	.026	107400	3.00	2.68
	20			2–12	20303	4– 9–14	2– 2	.69	.65	.025	.135	.017	.77	.65	.025	.132	.021	116400	15.50	23.14
	21			2–12	20305	7–11–14	2– 5	.65	.70	.027	.150	.015	.69	.73	.029	.150	.015	118650	14.50	21.04
	22			12	20314	5–22–13	0– 7	.66	.66	.030	.101	018	.73	.67	.033	.103	.019	112515	14.00	19.59
	23			12	20329	10–10–13	0– 9	.73	.69	.020	.110	.026	.83	.80	.024	.113	.027	126850	10.20	10.96
	24			12–12	20920	4–16–14	1– 5	.82	.57	.020	.061	.020	.80	.59	.022	.061	.026	120350	14.00	19.11
	25			4–01	Invis.	12–23–13	12– 8	.52	1.00	.102	.127	018	.51	1.00	.096	127	.018	121600	16.00	28.04

*Contains also, Corner, Cr .37 and Ni .47 and Interior, Cr .34 and Ni .47.
†Contains also, Corner, Cr .40 and Ni .527 and Interior, Cr .43 and Ni .512.

TABLE 1, CONTINUED.

Mill	Rail No.	Sec.	Wt.	Rolled	Heat No.	Broken	Age	Analysis Corner Head.					Analysis Interior Head.					Tensile Results.		
				Mo. Yr.		Mo. D. Yr.	Yr. Mo.	C	Mn	P	Si	S	C	Mn	P	Si	S	Tens. Str.	Elong.	Red. A.
Laekawanna	1	P. S.	100	09	4019	8-15-12	3- 0	.64	.82	.020	.122	.027	61	.82	.028	.132	.028	135450	10.50	11.95
	2			09	4319	11-29-11	2- 0	.84	.84	.028	.174	.030	.83	.81	.024	.165	.027	132550	9.00	13.50
	3			09	4719	12-15-12	3- 0	.86	.82	.027	.165	.030	.86	.84	.030	.165	.033	131300	10.00	14.15
	4			2-09	10030	12-12-12	3-10	.74	.91	.024	.153	.033	.75	.91	.032	.196	.032	136200	13.25	19.31
	5			09	10220	3- 4-12	3- 0	.80	.86	.022	.146	.030	.81	.89	.027	.155	.043	136400	10.00	13.60
	6			09	22798	2- 4-14	5- 0	.75	.86	.018	.123	.031	.70	.85	.012	.110	.030	125650	12.00	13.05
	7			09	87738	11-10-13	4- 0	.75	.69	.016	.103	.033	.76	.69	.024	.113	.037	128750	11.50	17.69
	8			2-09	None	4-11-13	4- 2	.76	.85	.030	.156	.028	.76	.82	028	.163	.025	134850	11.50	11.36
	9			09	None	4-16-13	4- 0	.84	.66	.028	.139	.038	.80	.66	.032	.136	.036	132525	9.50	12.59
	10			10	7737	11-28-13	3- 0	.75	.86	.023	.160	.027	.80	.86	.022	.160	.027	130400	12.00	17.39
	11			11	10239	1-19-13	2- 0	.78	.82	.021	.160	.029	.74	.82	.021	.166	.029	124100	5.00	6.84
	12			2-12	3056	5- 5-14	2- 3	.68	.72	.013	.075	.017	.66	.73	.016	.071	.017	114900	15.50	25.89
	13			12	8284	9- 7-14	2- 0	.79	.78	.014	.089	.025	.83	.80	.020	.089	.029	137000	6.50	10.59
	14			2-12	8915	8-25-14	2- 7	.77	.86	.039	.080	.024	.71	.84	.036	.080	.026	133050	12.00	14.44
	15			2-12	8915	4-27-14	2- 3	.79	.86	.020	.089	.020	.79	.86	.021	.089	.022	130150	12.00	17.18
Penna. S. Co.	1	P. R. R.	100	1-09	2313	6-00-12	3- 2	.91	.71	.018	.113	.021	.83	.70	.015	.103	.018	133250	8.30	11.10
	2	P. S.	100	09	24132	12- 9-13	4- 0	.90	.72	.021	.052	.038	.94	.74	.023	.056	.042	140000	8.50	10.38
	3			4-09	24905	3-30-14	5- 0	.52	.68	.013	.075	.022	.60	.67	.015	.080	.022	130050	8.50	9.90
	4			09	25175	3- 5-14	4-11	.96	.80	.012	.083	.020	.87	.80	.008	.061	.016	141400	9.50	12.61
	5			5-09	25905	3-27-13	3-11	.84	.70	.016	.071	.030	.82	.79	.014	.066	.028	128975	8.00	9.89
	6			1-10	3458	5- 6-13	3- 4	.79	.67	.048	.078	.063	.77	.65	.040	.071	.056	129350	9.50	14.68
	7			2-10	21539	13- 3-13	3-10	.79	.62	.016	.052	.038	.76	.62	.025	.056	.031	125900	12.50	15.89
	8			10	21974	10-20-13	3- 0	.65	.67	.016	.127	.068	.73	.75	.017	.127	.071	124100	14.50	23.65
	9			10-10	25459	12- 3-13	3- 2	.72	.65	.016	.132	.032	.67	.66	.014	.152	.030	135800	11.00	16.26
	10*			9-11	23402	1-26-14	4- 3	.73	.73	.013	.165	.037	.68	.73	.014	.160	.035	None		
	11†			12-12	21233	5- 6-14	1- 7	.72	.64	.015	.094	.067	.80	.66	.025	094	.035	138200	12.00	17.13

*Contains also, Corner, Cr .24 and Ni .27 and Interior, Cr .23 and Ni .26.
†Contains also, Corner, Cr .37 and Ni .68 and Interior, Cr .42 and Ni .68.

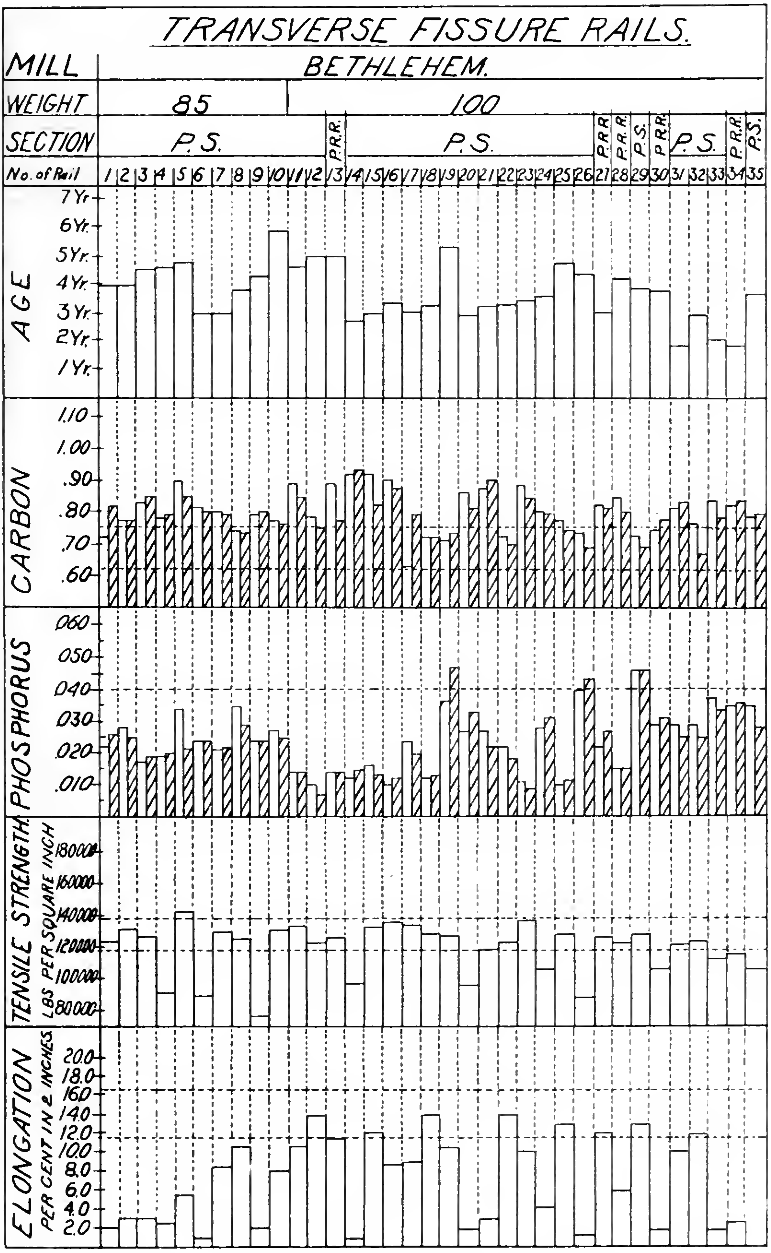

FIG. 4. DIAGRAMS OF TRANSVERSE FISSURE RAILS.

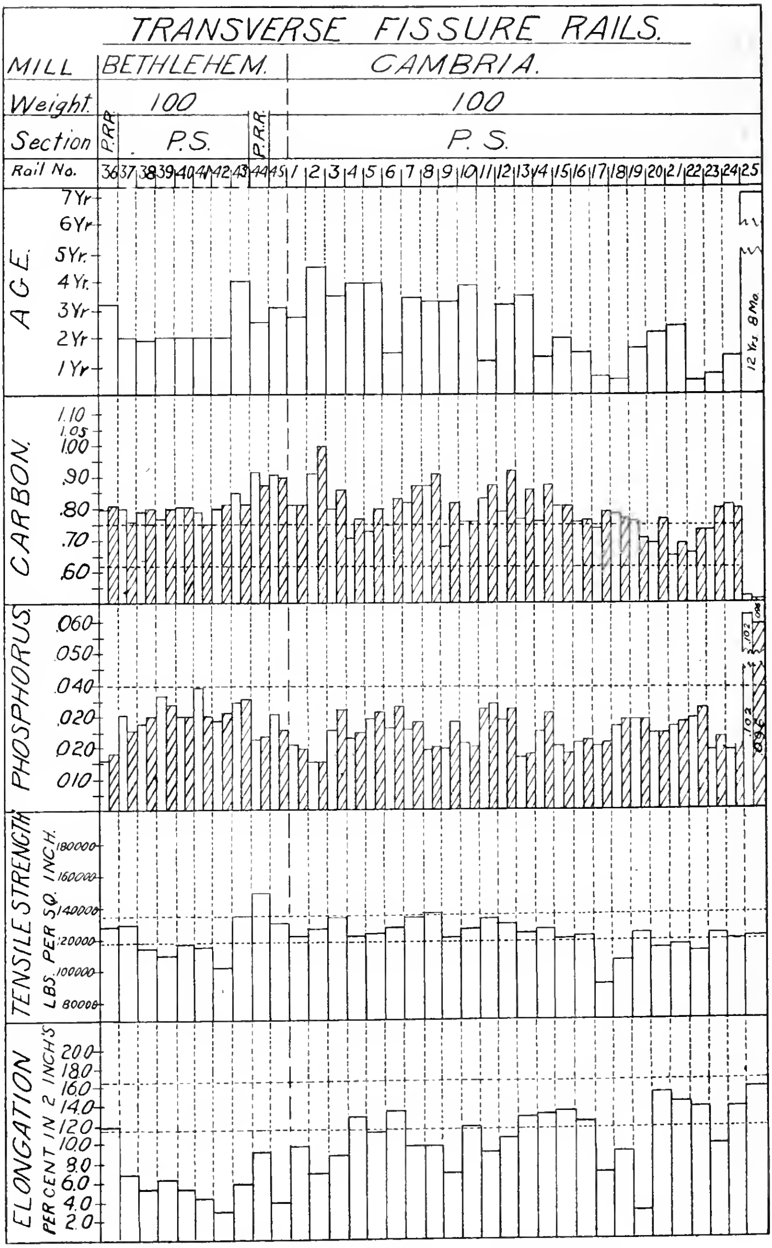

FIG. 5. DIAGRAMS OF TRANSVERSE FISSURE RAILS.

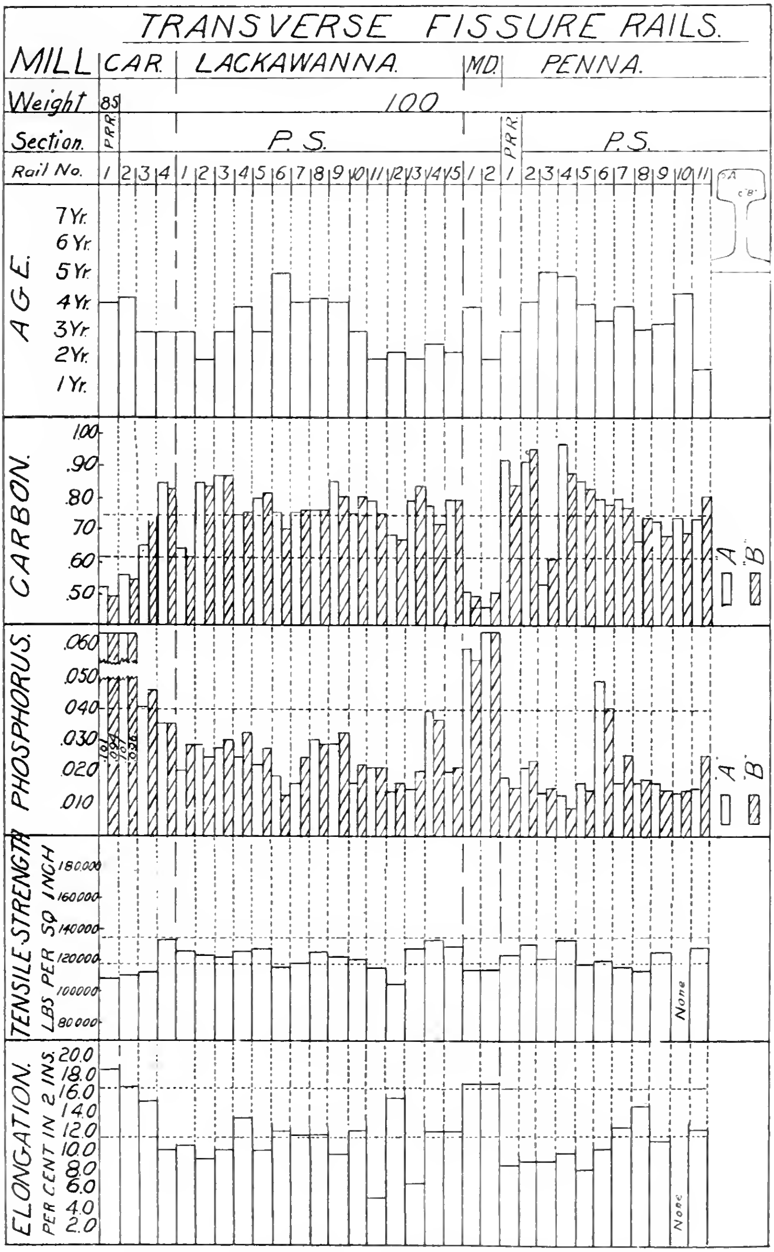

FIG. 6. DIAGRAMS OF TRANSVERSE FISSURE RAILS.

elongation of .62 per cent. carbon rail steel averages 16.5 per cent. and of .75 per cent. carbon rail steel averages 11.5 per cent. Two lines are drawn on the diagram to represent these elongations, and it will be noted that a great many of the individual elongations are considerably below the normal amount.

A matter of special interest and importance concerning these results is the light they throw on the relation of chemical composition to transverse fissures. A study of the carbon and phosphorus diagrams shows that some of the samples showed segregation, that is, had a concentration of carbon and phosphorus in the interior of the rail head, and that other samples showed a negative segregation, or impoverishment, that is, they had an impoverishment of carbon and phosphorus in the interior of the rail head. Only a few samples showed any considerable segregation. This comparison of the analyses of the interior and outer metals shows approximately the part of the ingot that the rail was rolled from. When the two samples show about the same analysis the rail was probably from the middle third of the ingot, or close to the bottom of the ingot. If segregation is shown, that is, if the interior of the rail head shows more carbon and phosphorus than the metal in the outer portions of the section, the rail was probably from the upper third of the ingot. If negative segregation is shown, that is, if the interior of the head of the rail shows less carbon and phosphorus than the metal in the outer portions of the section, the rail was probably from the lower third of the ingot, although close to the bottom of the ingot the metal is also of fairly uniform composition across the section.

The number of the rails for each amount of difference between the outside and interior steel is shown in Table 3:

TABLE 2. CARBON COMPARISON.

Approximately Lower Half Ingot. Hundredths Per Cent. Carbon That Center Head Is Less Than Corner.		Approximately Upper Half Ingot. Hundredths Per Cent. Carbon That Center of Head Exceeds Corner.	
Amount.	No. of Rails.	Amount.	No. of Rails.
.00	9	.01	9
.01	12	.02	4
.02	8	.03	3
.03	7	.04	5
.04	8	.05	3
.05	8	.06	2
.06	2	.07	3
.07	0	.08	5
.08	1	.09	2
.09	2	.10	2
.10	1	.11	0
.11	0	.12	1
.12	1	.13	1
	—	.14	1
	59	.15	0
		.16	1
			—
			42

It will be noted that an attempt has been made to assign each rail to one of the two halves of the ingot, which classification, however, can be regarded as only a rough approximation. It serves to indicate, in connection with the more detailed classification, that the rails are distributed indiscriminately over the whole ingot. The results in the table are presented diagrammatically in Fig. 7. About 6 per cent. of the rails showed segregation beyond the 12 per cent. allowed under the specifications and inspection used by the Pennsylvania Railroad in some of its recent rail purchases. It would seem, therefore, that segregation is not a large factor in causing transverse failures.

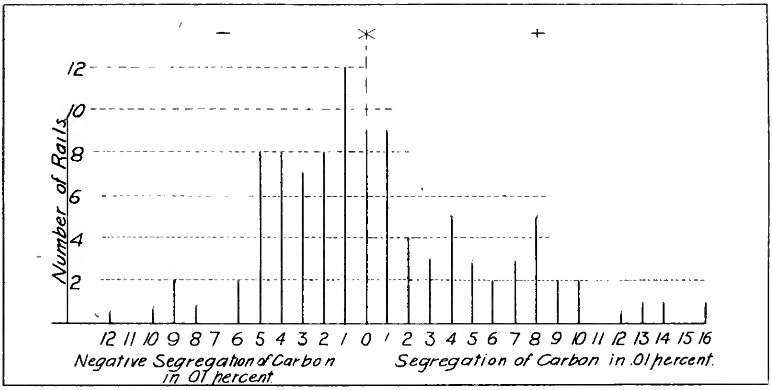

FIG. 7. DIAGRAM OF CARBON DIFFERENCES BETWEEN INTERIOR AND OUTER METAL.

To sum up, this study indicates that *transverse fissures occur indiscriminately in the several rails of the ingots and that segregation is not an important factor in causing the fissures.*

BUREAU OF STANDARDS.

The Government Bureau of Standards at Washington has been collecting samples of transverse fissure rails and has underway some extensive investigations, including physical, chemical, metallographic, magnetic and alternating stress methods. This work will probably develop some interesting and important information on the subject.

CARNEGIE STEEL COMPANY.

The Carnegie Steel Company has been making some vibratory or alternating stress tests of rails at the Edgar Thomson Works at Braddock, Pa. The machine used consists of a rail straightening press fitted with side arms so that both tension and compression are applied alternately to both the head and base of the rail. At first one machine was used, but the test takes so long that another machine was fitted

SOME OF THE CAUSES OF RAIL FAILURES.

PREFACE.

The original copy of this report of a study of rails which have failed in main track service has been placed for reference in the Library of the Institution of Civil Engineers, and an abstract of it has been included as a "Selected" Paper in Volume 201 of the Institution Proceedings. The Council has graciously allowed its publication in the Proceedings of the American Railway Engineering Association.

The study of rail design and of the material from which rails are manufactured has been a continuous one since the railway was fairly launched as a transportation system.

The establishment of engineering societies has made many of the studies available for engineers generally. In the United States of America, the American Society of Civil Engineers gave considerable attention to the subject until the year 1899. A committee, with Mr. Ashbel Welch as Chairman, reported "On the Form, Weight, Manufacture and Life of Rails" from 1874 to 1876, and another committee, with Mr. G. Bouscaren as Chairman, reported on "Standard Rail Sections" from 1891 to 1893, which resulted in the adoption by that Society of the "American Society of Civil Engineers (A. S. C. E.) Rail Sections." They were afterwards quite generally used by different railway companies.

In 1898-99, the American Railway Engineering Association was formed, and it immediately undertook the active study of the rail problem, as indicated by the many reports in its Proceedings. Some of these studies have been made by a standing committee, and some by various members of the Association in connection with their official work.

The study of rail failures has for the most part been a study of an "individual" or "single" rail which has failed in service, but there can also be a "collective" study of many samples of failures arranged in groups for the purpose, and the standing committee of the American Railway Engineering Association has given many such studies of rail failure statistics in its Proceedings.

The study embodied in the present paper is such a "collective" study, or study of a large number of failures arranged in groups of the same kind, but the presentation of the subject is quite different from that of previous studies, in that the defects in the rails found by physical tests

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Rail Report 53, March, 1916.

and chemical and microscopical analyses have been classified and so marked that they can be readily and comprehensively viewed by the eye, and the characteristic defect, influencing the failure, or pointing out its cause, picked out.

The numerous and characteristic defects of "Split Head" rails are so marked in comparison with, for instance, the rails which have given good service, that the lesson is very striking and impressive.

The fact that it was prepared for a British audience will justify the use of some explanatory passages in the paper which are now well understood by the members of our Association.

Pittsburgh, December 8, 1915. W. C. Cushing.

SOME OF THE CAUSES OF RAIL FAILURES.

By W. C. Cushing.

*In 1909 and 1910, the writer made a study of 108 rails which had failed in main track service in order to try and throw some light on a subject which had been engaging the attention of many railway engineers for several years, the problem being to arrest and diminish the growing number of rail failures in service in the main tracks of the railways.

This was followed in 1911 with an †analysis by Mr. M. H. Wickhorst of data relating to 17 rails with a record of good service in the main tracks, which had been supplied by Mr. R. Trimble and the writer.

. Since that time the study of such rails has been continued by the writer, and the results are now presented in the following pages.

From January 26, 1909, to December 16, 1912, practically a period of four years, there were 4,330 rail failures in 1,790 miles of single main track, being 60 failures for each 100 miles of track per annum. These were not all *broken* rails, but represent the sum total of all kinds of failures. It has been found advisable, by the railways of North America, to classify rail failures, as some kinds of failures are more dangerous than others, and this has been done in accordance with the scheme explained on the back of the Track Foreman's blank for reports, Form M. W. 34-A, (formerly M. W. 4.43), a copy of which accompanies each report of rail examination made at the Laboratory, and to which the reader is referred for the explanation of the terms used.

This classification consists of:

1. *Broken Rail*, illustrated by No. 196.
2. *Flow of Metal*, illustrated by No. 302.
3. *Crushed Head*, illustrated by No. 287.
4. *Split Head*, illustrated by No. 395.
5. *Split Web*, illustrated by No. 531.
6. *Broken Base*, illustrated by No. 505.
7. *Damaged*, illustrated by Nos. 655 and 656.

Of course, these classifications are but approximate, for they are made by the Track Foreman, and the defect named is just as it appears on the outside of the rail to the observer. Examination at the Laboratory often discloses a "split head" as the prime cause of a "crushed head," a "broken base" or a "split web" as the cause of a "broken rail," etc.

"Damaged" rails are not taken account of in rail failure statistics, being caused by wrecks or defective equipment, and so are not included

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*Proceedings American Railway Engineering Association, 1911, Vol. 12, Part II, pp. 230 and 293.

†Proceedings American Railway Engineering Association, 1912, Vol. 13, p. 573.

in the classification of the 4,330 rail failures spoken of above, which is shown in Table No. 1. The dimensions and the mathematical characteristics of the different rail sections mentioned in this table are given in Figs. A, B, C, D, E and F. Fig. A, the P. R. R. (Pennsylvania Railroad) section, was first in use, but gave way to the 85-lb. and then the 100-lb. A. S. C. E. (American Society of Civil Engineers) sections, Figs. B and C. These in turn, on account of their thin bases and greater proportion of metal in the head than in the base, gave way to the P. S. (Pennsylvania System) sections, 85 and 100 lbs. per yard, Figs. D and E. The A. R. A.—A (American Railway Association, Type A) section, Fig. F, was designed a short time afterwards for trial.

The *"broken base"* failures have been practically eliminated by the heavy base of the 100-lb. P. S. section.

All of the other classified failures, except *"broken rail,"* can be grouped into *"head and web"* failures, which usually give warning of their defective structure before rupture occurs, and so are not considered dangerous to the traffic. They make up by far the largest proportion of failures, and foreign writers, when speaking of the large number of failures in the United States, not being aware of this classification, often designate them as *"broken rails,"* which is very misleading.

The number of *"broken"* rails, 787, is, however, much too large, although it must be borne in mind that the period covered by these statistics includes the very severe winter of 1912, when breakages were so numerous in North America on account of the deeply frozen roadbed for a longer duration of time than usual.

It is not practicable to make a complete survey of the chemical condition and physical properties of every rail which fails, when they are so numerous, and therefore it has been our custom to select at random rails which have failed in the different ways indicated by the "classi-

TABLE NO. 1.

Pennsylvania Lines West of Pittsburgh—South West System.

STATEMENT OF RAIL FAILURES FROM JANUARY 26, 1909, TO DECEMBER 16, 1912, CLASSIFIED AS TO KIND OF FAILURE, SECTION, PROCESS AND WEIGHT.

Office of Chief Engineer M. of W. Pittsburgh, Pa., August, 1914.

Wt.	Section.	Process.	Kind of Failure.						Total Failures
			Broken	Flow of Metal.	Crushed Head.	Split Head.	Broken Web.	Split Base.	
100	A. S. C. E...	Bessemer....	100	4	59	156	13	3	335
100	P. S.........	Bessemer....	51	29	23	94	12	....	209
100	P. S.........	O. H.-A.....	3	....	1	....	1	....	5
100	P. S.........	O. H.-B.....	5	1	....	6	5	....	17
100	A. R. A.-A..	Bessemer. ..	3	....	4	113	10	....	130
85	P. R. R.....	Bessemer....	43	6	35	315	17	7	423
85	A. S. C. E...	Bessemer....	373	67	366	1279	129	87	2301
85	P. S.........	Bessemer....	202	12	211	326	73	35	859
85	P. S.........	O. H.-A....	....	7	18	....	....	....	25
85	P. S.........	O. H.-B.....	2	2	5	10	1	1	21
85	P. S.........	OH Mayari..	5	....	....	....	....	....	5
Total			787	128	722	2299	261	133	4330

fication," and send them to the laboratory for study, in order to determine the cause of the failure and learn from it, if possible, the course to be pursued for bringing about an improvement in rail manufacture. The chemical and physical examinations were nearly all made at the Altoona Laboratory of the Pennsylvania Railroad.

Naturally, a greater number of the "*broken*" rails has been selected for examination, on account of the greater element of danger to traffic, but it must be said that, considering the large number of failures, comparatively few serious accidents have resulted from the failures, a tribute to the vigilance and care of the trackmen, and to the fact that the great majority of the fractures are square breaks.

For the purpose of this study, there has been surveyed the following number of each classification:

1.	Broken	286
2.	Flow of Metal	15
3.	Crushed Head	19
4.	Split Head	153
5.	Split Web	18
6.	Broken Base	42
7.	Damaged (without fracture)	2
	Worn out in service	68
	Total	603

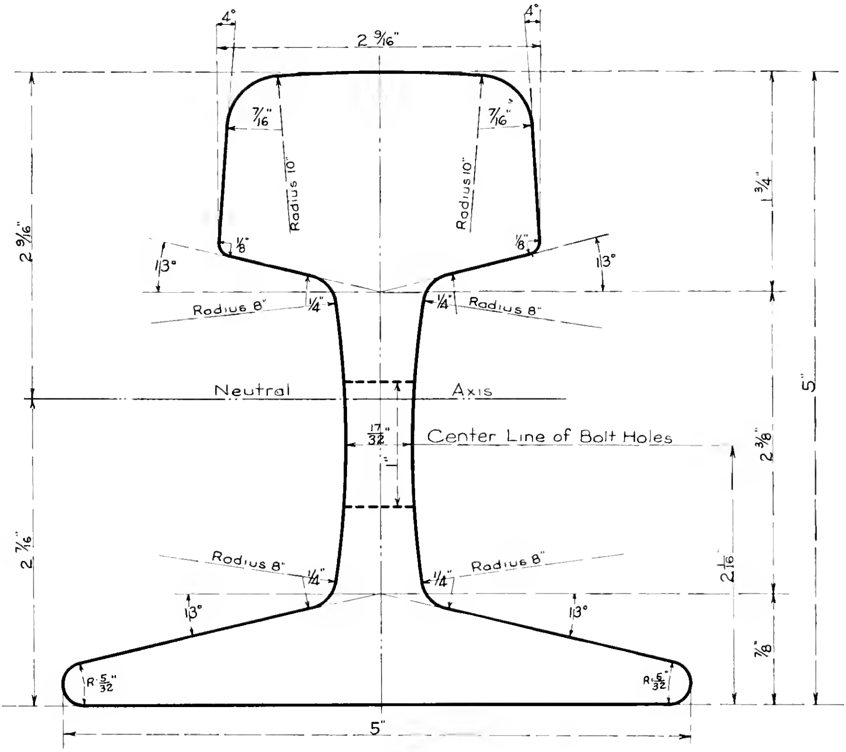
In order to make the study as convenient as possible, and to have the characteristics stand out in the clearest light, the results of the chemical and physical survey have been tabulated, and platted in diagram form, on the accompanying sheets. The principal defects in the quality of the material and the roadbed which are considered to have had some influence in causing the failures have been shown in a standard form in the last few columns of the tables, so as to catch the eye readily. The rails under consideration were all manufactured by the Bessemer process, except the few on sheets 17 and 19. They are of several different rail sections, or types, made by different manufacturers, weighing 85 and 100 lbs. per yard, and having a life before removal varying from the rail which broke before it was put in the track to the one which lasted 17 years.

BROKEN RAILS.

In looking at the right-hand side of the sheets of the tabulated statement (Nos. 2 to 8), the observer is struck with the large number of breakages which has occurred at a time when the roadbed was frozen, 203 out of 286, or 71 per cent. Furthermore, 96, or one-third of the fractures, occurred within the limits of the joint. If there was no fault to be found with the material, this would be a clear indication that the margin of safety of the rail under ordinary service conditions was quite small, because when the conditions became unusually severe, as in the case of a long-continued frozen roadbed, the rails immediately began to

Fig. A

P.R.R. 85 lb.



Area of Head	3.823 sq. in.	46.1 %
" Web	1.575 " "	19.0 %
" Base	2.894 " "	34.9 %
Total	8.292 " "	100.0 %

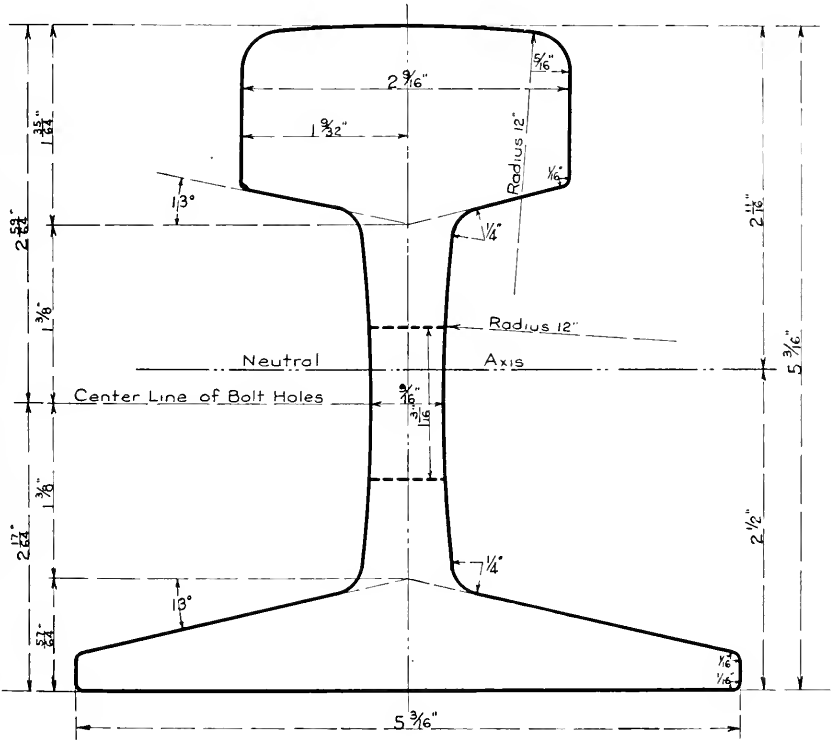
Moment of Inertia = 27.428

Section Modulus of Head = 10.65
" " " Base = 11.32

PENN'A LINES WEST OF PITTSBURGH
Office of Chief Engineer M of W
SOUTH-WEST SYSTEM

Fig. B

A.S.C.E. 85 lb.



Area of Head	3.50	sq in	42 %
" Web	1.75	" "	21 "
" Base	3.09	" "	37 "
Total	8.34	" "	100.0 %

Moment of Inertia = 30.00

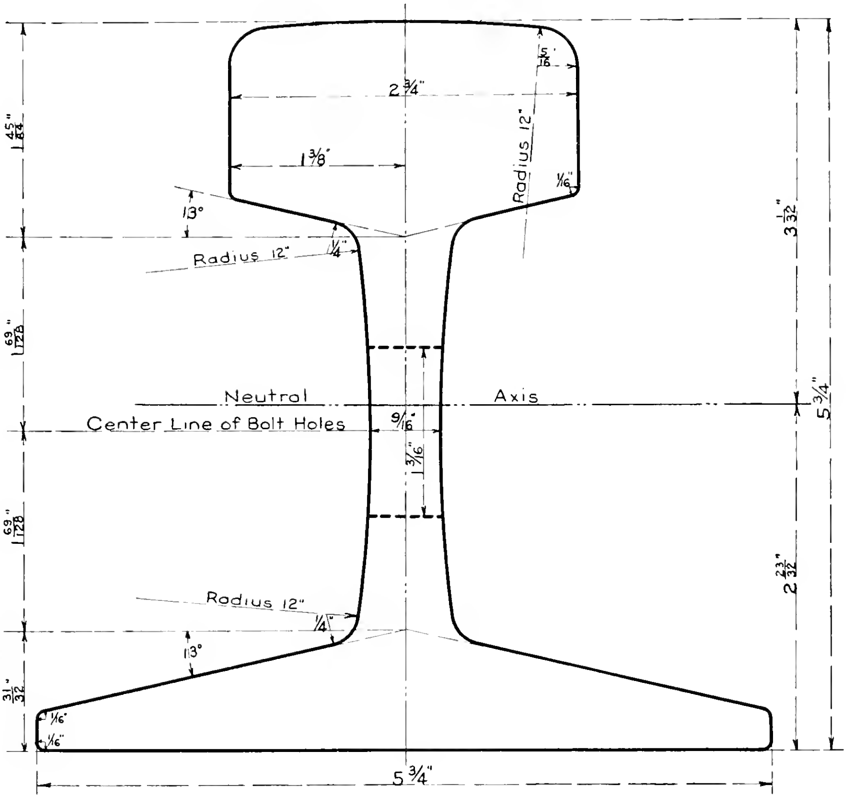
Section Modulus of Head = 11.16

" " " Base = 12.00

PENN'A LINES WEST OF PITTSBURGH
Office of Chief Engineer M of W
SOUTH-WEST SYSTEM

Fig. C.

A.S.C.E. 100 lb.



Area of Head		4.13	sq in	42 %
"	Web	2.06	" "	21 "
"	Base	3.63	" "	37 "
	Total	9.82	" "	100.0 %

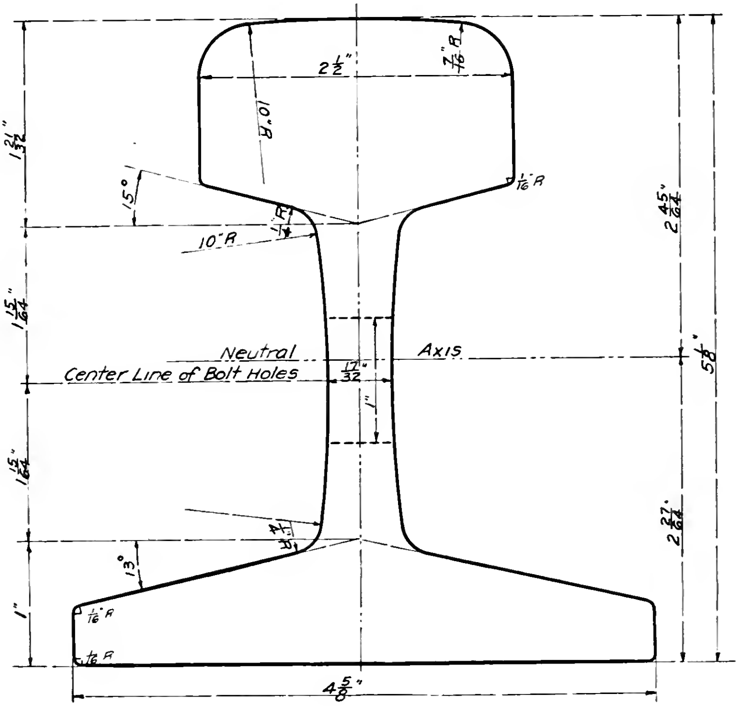
Moment of Inertia = 43.80

Section Modulus of Head = 14.85
" " " Base = 15.64

PENN'A LINES WEST OF PITTSBURGH
Office of Chief Engineer M of W
SOUTH-WEST SYSTEM

Fig. D.

P. S. 85 LB.



Area of Head	3.57	sq in	42.2%
" " Web	1.51	" "	17.8
" " Base	3.39	" "	40.0
Total	8.47	" "	100.0%

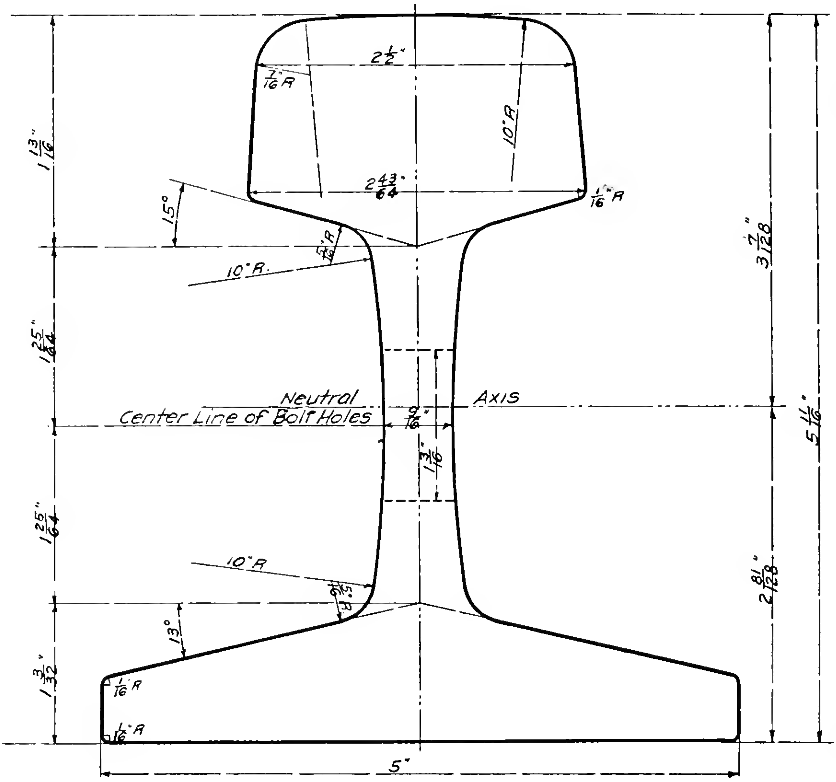
Moment of Inertia = 29.1

Section Modulus of Head = 10.77
Base = 12.02

PENN'A. LINES WEST OF PITTSBURGH
Office of Chief Engineer M of W
SOUTH WEST SYSTEM

Fig. E.

P. S. 100 LB.



Area of Head	4.09	sq in.	41.0%
" " Web	1.85	" "	18.6 "
" " Base	4.03	" "	40.4 "
Total	9.97	" "	100.0%

Moment of Inertia = 41.9

Section Modulus of Head = 13.71

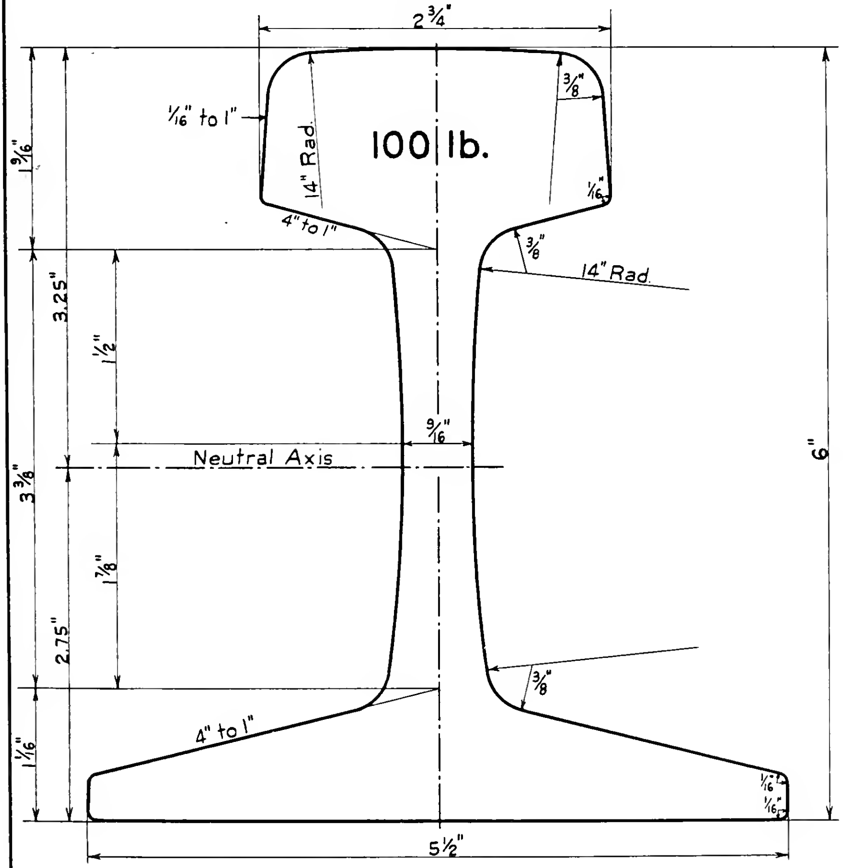
" " " Base = 15.91

PENN'A. LINES WEST OF PITTSBURGH
Office of Chief Engineer M of W.
SOUTH WEST SYSTEM

Fig. F.

AMERICAN RAILWAY ASSOCIATION.

Standard A.R.A. Rail Section. Type A.



Area of Head = 3.64 sq. in = 36.9 %
" " Web = 2.29 " = 23.4 "
" " Base = 3.91 " = 39.7 "
" Total = 9.84 " = 100.0 "

Ratio Periphery of Head to Area of Head = 1.80
" " Web " Web = 3.21
" " Base " Base = 3.29
" Total Periphery to Total Area = 2.92

Moment of Inertia = 48.94
Section Modulus, Head = 15.04
" " Base = 17.78

break, and, to a considerable extent, at the weakest point, namely, the joint.

Examination in detail, however, discloses many defects in the chemical composition and the strength and ductility of the material, which must have had a detrimental influence and helped in a large measure to bring about failure, when the very small percentage of breakages to the total number of rails in service is borne in mind.

For instance, the material in a very large proportion is hard, a property which is usually accompanied by brittleness or segregation more or less accentuated or both, and in that condition it is especially subject to fracture when the roadbed is frozen. There were but 31 cases of hardness not accompanied by brittleness, segregation or some other defect, such as rolling seam, slag, or the presence of foreign metal due to the cutting of the ingot mould stool, or pieces of steel thrown on the stool to prevent cutting.

Some of the 31 fractures of rails exhibiting only hardness of material without other defects, were probably helped along by rather inferior line and surface of track and poor condition of ties, but such conditions of track will always be met with, as perfection of roadbed and equipment cannot be continuously maintained, and consequently the rail material is expected to be strong enough to meet the conditions imposed.

In the case of 12 breakages in the joint only does one fail to account for the additional weakness at that point by defective material.

In 21 of the rails, slag was present. As 19 of these were of the P. S. section, which was introduced with the year 1908, it would appear that the methods used by the mills for pouring ingots are not as good as those formerly used, or there is increased carelessness on the part of the workmen.

Photomicrograph No. 18 shows very clearly the presence of a large amount of slag in a rolling seam in the rail base.

The diagrams on the plates have been prepared to show graphically how close to the specification limits the chemical constituents usually come, and also the variations of the physical qualities. Plates 1 and 2 are of "*broken*" rails, with a few "*good service*" rails for comparison, the latter not being worn out when removed (Sheet 1). The P. S. or latest type of rails have been grouped together, and it is noticeable how much shorter the period of life has been than in the case of the others. This is largely because the fragile rails had already been weeded out of the others, such weeding out usually taking place during the first 4 or 5 years' life. No comparison can be exact unless the age and conditions of service are the same, a state of affairs which can only be brought about by a "special experiment."

In the case of the A.S.C.E. and P.S. rails, it is noticeable in what a large percentage the carbon and phosphorus keep well up to the upper limit, and in many cases they are quite in excess. The manganese keeps more uniformly within the bounds assigned for it.

In the case of the P.R.R. *"broken* and *"long service"* rails, the carbon keeps well below the upper limit, due largely to the fact that when they were rolled, the limits were 5 points less in each case, that is 0.40 and 0.50 per cent. instead of 0.45 and 0.55 per cent. The long life of these rails, 13 to 17 years, indicates a less hard and brittle condition of the material, which is borne out by the tabulated statements. There are a few exceptions, 2N—(659), 2S—(660), 5N—(665), 5S—(666), 8, 9 and 10, which cause the observer to wonder whether the defects were kept dormant during all those years by the quantity of metal in the large heavy head. No. 9, in addition, contained a flaw in the head, while No. 10 had a split head. In the case of Nos. 5N—(665) and 5S—(666), which did not fail in service, but lasted 15 years before removal, the segregation was very bad. No. 314 is a case of the P.R.R. section with a split head, which gave a service before removal of 13 years and 10 months. It was badly segregated and the phosphorus extremely high. No. 329 is another very bad case of split head, with much segregation and slag present, which lasted 11 years, but this time of 85-lb. A.S.C.E. section, a smaller head. The high manganese and silicon in the web, as ordinarily these elements do not segregate, lead to the suspicion of the presence of the slag.

Generally, the tensile strength of the *"broken"* and "good service" P.R.R. is less, and the ductility, measured by the elongation, higher than in the case of the other rails, due possibly to the lower carbon. No. 4N—(663) is a very soft rail with a long life, 15 years, and yet with the metal in an unsatisfactory condition, as indicated by the deep etching.

Nos. 621 and 622, of Bessemer rail, were located in the same curve, 4½ degrees (radius 1273.57 feet), where a special experiment was being conducted, and measurements to show the amount of material abraded by the train wheels from the head were made semi-annually. As these two rails have different percentages of carbon, it will be interesting to compare them.

COMPARISON OF RAIL WEAR.

	No. 621	No. 623	No. 6
Carbon, average per cent	0.46	0.56	0.37
Manganese, average per cent	0.81	0.98	0.63
Phosphorus, average per cent	0.101	0.090	0.094
Silicon, average per cent	0.058	0.108	0.075
Sulphur, average per cent	0.051	0.043	0.021
Tensile strength, pounds per square inch	101,750	116,350	85,095
Elastic limit, pounds per square inch	48,270	58,740	40,675
Elongation, per cent in two inches	20.5	15.5	26.75
Reduction of area, per cent of original section	35.31	26.80	46.83
Hardness, Brinell number	190	230	167
Rail section and weight per yard	100 PS	100 PS	85 PRR
Years and months in service	3 years 6 mos.	3 years 6 mos.	15 years 10 mos.
Square inches abraded from head	0.85	0.90	0.75
Percentage of area of head abraded	20.78	22.05	19.63
Percentage of area of whole section abraded	8.53	9.03	9.05
Pounds per yard of rail abraded	8.68	9.18	7.69

The higher carbon and manganese of No. 622 seems to have resulted in:

increased tensile strength and elastic limit,
reduced ductility,
increased hardness,

while at the same time the abrasion has been greater.

No. 6 has been added for information, although not strictly comparable on account of having been in service under different conditions. It was laid in straight track, and the relative tonnage of traffic borne by it is unknown, but it had a very long life with much less carbon and manganese than the other two. It is also less strong, but more ductile.

Consequently, there must be other unknown conditions entering into the manufacture and service of these rails, and the mill practice with reference to mixing the ingredients, holding the molten metal for thorough chemical action, teeming it into the ingot moulds with care, soaking, and then rolling, must play a very important part in the quality of the material and its endurance in service.

Additional experiments seem necessary, therefore, to settle the questions of percentage of carbon and size of rail head, as good results have also been obtained with much higher carbon and much thinner rail heads.

In the great majority of the rails studied, the fracture has been a simple one, that is, the rail broke into two parts, and no accident resulted on account of being discovered in sufficient time by the trackmen. Occasionally, however, a rail flies into many pieces, and it is usually the cause of a train wreck. Such failures are the most dangerous and the most to be dreaded. No. 51 is a good example of this and a passenger train was wrecked by it. It was a very bad case of hardness, brittleness, segregation and split head, and had been 6 years in service. No. 15 also illustrates this kind of fracture very well. Another very bad case of segregation and unsoundness (0.87 per cent. carbon in the web), even worse than the other, is No. 213, although it did not cause an accident in spite of being broken into 3 pieces. The web was in very bad condition, having considerable slag and graphitic carbon.

Nos. 138 and 142 are cases of broken rails, the material of which seemed sound, and no cause could be assigned for their failure, except that the fracture occurred in a joint.

A few rails which broke shortly after a broken wheel passed over them were examined in order to ascertain if such fractures occurred only when the metal was of poor quality, or whether the fractures occurred because of the additional punishment by the broken wheel when the metal was of fairly good quality. While in all of the examples the roadbed was frozen at the time, yet the material was reasonably satisfactory except in one case, No. 110, which was above the average of hardness and had a rolling seam in the base. No. 656 is a rail which was struck a severe blow by a wheel with a flat spot about 8 inches long and with a middle ordinate of about ½-inch, and which was removed from the track before fracture. The object of the examination was to determine what effect was produced on the metal by the impact. With reference to the quality of the material, there was an inclination to brittleness in the interior of the head, and although the chemical analysis does not show any segregation, the deep etching indicates an unsound condition of metal. The photomicrograph near the surface at the dent on the rail discloses that the original structure is entirely changed by the force of impact.

No. 655 contained a flat spot, which was burned in by the slipping driver of a locomotive. As in the previous case, the chemical analysis showed no segregation, but the deep etching disclosed a poor structure, and there was a tendency to brittleness in the interior of the head, due probably to the rather high phosphorus. Photomicrographs were taken near the edge of the flat spot, 1/16-inch, ⅛-inch and ½-inch below the surface, to observe the different arrangement of the grain at each depth. The one taken near the surface showed a granular appearance of the steel broken up, resembling the structure of heat-treated steel.

The effect of wheels on the running surface of rails is illustrated also in Nos. 639, 644 and 652. No. 639 is a Bessemer rail from an 8 degree, 27 minute (radius 678.67 feet) curve, of good material though of low hardness, which shows by the photomicrograph the grain on the top of the head distorted by the wheel load. No. 644 is an open-hearth rail of good material, from an 8 degree (radius 716.78 feet) curve, and shows a hardened area, probably due to the slipping of the locomotive drivers. No. 652 is another open-hearth rail, but of low hardness, which shows the distorted grain and narrow hardened surface after an unusual amount of material has been worn from the top of the head in the short period of nine months. It was from the same curve as the last, but of different manufacture.

DEFECTIVE HEADS.

The rails classified as "flow of metal," "crushed head," "split head" and "split web" will be treated under the heading "Defective Heads," because what appears to be one defect is often another when cut open and examined. For instance, No. 309 appeared to the trackman to be a case of *"flow of metal,"* but turned out to be a *"split head"* when cut open. It is also rather difficult at times to distinguish between "flow of metal" and "crushed head." Again, Nos. 291, 292 and 293 appeared to the trackman to be cases of "crushed heads," but it turned out that the crushing was due to "split heads," and No. 454 was also a "split head" instead of a "split web," although the first sign of failure was a crack longitudinally along the web.

It will be noticed from Table I that "defective heads" were very numerous during the period in question, 3,410, and that 2,299 of them were classified as "split heads." Of the total, 205 were examined, or surveyed, at the Altoona Laboratory, and the results are tabulated on the accompanying sheets, Nos. 9 to 15.

The first thing noticeable in examining these sheets is that scarcely any of the failures have occurred in the joints, and the condition of the roadbed has no important bearing on the problem. Segregation, however, is an almost invariable companion of the defective head and web, and that is nearly always accompanied by one or both of the other defects, brittleness and hardness. Sometimes slag is present and sometimes foreign steel, due to the cutting or protection of the ingot mould stool, but an examination of a rail with a bad head will nearly always disclose segregation, brittleness and hardness. One or two of them is sometimes absent. A split head, however, very rarely occurs without the accompaniment of one or more of the defects, which is pretty positive proof that the metal will stand up under the load if it is homogeneous and free from defects. The segregation is nearly always confirmed by the deep etching, as well shown by No. 441, but No. 370 is a case of split head with segregation in which the latter is not shown by the etching. No. 158 is a similar case of a segregated broken rail.

In the case of "flow of metal" and "crushed head" failures, the sulphur has often been found to be rather higher than normal.

A good example of the effect of using scrap steel on the stool of the ingot mould to prevent cutting is shown by Nos. 290 and 368. The former is a "D" rail and the latter a "C" rail, that is, rails from the lower part of the ingot. It is the general custom now to have the rails stamped with letters to designate their location in the ingot, with the object of tracing defects back to the ingot in the study to bring about improved mill practice. The rails are stamped "A," "B," "C," etc., beginning with the top. The foreign steel is, therefore, usually found in the rails from the lower part of the ingot. No. 460, however, is an example of such a defect in an "A" rail, indicating a rather turbulent teeming of the ingot. It is a remarkably bad rail, containing many irregularities, and it is a wonder that it gave a service of 2 2/3 years before failure. The difference in the texture of this soft included steel and the rail steel is well brought out in the photomicrographs of Nos. 290 and 460. Sometimes old scrap tieplates were used for stool protection, and the shape of the plate was still discernible in the rail section. No. 522 is a sample of this kind, though *other cases occurred at this same mill in which the shape of the plate was much more distinct. These discoveries brought about the discontinuance of the practice. Sheet No. 17 shows a good many failures due to this cause.

A very bad case of segregation with unusually high carbon and phosphorus for Bessemer rail is given by No. 293, a "C" rail which lasted a year and a half. As a consequence, the brittleness and hardness are excessive.

Another extremely bad case of segregation, brittleness and hardness is No. 388, which fortunately never got into service, because it was discovered by the trackmen before laying. It is rather unusual to have such a bad case of segregation in a "D" rail, but slag to the amount of 3 per cent. was also present, having been suggested by the high silicon in the

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*Proceedings American Railway Engineering Association, 1911, Vol. 12, Part II, p. 269.

web. Being so low down, one is led to believe that it is a case of the spiegel iron not having been given sufficient time to mix properly, a fault which seems to have been too common in some of the mills in the past, if not at present. An effort was made to rush the process and increase the tonnage at the expense of quality.

Sometimes brittleness and hardness are found unaccompanied by segregation, as in the cases of Nos. 399 and 466. The latter case seems to have been due to very high carbon and manganese uniformly distributed.

No. 384 is a case of "pipe" rather than "split head."

The results of the examination of so many "split head" rails seem to show that they are nearly always found in segregated rails having hard, unsound metal in the interior and softer metal at the surface. The flow of the softer metal develops a split in the harder unsound and less ductile metal in the interior of a badly segregated rail, resulting in a split head. The remedy seems to be to reduce segregation by making sounder and more homogeneous ingots, which can be done by the use of a sink head, as advocated by Sir Robert Hadfield.† Nos. 607 and 614 show what even soft rails will stand, if the metal is fairly sound and homogeneous.

Plates Nos. 3 and 4 show at a glance that in this type of failure the phosphorus is nearly always above the limit of 0.10 per cent. In Bessemer rail steel as now made, it is very difficult to keep it below that limit. In the case of the "P.S." failures, the life of service has only been from 1 to 3 years, while the "P.R.R." section rails were in the track 12 to 14 years, and even as high as 17 years in one case, before failure, while the phosphorus percentage was generally much above the 0.10 per cent. limit. High phosphorus, therefore, is only one of the contributing causes of "split heads."

The "tensile strength" was about 110,000 lbs. per square inch in the general run. It was rather more than this in the case of the "broken rails." Great irregularity, however, is noticeable in the ductility as indicated by the "elongation" percentage, showing that the material was quite erratic in its quality. If 12 per cent. indicates a measure of ductility below which it is not desirable to go, then brittleness of material was quite prevalent.

A reasonable index figure for the hardness of Bessemer steel made according to these specifications, as determined by the Brinell method, is between 205 and 225, and it will be noticed that the 225 was exceeded in many cases. The same is also true of the "broken" P.S. rails (Plates 1 and 2). It is not so, however, with the P.R.R. and A.S.C.E. rails, as they were made with somewhat lower carbon limits.

The shaded portions of the upright blocks representing rails in the diagrams give the amount of carbon and manganese in the ingot, as obtained by the analyses of the test ingot taken during the teeming opera-

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†Proceedings American Railway Engineering Association, 1913, Vol. 14, p. 449.

tion, while the full height of the blocks shows the amounts as determined by the analyses of the rails when sent in to the laboratory. The wide differences between the two in the cases of "broken" and "split head" rails is very apparent, which illustrates very irregular and badly segregated material. This difference is not nearly so marked in the case of the "worn out" rails, Plate 6. The ductility of these latter, and also of the "broken bases" in Plate 5, as indicated by the "elongation" percentage, is also more uniform, bearing in mind that Nos. 643 to 654 (no illustrations) are of Open-Hearth steel.

BROKEN BASES.

An inspection of sheet No. 16 shows clearly that the material was generally of fair quality, but that the roadbed was frozen in nearly all cases, indicating that the base was too weak to withstand the additional severity of conditions. In several cases, however, rolling seams were evident, and sometimes the material was hard, and occasionally somewhat brittle and segregated, although the ductility was above 12 per cent. (Plate 5). No. 505 is a sample of good material without the disclosure of any defects by the chemical or physical examinations. The deep etching is especially noteworthy. Although of 85-lb. weight, it is of P.S. section with the heavy base.

Photomicrograph No. 18 serves to show this serious defect in manufacture, that of the rolling seam. When present in the base, it has been considered as the prime cause for broken rail bases which have been very numerous in the product from some mills. Special studies of seams in rail bases have been made by Messrs. Jas. E. Howard,* Engineer-Physicist of the Interstate Commerce Commission; M. H. Wickhorst,† Engineer of Tests for the Rail Committee of the American Railway Engineering Association, and H. B. MacFarland,‡ Engineer of Tests, Atchison, Topeka & Santa Fe Railway System.

Mr. Wickhorst§ made "an investigation concerning the influence on the finished rail of the amount of draft in rolling the ingot into a bloom, and particularly with reference to the transverse ductility of the base and the presence of seams. Five companion ingots of one heat of titanium-treated open-hearth steel were used and all handled in the same way, except that the draft used in making the bloom from the ingot was varied from about 3 inches per pass in the initial passes down to about 0.4 inch per pass in the early passes as the smallest rate of reduction used. These

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*Proceedings American Railway Engineering Association, 1908, Vol. 9, p. 475. Transactions American Institute of Mining Engineers, 1908, Bulletin No. 20, p. 151. Journal of Association of Engineering Societies, Vol. XLI, No. 1, 1908. Proceedings American Society for Testing Materials, 1908, Vol. VIII.

†Proceedings American Railway Engineering Association, 1914, Vol. 15, pp. 211 and 315.

‡Proceedings American Railway Engineering Association, 1913, Vol. 14, p. 315. Proceedings American Railway Engineering Association, 1914, Vol. 15, p. 267.

§Proceedings American Railway Engineering Association, 1914, Vol. 15, p. 238.

ingots were rolled into rails and in addition another companion ingot of the same heat was cooled and split open to note its interior condition as regards cavities and to make a chemical survey.

"To sum up, it may be said that rails made with initial drafts in blooming of 3 inches and 1.5 inches contained a larger number and deeper seams in the base than those made with 0.8 inch or less of initial draft. This resulted in poorer results in the drop tests and transverse tests of the base in the rails made with the heavier drafts. These results could be considered only as indicative and final conclusions should be withheld until sufficient work along this line has been done to warrant them."

Mr. Wickhorst also took a cold ingot with a badly cracked surface, and lightly skinned off the four sides in a planer to show the condition of the surfaces.[†] "The cracks in the top and bottom sides of the ingot as it first entered the rolls (after reheating) did not open up and finally disappeared as far as could be determined by the appearance of the surfaces of the blooms and rails after pickling in sulphuric acid," but "the cracks on the right and left sides of the ingot as it first entered the blooming rolls opened up or yawned open, forming double Vs, one inside the other," and resulted in seams in the rails.

Mr. MacFarland found that[‡] the base failures which precede the ultimate failure of about 90 per cent. of the square and angular breaks are developed along the seams in the center of the base." He believes that these "laminations in the base of the rails are due to the flowing of the metal when it is being reduced in passing through the rolls; the temperature being too low for the given pressure to form a solid molecular bond at the laminations." These conclusions seem to be confirmed by Mr. Wickhorst's investigations, and Mr. McFarland also found[§] a reduction in the tensile strength of the material due to the cracks.

The bad effect of rolling seams is therefore very apparent, and appears to point to lighter initial reductions in blooming as one of the necessary improvements in rail rolling, and that was advocated at some length by Dr. J. Puppe of Breslau,[||] in his paper on the "Rolling Mill Practice in the United States," presented to the meeting of the Iron and Steel Institute of Great Britain and Leeds, England, on October 1, 1912. The number of failures of this kind is much greater with the product from some mills than others.

RAILS WORN OUT IN SERVICE.

The fewer number of defects in the material of these rails, shown on sheets Nos. 18 and 19 (and the same is true of sheet No. 1), than on the sheets of failures previously studied, are markedly noticeable. As

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[†] Proceedings American Railway Engineering Association, 1914, Vol. 15, p. 336.

[‡] Proceedings American Railway Engineering Association, 1913, Vol. 14, p. 334.

[§] Proceedings American Railway Engineering Association, 1914, Vol. 15, p. 314.

[||] Proceedings American Railway Engineering Association, 1913, Vol. 14, p. 502 (abstract).

they were located on sharp curves, of course the duration of service was short.

The same qualities are shown graphically by Plate 6. The phosphorus was generally below the 0.10 per cent. limit, and the agreement between ingot and rail analysis is better than in the cases of "broken" and "split head" rails. The ductility was fairly uniform, and the "hardness" index in the neighborhood of 200 for Bessemer rail and 250 for Opean-Hearth rail.

The photomicrograph of No. 633 is rather interesting on account of showing an unusually fine grain in the head. It is believed that these rails were rolled at a lower temperature than usual. The etchings show the segregation. No. 638 has also a fine grain in the head.

The different appearance of the grain with the higher carbon of the Open-Hearth rail from that of Bessemer steel is shown by the photomicrographs of No. 651. Brittle cementite structure is shown by No. 653.

SUMMARY.

The object of the examination of "broken" and "defective" rails was to compare their chemical and physical characteristics with those which had given comparatively long service, and those which were worn out in service in the main tracks without failure, in order to determine the causes of failure, and, with that knowledge, determine as far as practicable some of the improvements which should be made in rail manufacture. It is idle to point out, in an attempt to controvert the necessity for such improvement, that the maintenance of tracks is far from perfect, and that there would not be so many failures with more perfectly maintained line and surface, and more even bearing on the ties. All this is granted to a limited degree, but the service to be exacted of a rail is intended to be severe from its very nature, and it cannot be coddled and treated with so much consideration. The railway companies desire to have material which will endure severe punishment, and they are not yet satisfied that it cannot be obtained with proper methods of manufacture. This study reiterates faults which have been previously pointed out in other studies, and suggests remedies.

The broken rails studied show that the number of breakages has been increased by the condition of the roadbed, and of the joint, but such fractures are nearly always accompanied by defective condition of the metal. This is usually found to be hard, and generally accompanied by brittleness or segregation, more or less accentuated, or both. Other defects are also found, such as rolling seams and the presence of slag or foreign soft steel. The comparative absence of these defects, or their greatly reduced number, in the rails which have not failed in service, proves the necessity for their elimination, whether or not the material is being taxed rather closely to the limit of its strength. That is another problem. Defects should not be covered up by excess quantity of poor material.

"Defective heads" are nearly always accompanied by a poor quality of metal, and the segregation of the elements carbon and phosphorus is for the most part responsible for the trouble. Brittleness and hardness nearly always follow along in the train of segregation, and the sulphur is in many cases found to be rather higher than the average.

It would appear that the removal of slag could be accomplished by better care in tapping the furnace stack, and pouring from the ladles, plenty of time having been allowed for it to come to the surface in each operation.

It should be no more than necessary to call attention to the defective heads with pieces of old tie-plates and other scrap material in them to put a stop to the practice of using that method for protecting the stool of the ingot mould from cutting, yet instances of this have been found in rails rolled since 1909, when such complaint was first made.

As the percentage of phosphorus is nearly always above the limit of 0.10 in cases of "split head," the use of Open-Hearth steel will tend to control the evil effects of that element, but it is worthy of note that in the "long service" and "worn out" rails it is lower.

The segregation of the elements, however, seems to be responsible in a large measure for broken and defective rails, and its control is, therefore, extremely desirable. This seems to be possible by the use of the "sink-head" for making sounder ingots, and more careful teeming, plenty of time having been given to allow the chemical reactions to take place. One mill has already used this method with good results.

The sources of trouble are not ended with the production of a sound ingot. Greater care should be exercised in blooming and rolling, and improved methods should be introduced. Previous studies indicate that the large and heavy reduction in the blooming rolls is injurious to the finished product, as it initiates the cracks which result later on in seams, which have been responsible for many failures, especially broken bases. The remedy seems to be lighter reductions. Base breakages have been practically eliminated by the heavy base of the 100-lb. P.S. section, but that is not the correct way to remove the defect, which still exists in the case of the 85-lb. P.S. section, which has a heavier base than was customary in former practice. These heavier bases were introduced primarily to make the rolling conditions better by equalizing more nearly the areas of metal in head and base. The rails come out straighter on the cooling beds, and thus the amount of "gagging" has been reduced.

These cases of long service rails and rails worn out in the tracks seem to show that high carbon is not the only consideration for more durable material, as rails with low carbon have lasted longer under the same conditions than rails with higher carbon, though this is by no means always the case. The temperature of rolling is undoubtedly a very strong if not the strongest factor in producing homogeneous and durable material.

Appendix A.

METHOD OF MAKING ETCHINGS.

The method adopted by the Pennsylvania Railroad Company at its Laboratory at Altoona, Pa., for making the etchings for these studies of rail failures, is described in the following paragraphs:

"In making the deep etchings. a ½-inch section of the rail is cut off and polished on one side. This is immersed in a solution of sulphuric and hydrochloric acid and water mixed in the proportions of 3, 9 and 1. The solution is placed in a shallow dish and the rail section immersed with the polished face down, being prevented from touching the bottom of the dish by small glass rods. The dish is then placed on a hot plate and the etching allowed to continue until the rail is deeply marked so as to bring out any defects or points of segregation, this process usually taking about two hours. The rail section is then removed from the solution, washed and the etched surface inked and impressions made from it on thin paper in the letter press.

"In making the light etchings, a ½-inch section of the rail is cut off, one side is carefully polished, thoroughly cleaned with alcohol and then etched with a 1 to 4 solution of nitric acid and grain alcohol. This etching solution is only allowed to remain on the polished surface long enough to bring out the grain structure of the steel and is then washed off and the rail section photographed."

Appendix B.

METHOD OF MAKING DROP AND IMPACT TESTS.

Form M. W. 34-F (see No. 607) is the blank on which the results of the complete Laboratory investigation of each rail, with the exception of the etchings and photomicrographs, are reported, and one accompanies each rail report.

One of the tests provided for is the "drop test" on two pieces, one from the corner of the head, "D," and the other from the web, "E," in order to investigate the brittleness of the material under shock. It is conducted as follows:

"One test piece measuring $\frac{29}{32}$ inch square by 18 inches long is taken from the head of the rail at location 'D' and another test piece 1 inch by ½ inch by 18 inches long is taken from location 'E.' The general arrangement of the drop test machine is shown in Photograph T-4380. The pieces are all tested on a 12-inch span. In making the test of the square piece 'D' the face is placed in position as shown in photograph T-4380 and is given one blow with a 50-lb. tup from a height of 5 feet, after which the permanent deflection is measured, this being entered under column 'Initial Deflection' on M. W. 34-F. Another blow is then struck on the same side of the piece; it is then turned over and a third and fourth blow struck, after which it is again turned and the fifth blow struck, all from a height of 5 feet. Five blows are then struck from a height of 10 feet, the piece being turned after every second blow. The height of drop is then increased to 15 feet and the piece turned after every blow until failure occurs. The item 'Accumulated Ft. Lbs.' is calculated from the weight of the tup and number and height of the blows struck.

"The test piece 'E' is laid on the supports with the 1-inch surface horizontal and tested in the same way, with the exception that the blows are started from a height of 3 feet, striking five blows from this height, then five blows from a height of 6 feet and finally as many blows as are necessary to break the piece from a height of 10 feet."

The test bears quite a resemblance to the Fremont tests,* which had the same object in view, the investigation of the brittleness of the material. The same principle of shock is used, and the weak interior of the metal is exposed, but the machine used is different, being of the fly-wheel type, with an energy in the fly-wheel of 1,500 kilogram-metres (10,800 foot-pounds).

Fremont proved that mild steel of good quality which had been exposed to a particular detrimental treatment could pass satisfactorily the usual tension tests in respect of strength and ductility, but was, notwithstanding, so brittle or fragile that it would break under a single blow.

This same result seems to have been attained in some of the tests of rails at the Altoona Laboratory, No. 452 being an example of that kind.

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*Le Génie Civil, Tome LIX—Nos. 1, 2, 3 and 4, May 6, 13, 20 and 27, 1911. Nouvelle Méthode d'Essai des Rails—Ch. Fremont. Reviewed in "The Engineer" (London), November 10, 1911, p. 478.

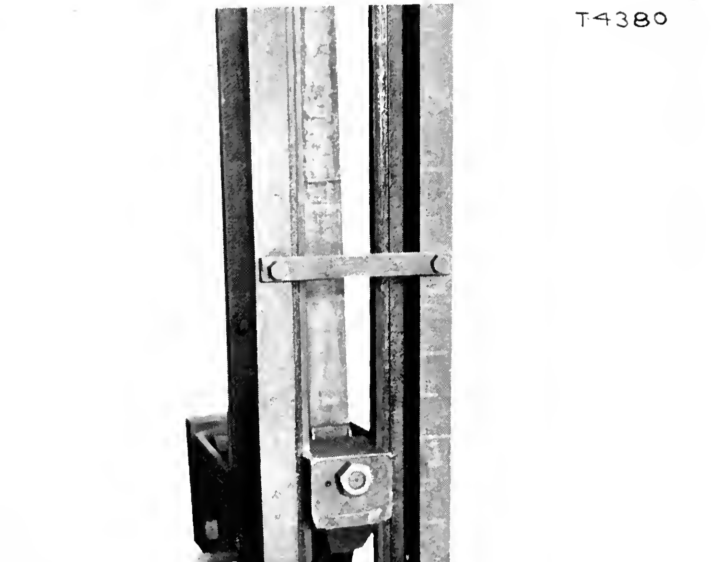

Fig. T-4380. "Low" Drop Machine.

This rail showed a tensile strength of 119,100 lbs. per square inch, an elastic limit of 66,600 lbs. per square inch, an elongation of 18 per cent. in 2 inches, and a reduction of area of 28.6 per cent. of original section, but the drop test on the test piece from the head gave only 1,750 accumulated foot-pounds, a low figure, when it is realized that good material shows 40,000 to 50,000 accumulated foot-pounds. The Brinell hardness, moreover, is considerably above the average. The same degree of fragility did not appear in the web, although the Brinell hardness was even greater than in the head.

"In making the impact test, a Landgraf-Turner machine is used, such as is shown in photograph T-4379. The test pieces are ⅜-inch in diameter by 8 inches long and are taken from the base of the rail, locations 'G' and 'F,' as shown on M. W. 34-F. One end of the test piece is clamped in the vise of the machine at 'A' (see photograph T-4379), the other end extends up through a slot ½-inch wide by 11/16-inch long in the vibrating hammer 'B;' the hammer 'B' strikes the piece at a point 4 inches above the top of the vise 'A.' The hammer has a swing of 17/32-inch out of the vertical position and the test piece is vibrated ⅜-inch from the vertical at the point of impact, which is sufficient to exceed the elastic limit of the material. The machine runs at about the rate of 200 double vibrations per minute and a record of the number of vibrations to cause breakage is obtained by means of the counter 'C,' which is automatically stopped when the piece breaks. After one end of the test piece has broken, the other end is inserted in the vise and clamped and the test repeated as before, the results of the four tests being averaged and recorded in the report."

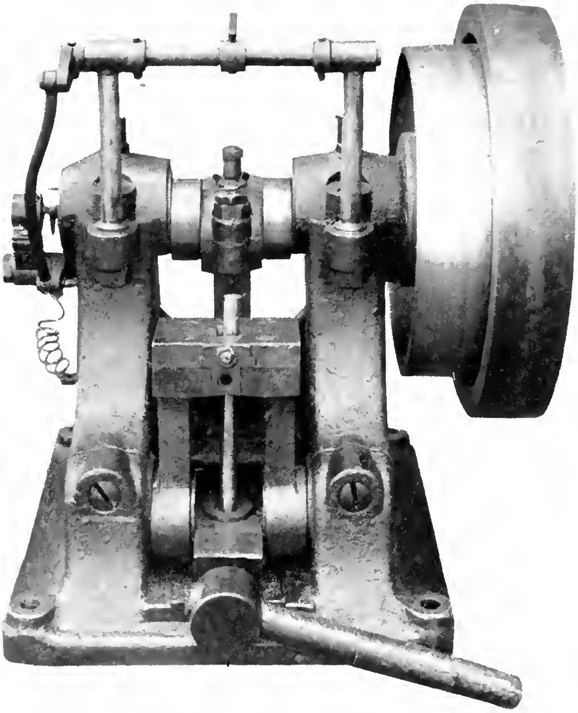

FIG. T-4379. LANDGRAF-TURNER ALTERNATING IMPACT MACHINE.

Sheets
Plates and
Figures
Illustrating the Text

FIG. 6A. FRACTURE OF "BROKEN" RAIL 6.

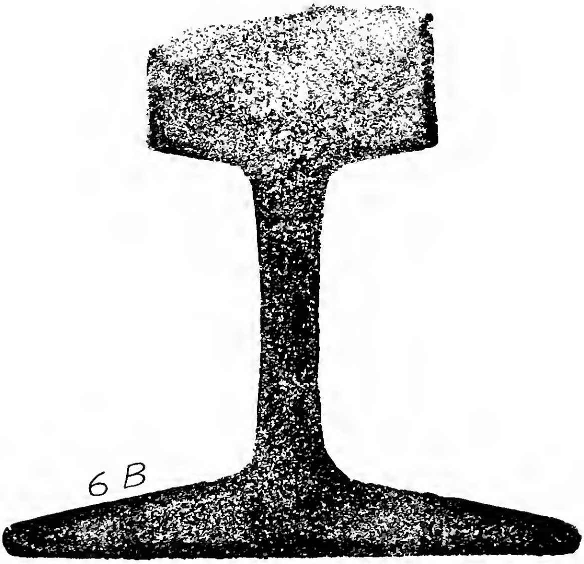

FIG. 6B. DEEP ETCHING OF RAIL 6.

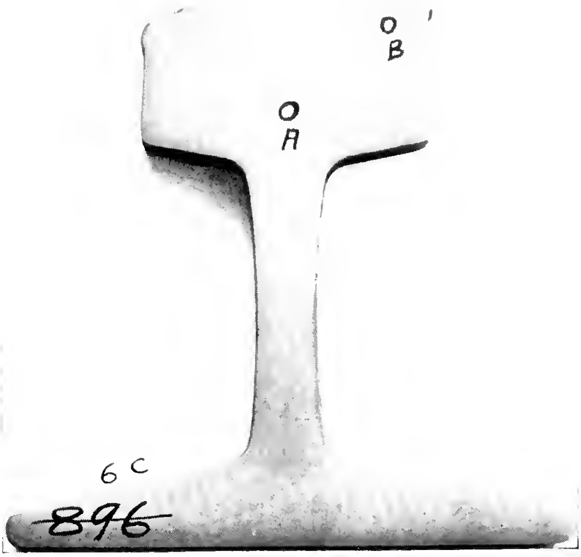

Fig 6C. Light Etching of Rail 6.

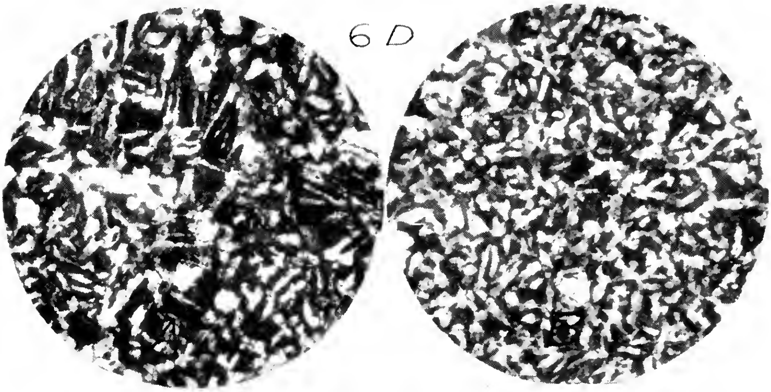

Fig. 6D. Microphotographs of Rail 6, Magnified 65 Diameters. Locations A and B on Fig. 6C.

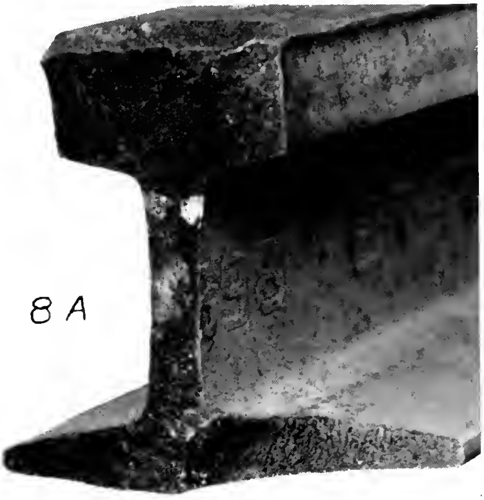

Fig. 8A. Fracture of "Broken" Rail 8.

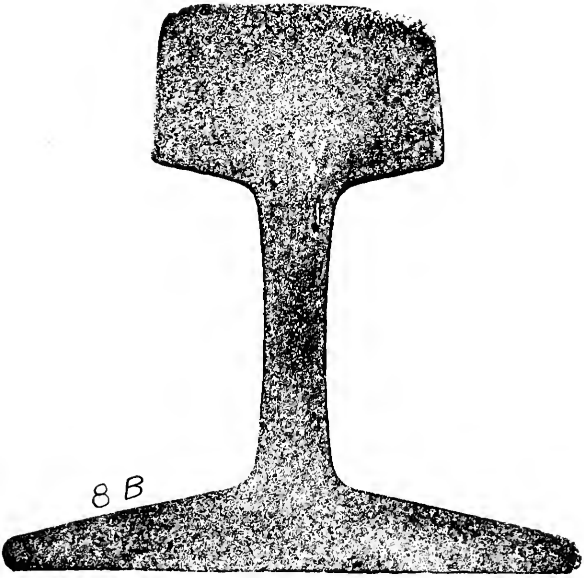

Fig. 8B. Deep Etching of Rail 8.

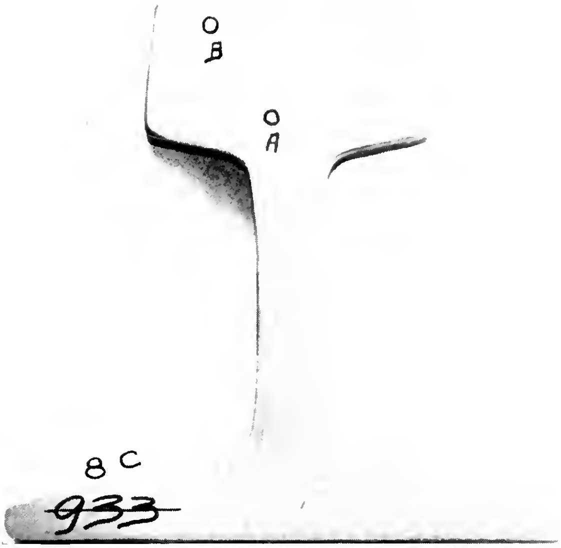

Fig. 8C. Light Etching of Rail 8.

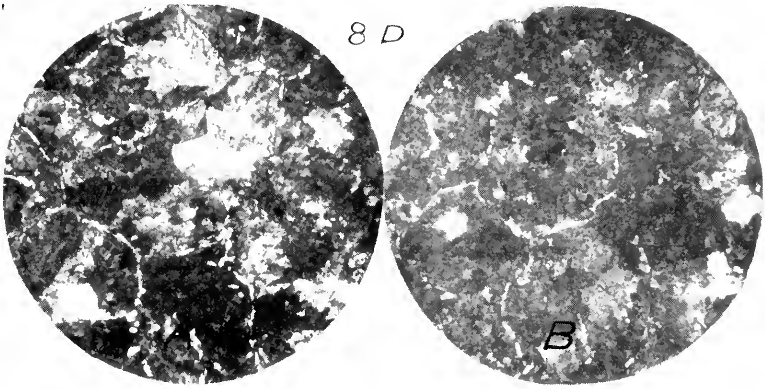

Fig. 8D. Microphotographs of Rail 8, Magnified 65 Diameters. Locations A and B of Fig. 8C.

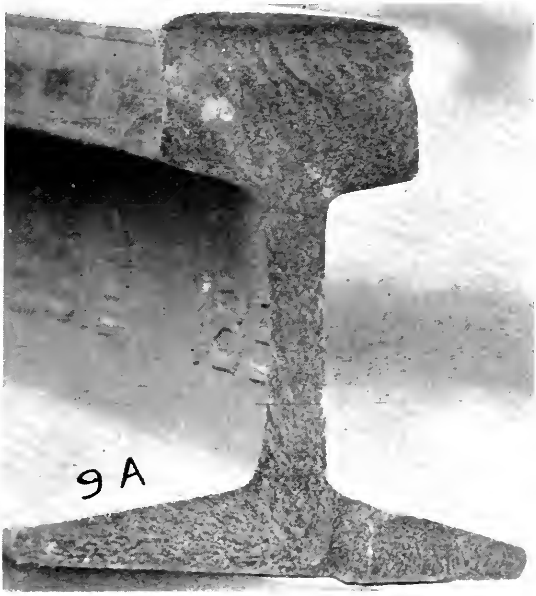

Fig. 9A. Fracture of Broken Rail 9.

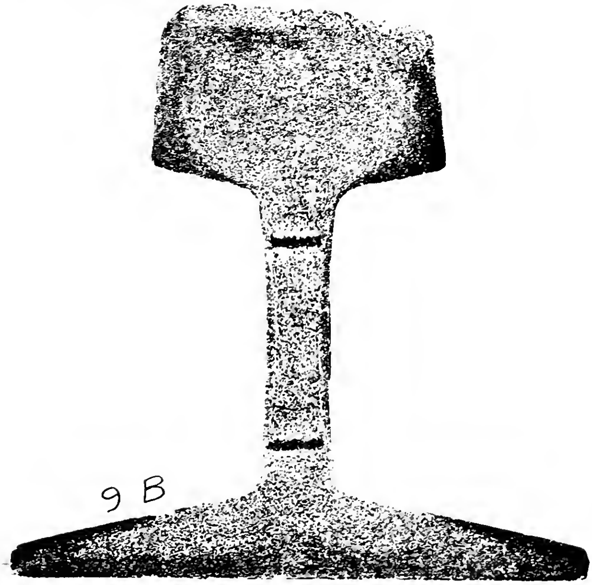

Fig. 9B. Deep Etching of Rail 9.

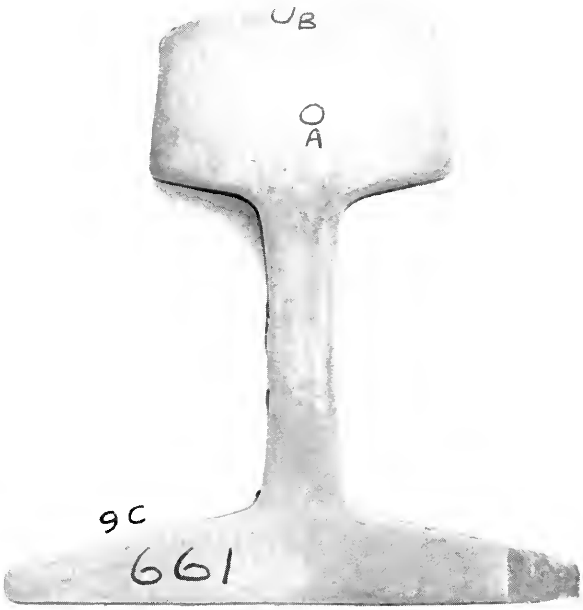

Fig. 9C. Light Etching of Rail 9.

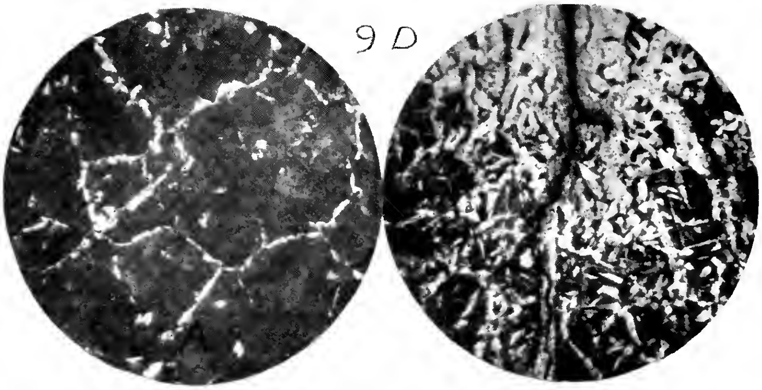

Fig. 9D. Microphotographs of Rail 9, Magnified 65 Diameters. Locations A and B on Fig. 9C.

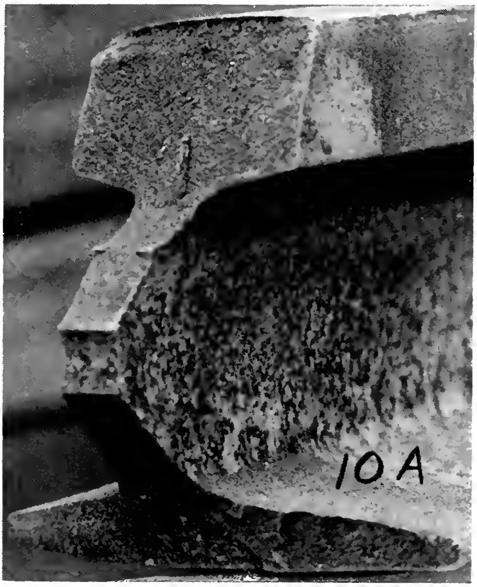

Fig. 10A. Fracture of Broken Rail 10.

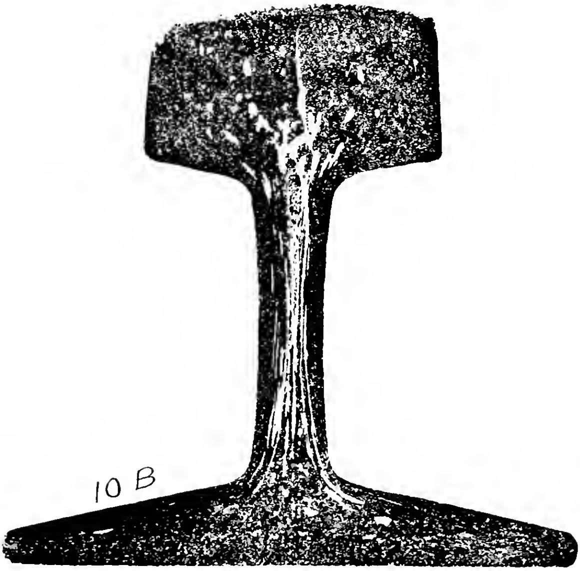

Fig. 10B. Deep Etching of Rail 10.

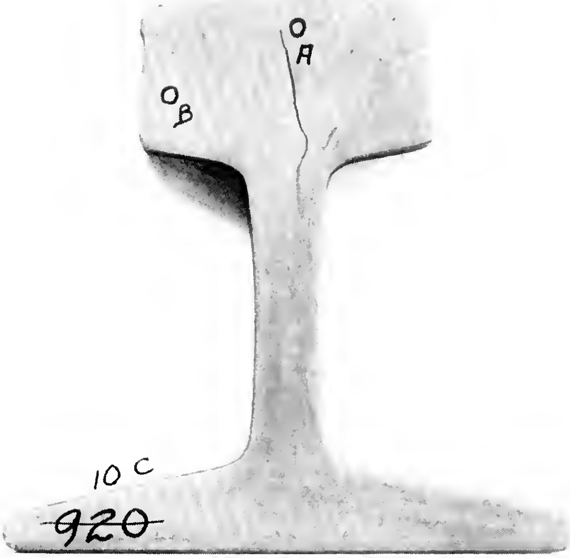

Fig. 10C. Light Etching of Rail 10.

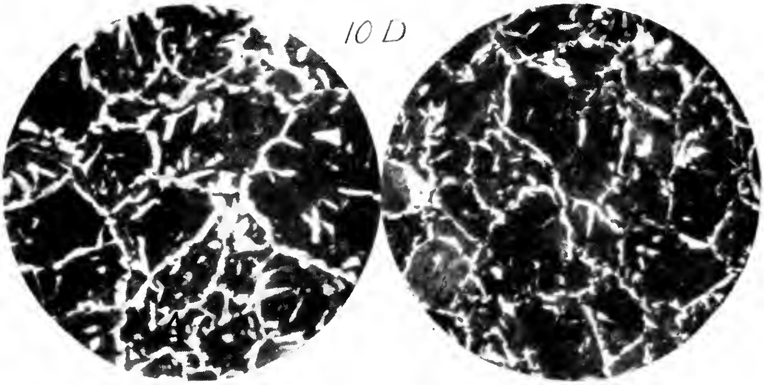

Fig. 10D. Microphotographs of Rail 10, Magnified 65 Diameters. Locations A and B of Fig. 10C.

FIG. 15A. COLLECTION OF PIECES OF RAIL 15.

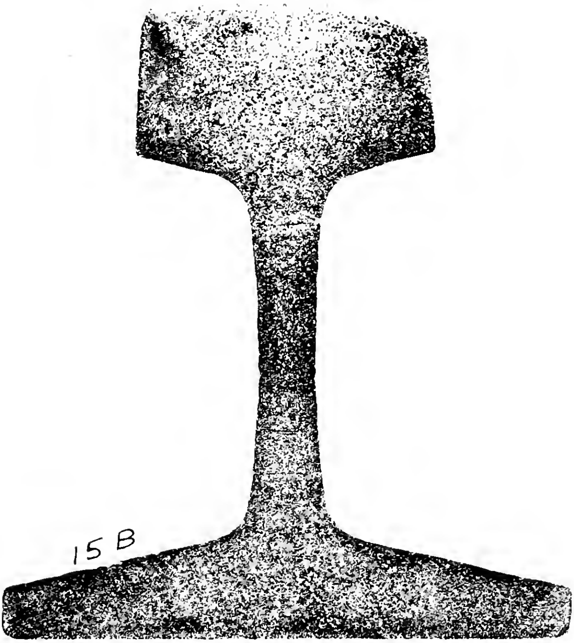

FIG. 16B. DEEP ETCHING OF RAIL 15.

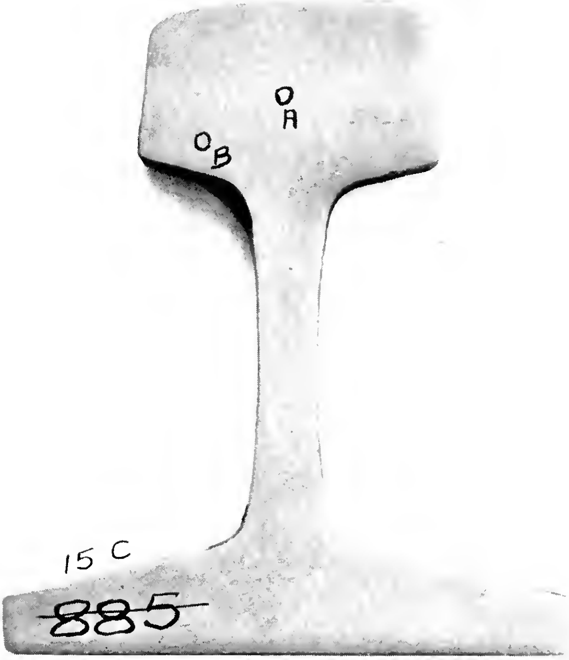

FIG. 15C. LIGHT ETCHING OF RAIL 15.

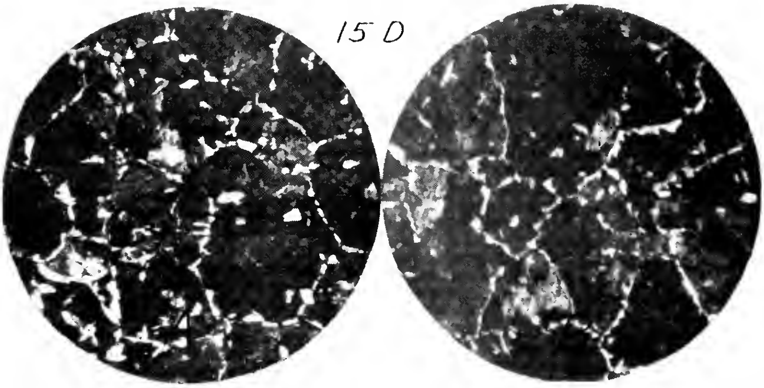

FIG. 15D. MICROPHOTOGRAPHS OF RAIL 15, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 15C.

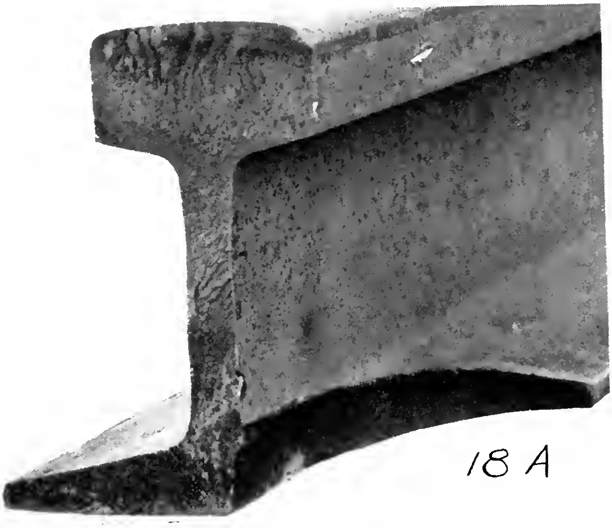

Fig. 18A. Fracture of "Broken" Rail 18.

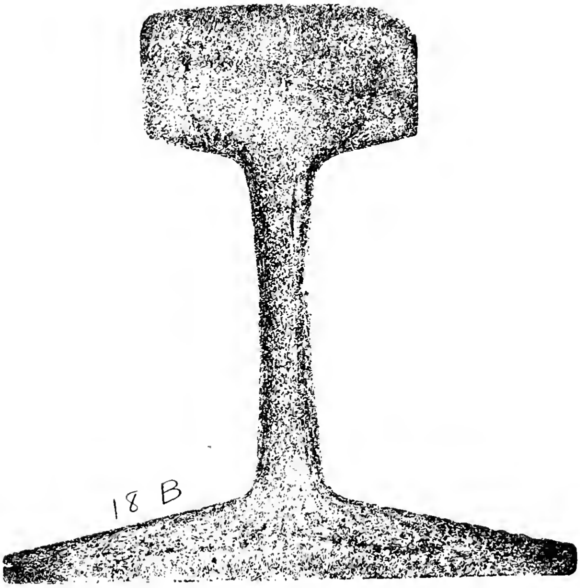

Fig. 18B. Deep Etching of Rail 18.

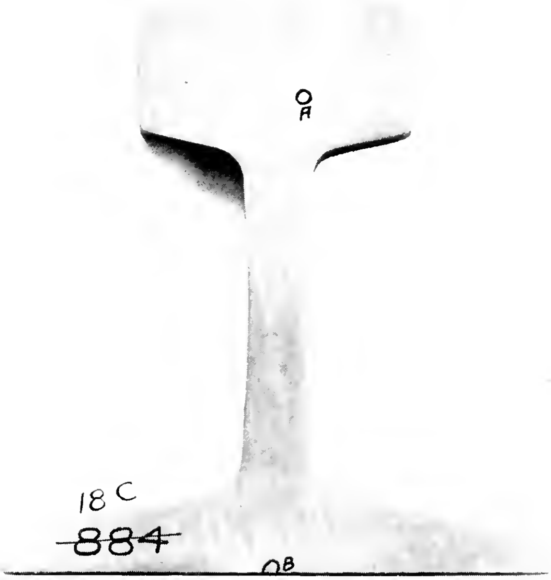

FIG. 18C. LIGHT ETCHING OF RAIL 18.

FIG. 18D. MICROPHOTOGRAPHS OF RAIL 18, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 18C.

Fig. 51A. Collection of Pieces of Rail 51.

Fig. 51B. Showing Flaw in Web of Rail 51, Dark Portion Showing Old Crack.

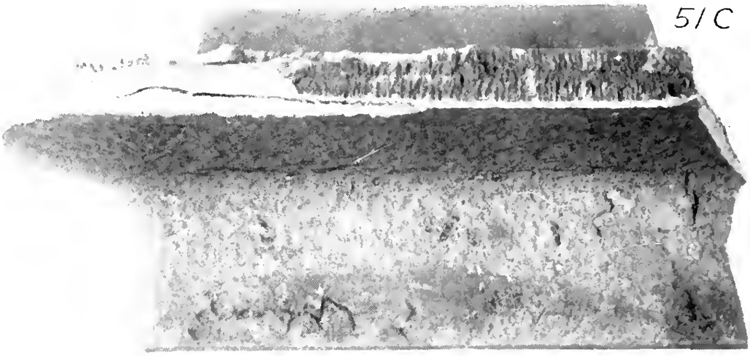

Fig. 51C. Another View Showing Flaw in Web of Rail 51, Dark Portion Showing Old Crack.

Fig. 51D. Showing Cracks in Head of Rail 51, the Light Portion in Top Showing Fresh Breaks.

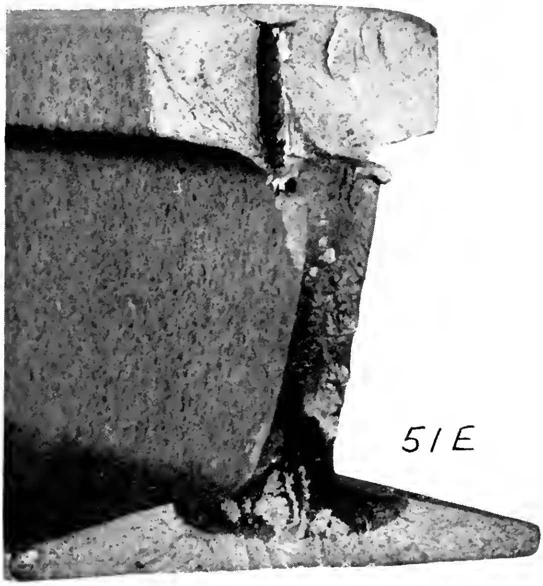

FIG. 51E. SHOWING SPLIT IN HEAD AND FLAW IN WEB OF RAIL 51.

FIG. 51F. ANOTHER VIEW OF SPLIT IN HEAD OF RAIL 51.

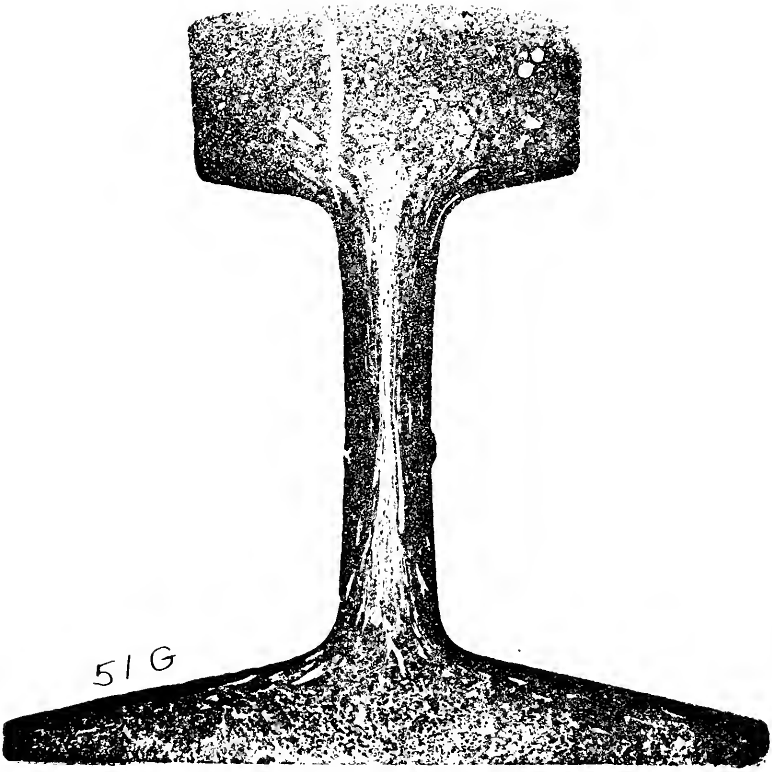

Fig. 51G. Deep Etching of Rail 51.

FIG. 51H. LIGHT ETCHING OF RAIL 51.

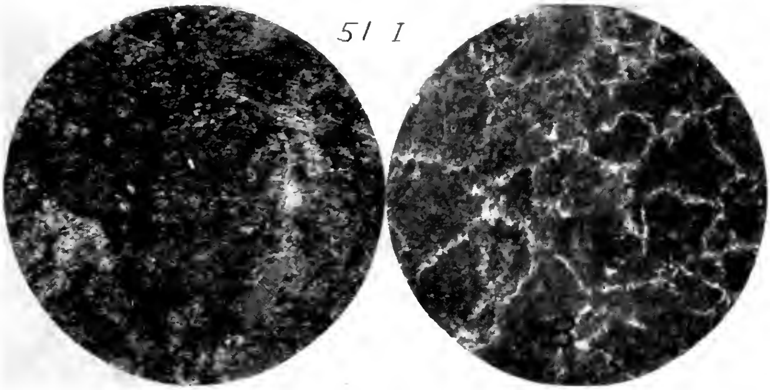

FIG. 51I. MICROPHOTOGRAPHS OF RAIL 51, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 51H.

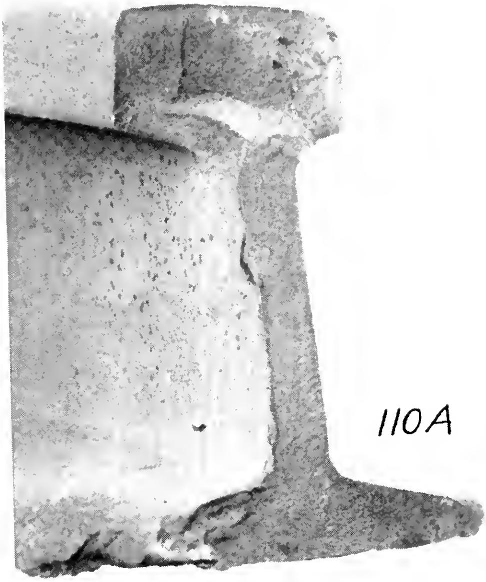

Fig. 110A. "Broken" Rail 110.

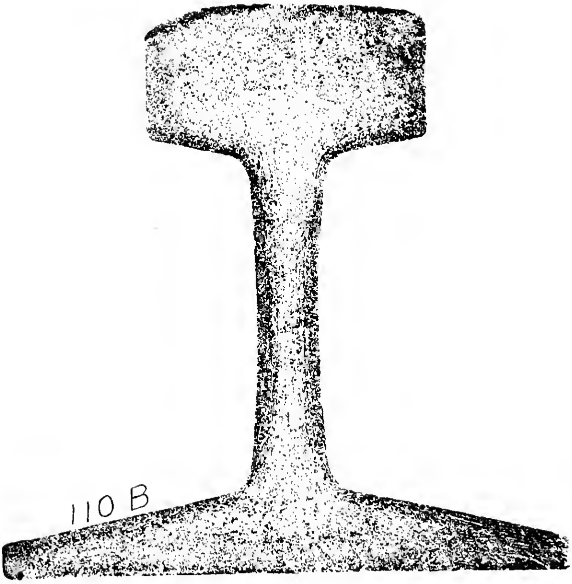

Fig. 110B. Deep Etching of Rail 110.

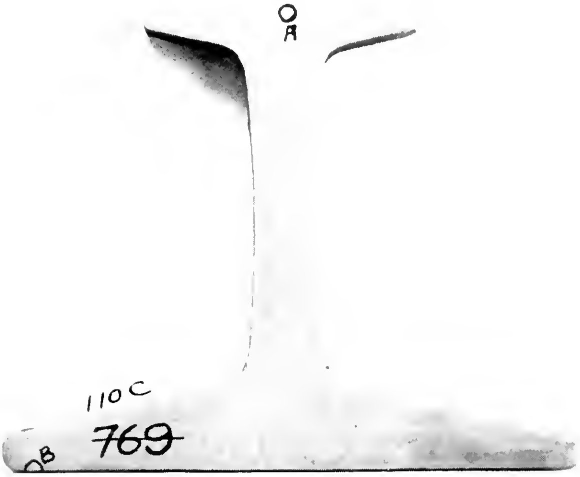

FIG. 110C. LIGHT ETCHING OF RAIL 110.

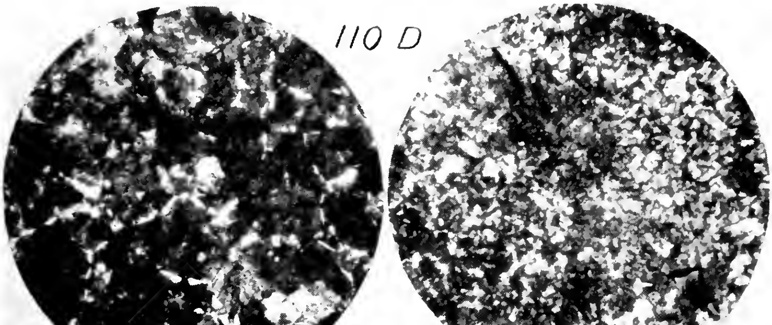

FIG. 110D. MICROPHOTOGRAPHS OF RAIL 110, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 110C.

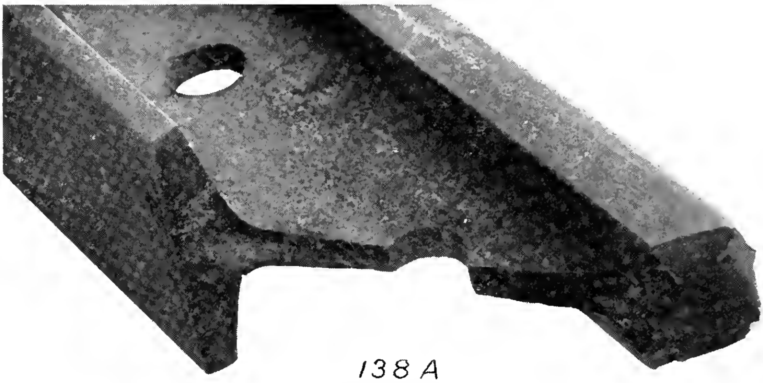

Fig. 138A. "Broken" Rail 138.

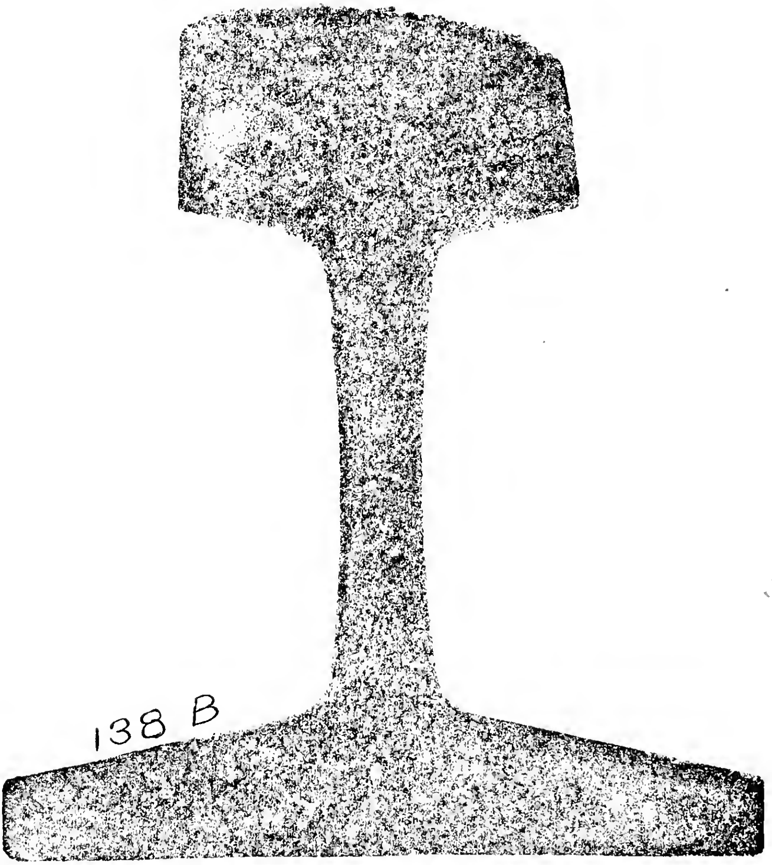

Fig. 138B. Deep Etching of Rail 138.

FIG. 138C. LIGHT ETCHING OF RAIL 138.

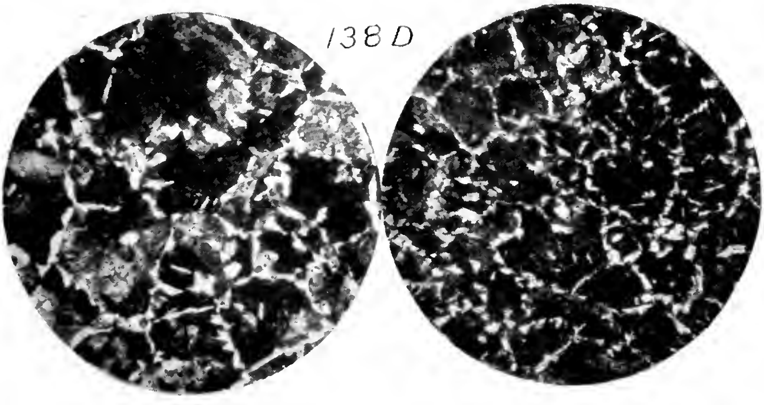

FIG. 138D. MICROPHOTOGRAPHS OF RAIL 138, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 138C.

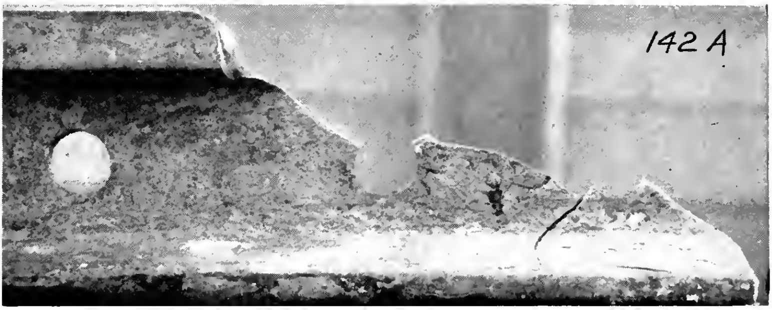

Fig. 142A. Broken Rail 142.

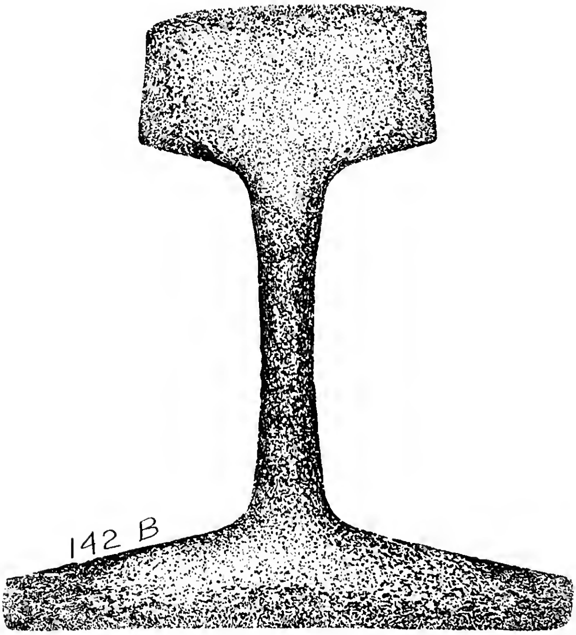

Fig. 142B. Deep Etching of Rail 142.

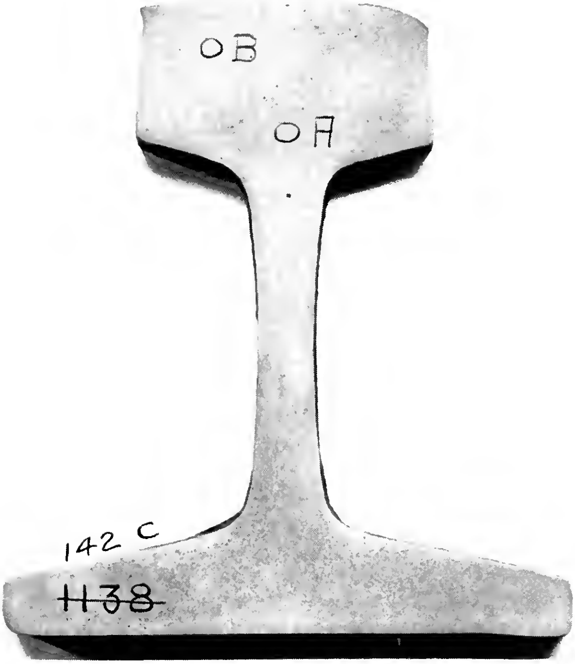

FIG. 142C. LIGHT ETCHING OF RAIL 142.

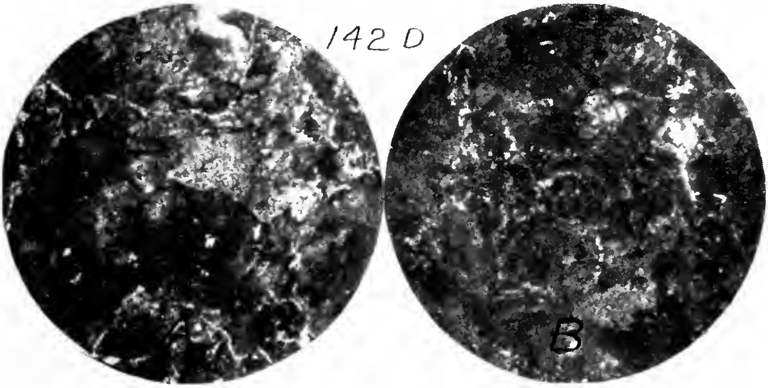

FIG. 142D. MICROPHOTOGRAPHS OF RAIL 142, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 142C.

A and B—Average structure, an unusually good rail, being free from segregation and other defects.

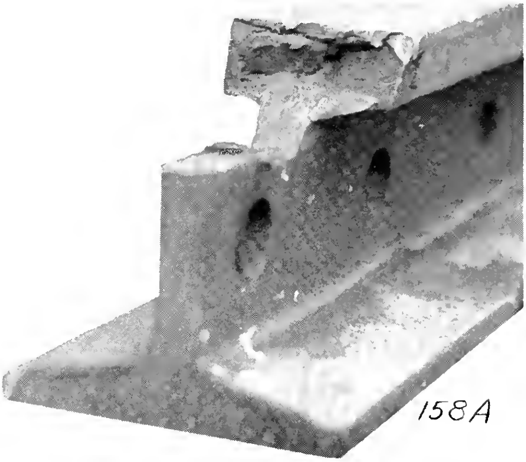

Fig. 158A. Rail 158, Head Broken at End.

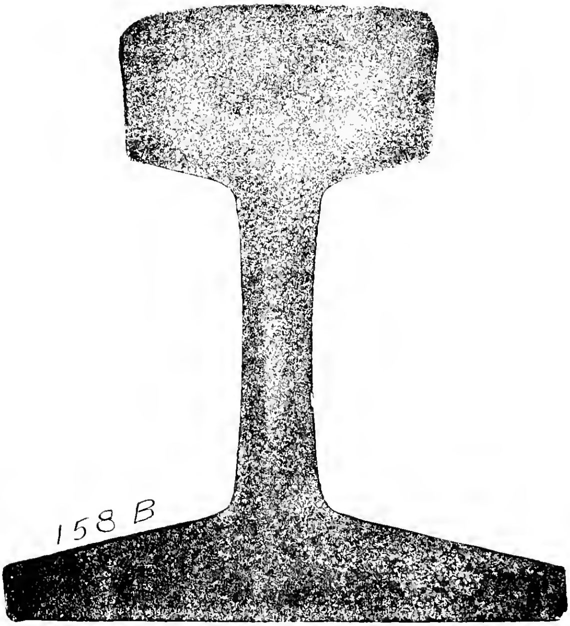

Fig. 158B. Deep Etching of Rail 158.

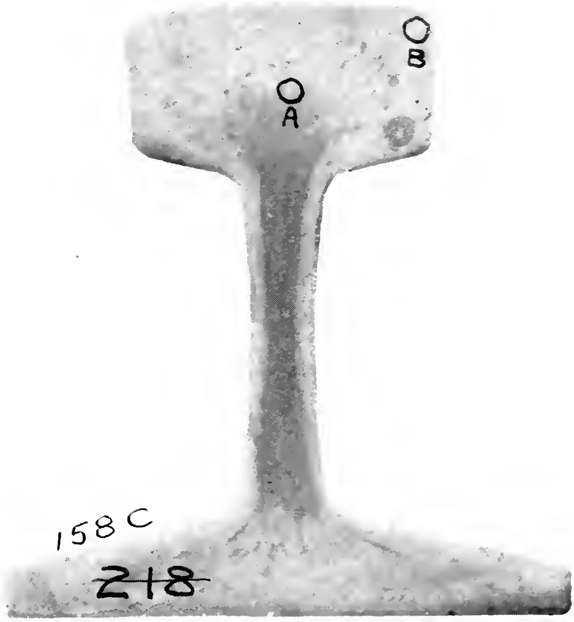

FIG. 158C. LIGHT ETCHING OF RAIL 158.

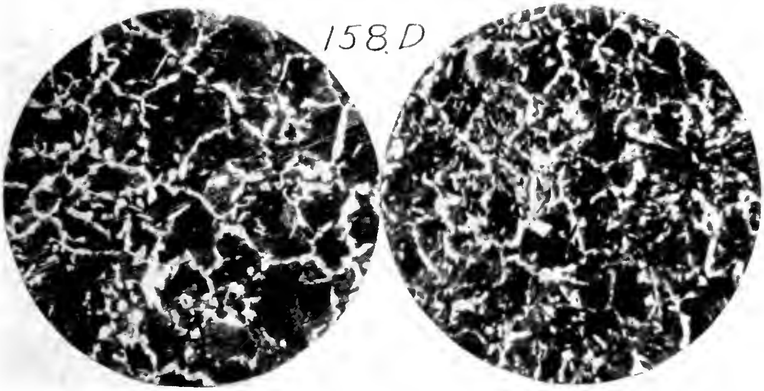

FIG. 158D. MICROPHOTOGRAPHS OF RAIL 158, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 158C.

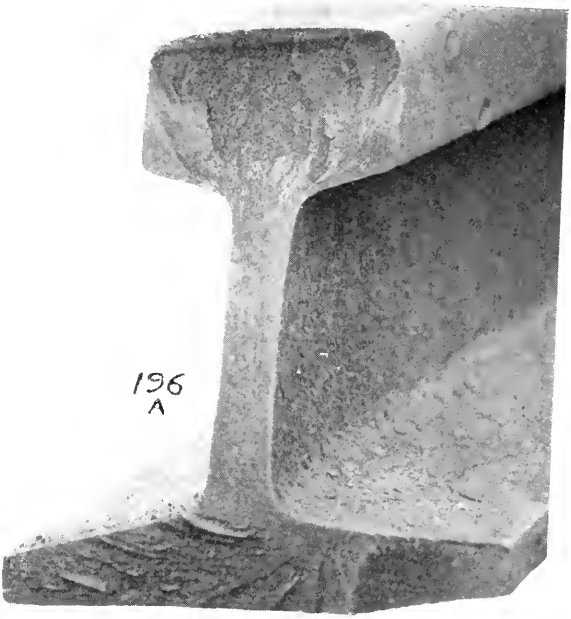

Fig. 196A. Broken Rail 196.

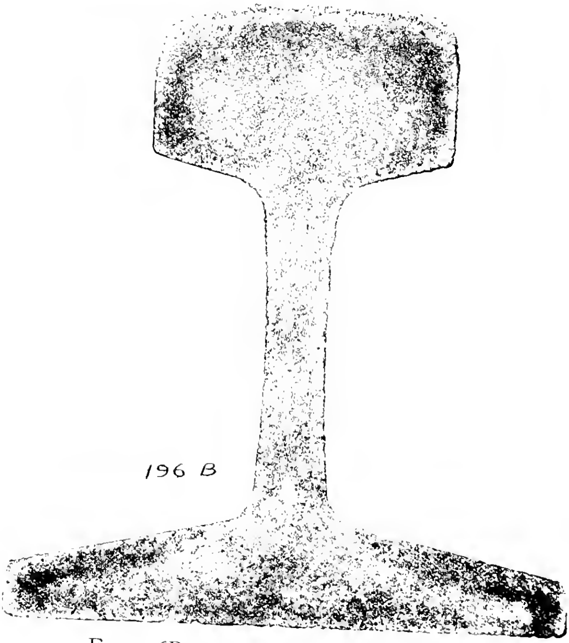

Fig. 196B. Deep Etching of Rail 196.

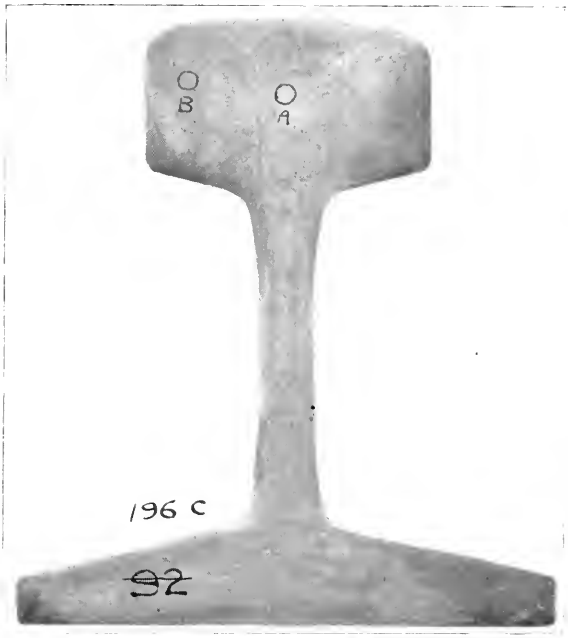

Fig. 196C. Light Etching of Rail 196.

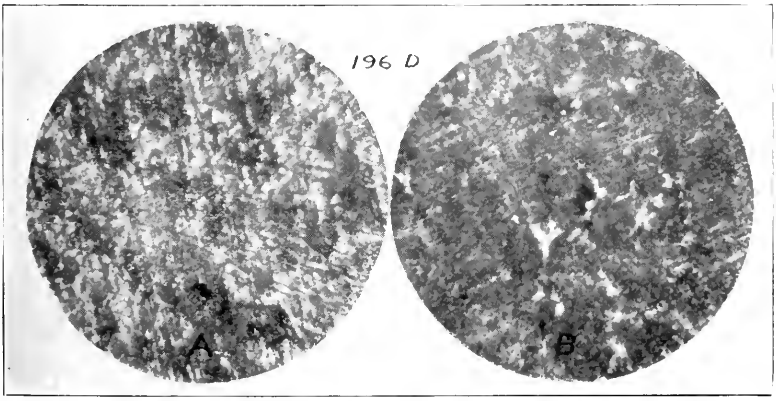

Fig. 196D. Microphotographs of Rail 196, Magnified 65 Diameters. Locations A and B on Fig. 196C.

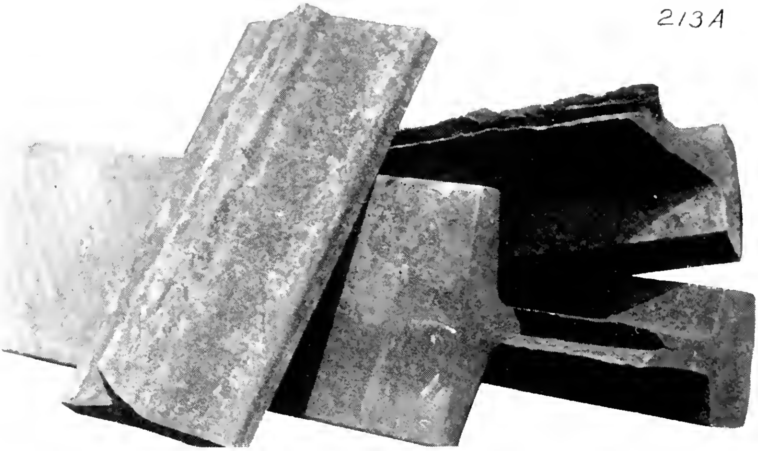

Fig. 213A. Pieces of Rail 213.

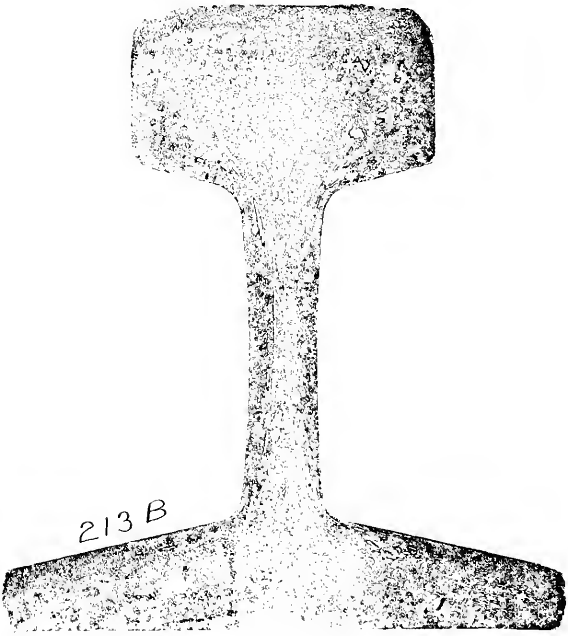

Fig. 213B. Deep Etching of Rail 213.

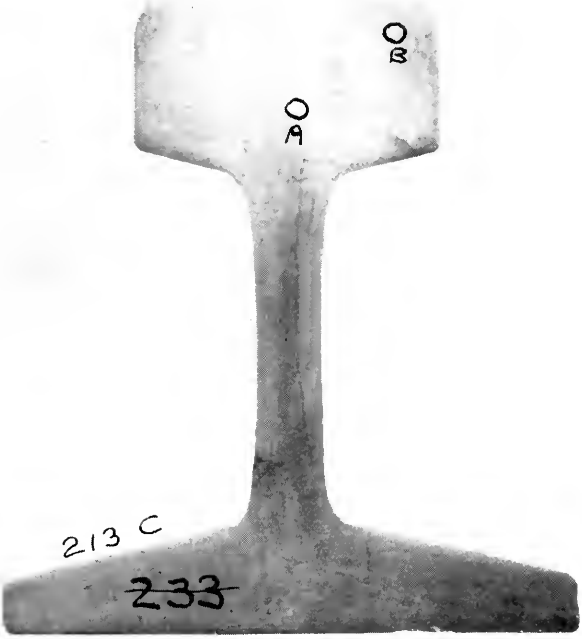

FIG. 213C. LIGHT ETCHING OF RAIL 213.

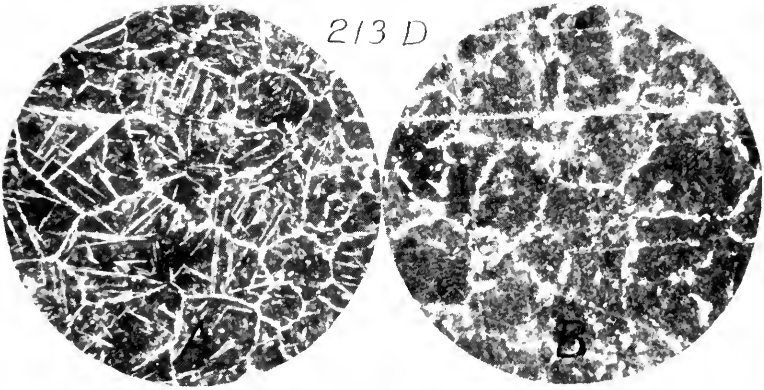

FIG. 213D. MICROPHOTOGRAPHS OF RAIL 213, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 213C.

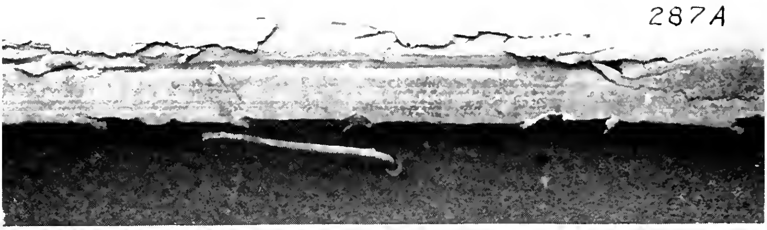

Fig. 287A. Crushed Head of Rail 287.

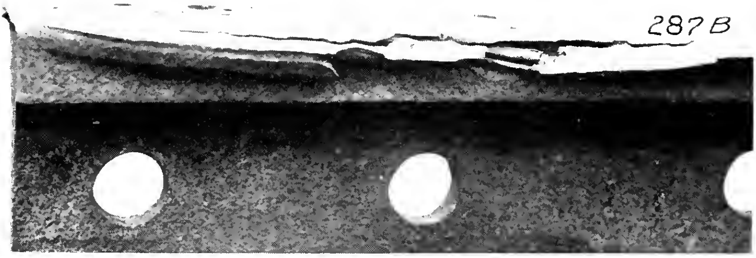

Fig. 287B. Another View of Crushed Head of Rail 287.

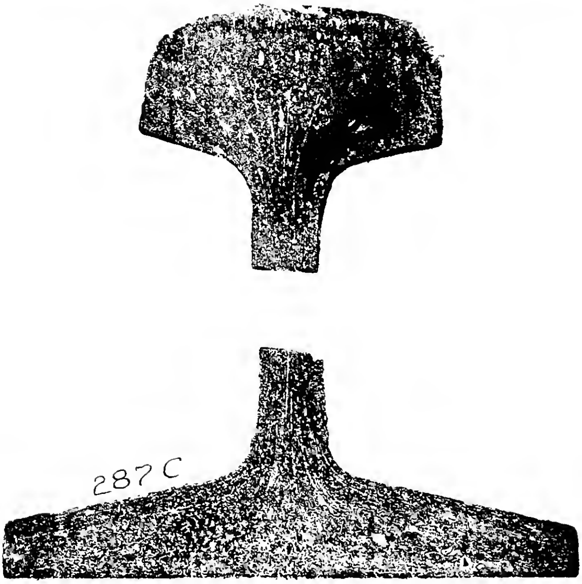

Fig. 287C. Deep Etching of Rail 287.

FIG. 287D. LIGHT ETCHING OF RAIL 287.

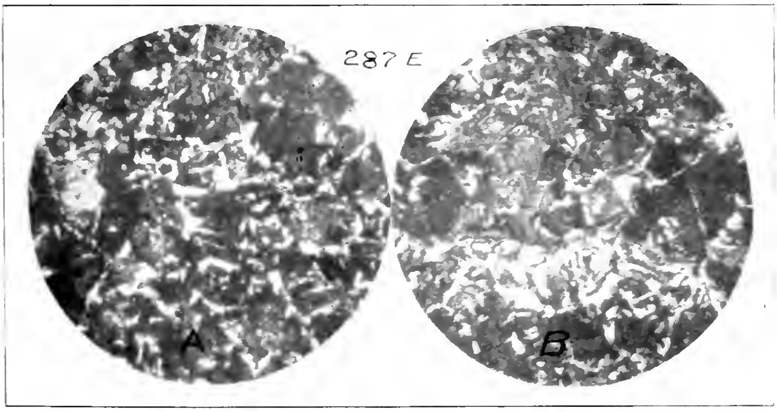

FIG. 287E. MICROPHOTOGRAPHS OF RAIL 287. MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 287D.

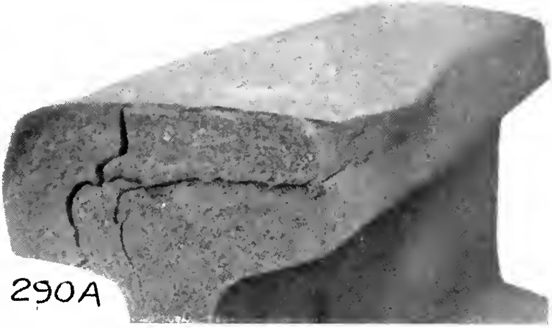

FIG. 290A. VIEW OF END OF "CRUSHED" HEAD RAIL 290.

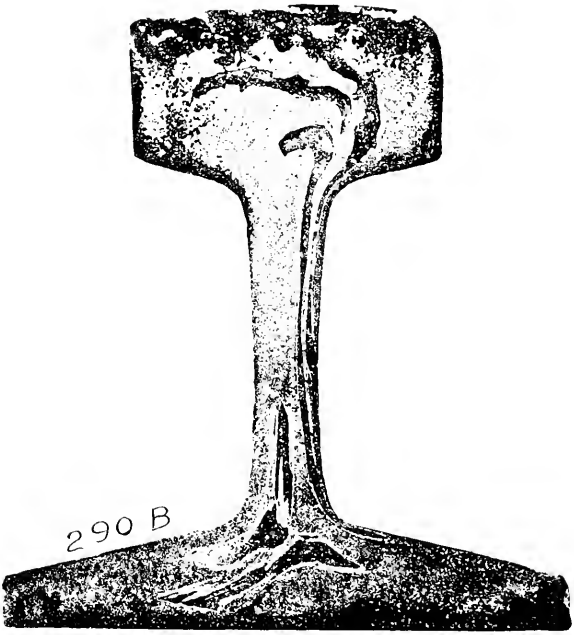

FIG. 290B. DEEP ETCHING OF RAIL 290.
View showing scrap tie-plate in the head.

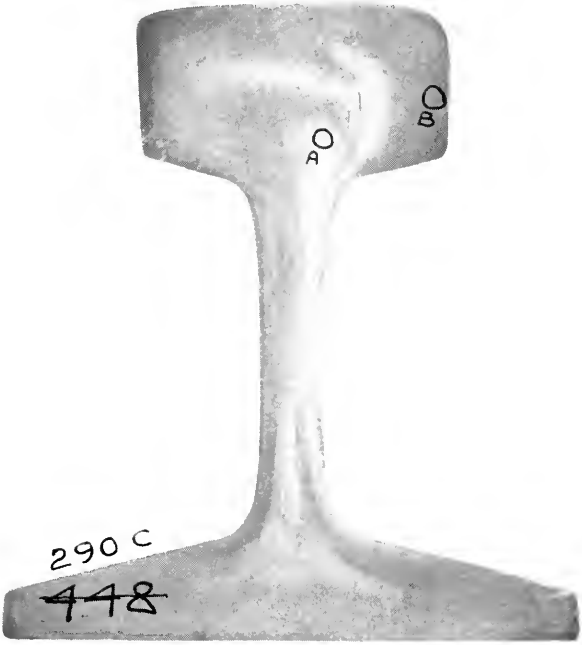

FIG. 290C. LIGHT ETCHING OF RAIL 290.

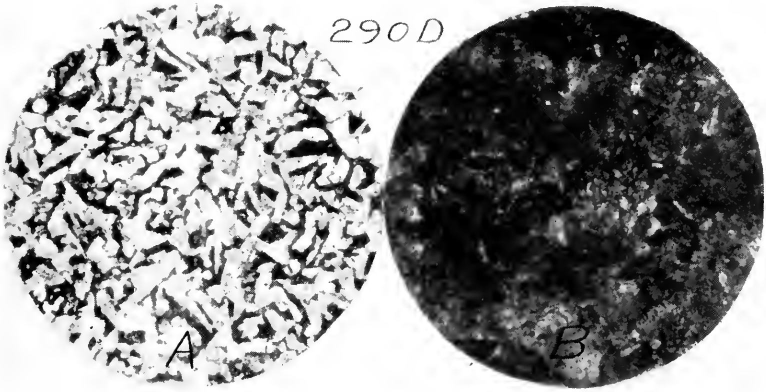

FIG. 290D. MICROPHOTOGRAPHS OF RAIL 290, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 290C.

Fig. 291A. Showing Split in Crushed Head of Rail 291.

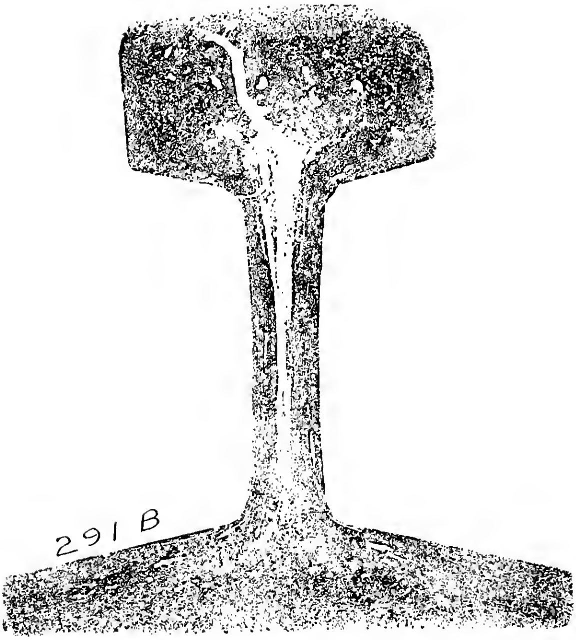

Fig. 291B. Deep Etching of Rail 291.

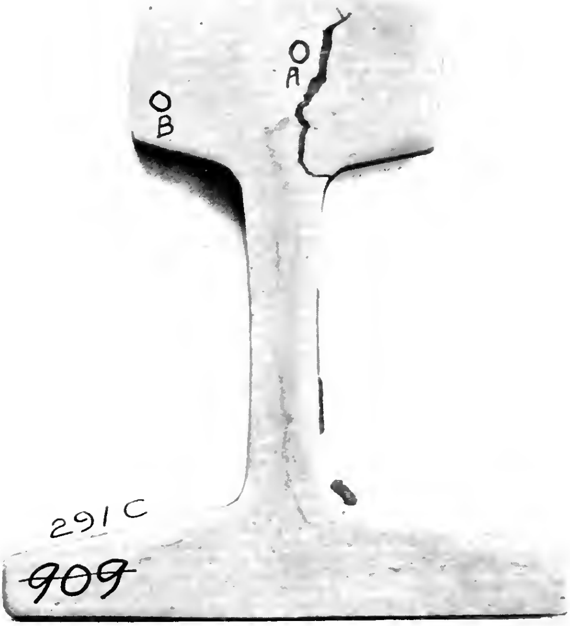

FIG. 291C. LIGHT ETCHING OF RAIL 291.

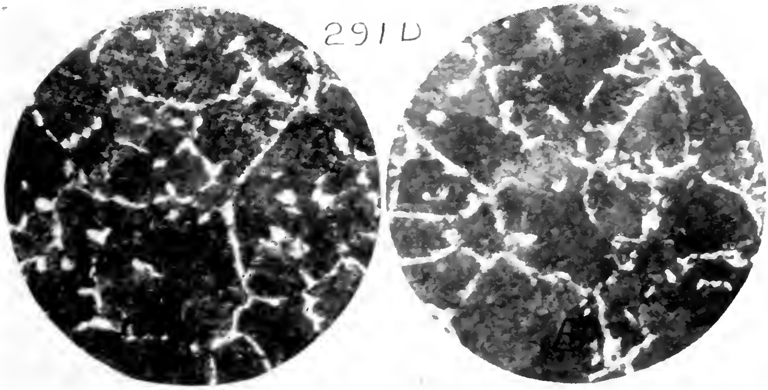

FIG. 291D. MICROPHOTOGRAPHS OF RAIL 291, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 291C.

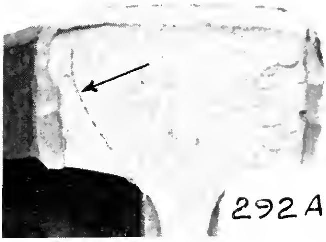

Fig. 292A. Showing Split in Crushed Head of Rail 292

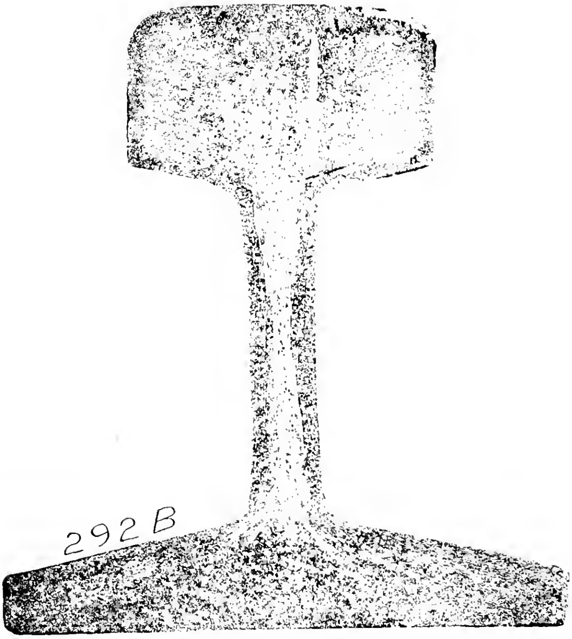

Fig. 292B. Deep Etching of Rail 292.

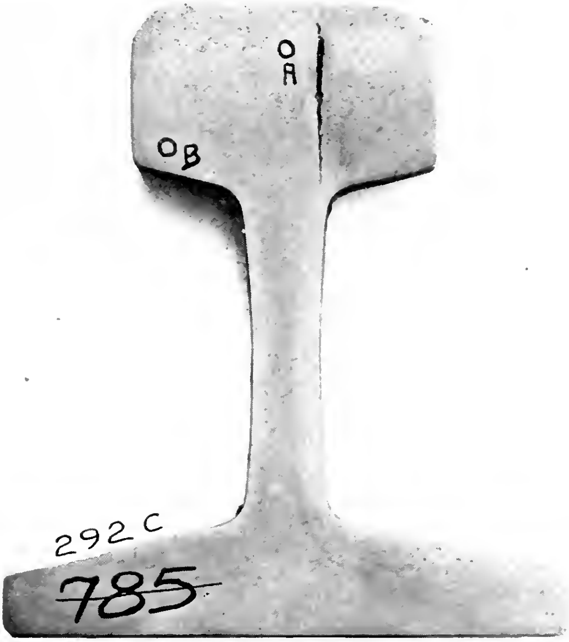

FIG. 292C. LIGHT ETCHING OF RAIL 292.

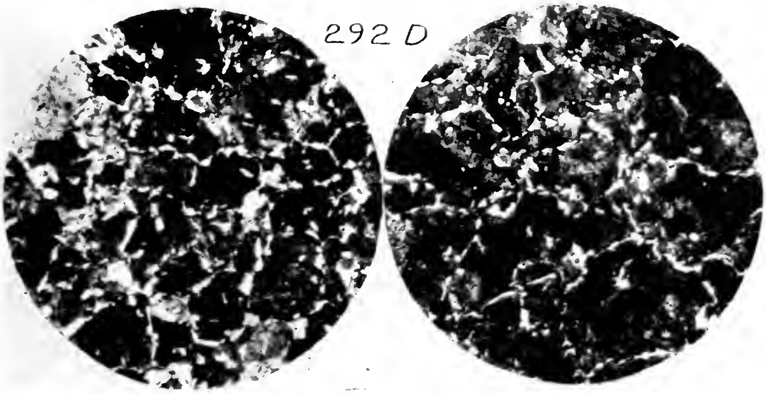

FIG. 292D. MICROPHOTOGRAPHS OF RAIL 292, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 292C.

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PENNSYLVANIA RAILROAD COMPANY

P. B. & W R R. N C. RY. W J & S R R.

LABORATORY REPORT

CHEMICAL AND PHYSICAL EXAMINATION OF RAIL AND OTHER TRACK MATERIAL

Referred to in letter W.C.Cushing to J.T.Wallis, dated March 18, 1912.

Laboratory No. 25617-19. Sample Represents rail which failed 1848 ft. west of M.P. 156, Logansport Division, 2-28-12. (85-lb. rail, P.S. Section, Mar.ET 4-09, Heat No. 76). Laid Aug. 1910.

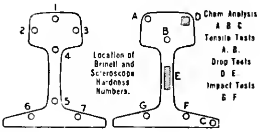
Place and Date Altoona, Pa., August 13, 1912.

CHEMICAL ANALYSIS								PHYSICAL TESTS					
Location of Borings	C.	Mn.	P	Si.	S			Mill Drop Test Permanent Set-Inches	Tensile Strength Lbs Per Sq In	Elastic Limit Lbs Per Sq In	Elongation Per Cent in 2 ins.	Reduction of Area—% of Original Sec	Character of Fracture
Head	.78	1.11	.116	.061	.042			1-3/8"	112850	61995	3Note	1.01	G
Web	.98	1.20	.170	.071	.060								
Base	.76	1.13	.115	.061	.054								
Average	.84	1.15	.134	.064	.052								
Heat Analysis	.46	.96											

NOTE The word ''Borings'' refers also to ''Chippings'' and other kinds of test fragments.

DROP TEST SUPPORTS 12" APART WEIGHT OF TUP, 50 LBS.										Impact Test. No of Double Vibrations
Test Piece at "D" $\frac{23}{32}$" x $\frac{28}{32}$"					Test Piece at "E" $\frac{1}{2}$" x 1"					
Blows at 5 Ft.	Blows at 10 Ft.	Blows at 15 Ft.	Initial Deflec	Accum Ft. lbs	Blows at 3 Ft.	Blows at 6 Ft.	Blows at 10 Ft.	Initial Deflec.	Accum Ft lbs.	
1	—	—	—	250	5	5	14	1-1/8"	9250	727

	Location	1	2	3	4	5	6	7	Average
Hardness Number	Brinell	249	259	268	313	310	256	281	277
	Scleroscope	43	41	41	38	37	37	43	40



REMARKS — Note: One piece broke outside of punch mark.

Carbon is very high. Phosphorus is high. The rail is badly segregated. Brinell hardness is irregular with a very high average. Tensile and drop tests indicate brittle material. The etching tests indicate that failure was due to a split head, a natural result of the conditions found.

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Test Dept. No. 799.

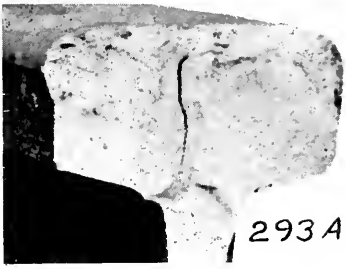


FIG. 293A. SHOWING SPLIT IN CRUSHED HEAD OF RAIL 293.

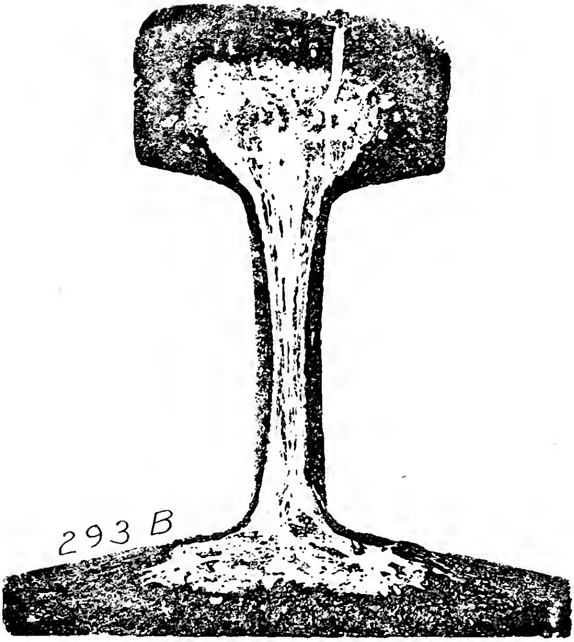


FIG. 293B. DEEP ETCHING OF RAIL 293.

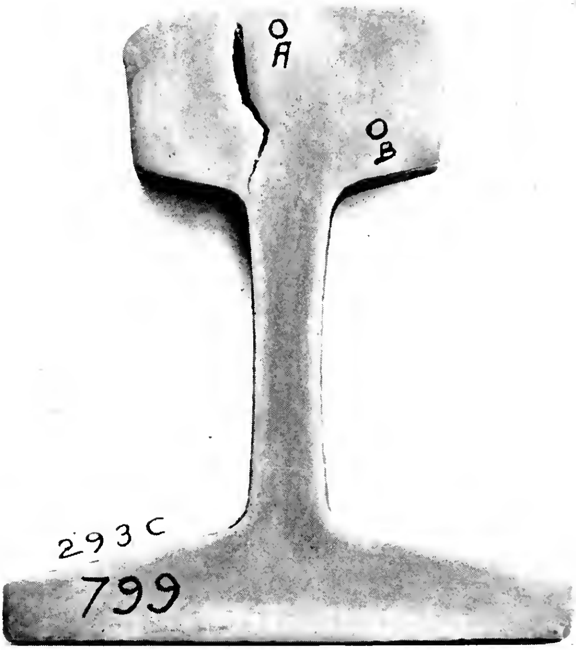


Fig. 293C. Light Etching of Rail 293.

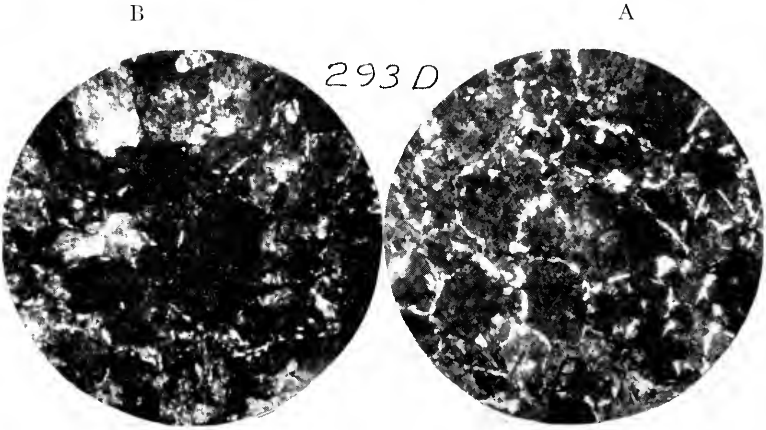


Fig. 293D. Microphotographs of Rail 293, Magnified 65 Diameters.

FIG. 302A. SHOWING "FLOW OF METAL" OF RAIL 302.

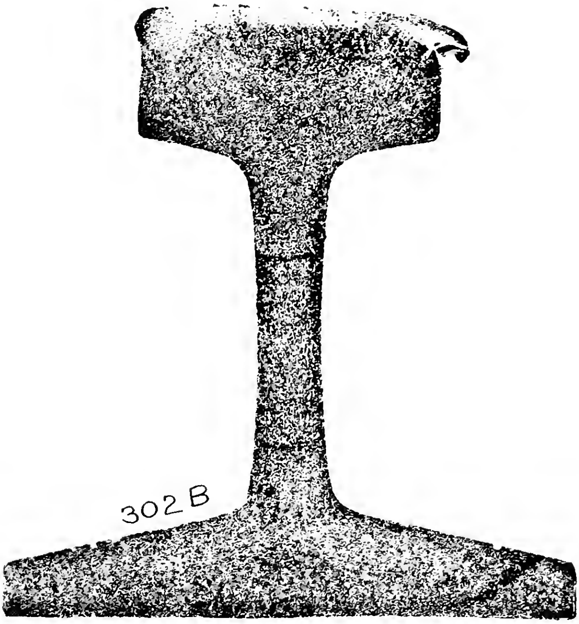


FIG. 302B. DEEP ETCHING OF RAIL 302.

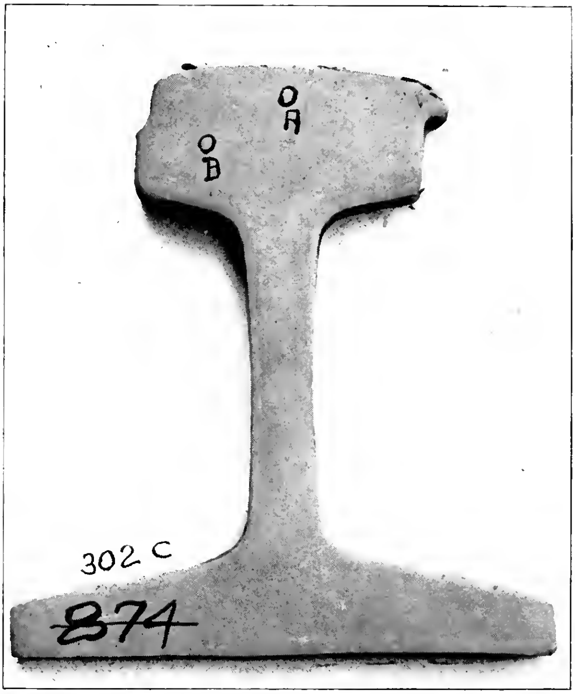


FIG. 302C. LIGHT ETCHING OF RAIL 302.

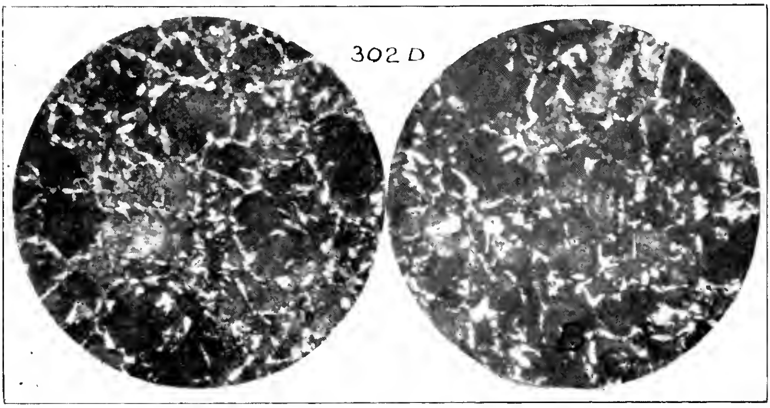


FIG. 302D. MICROPHOTOGRAPHS OF RAIL 302, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 302D.

FIG. 309A. SHOWING SPLIT IN HEAD OF RAIL 309, WHICH FAILED DUE TO "FLOW OF METAL."

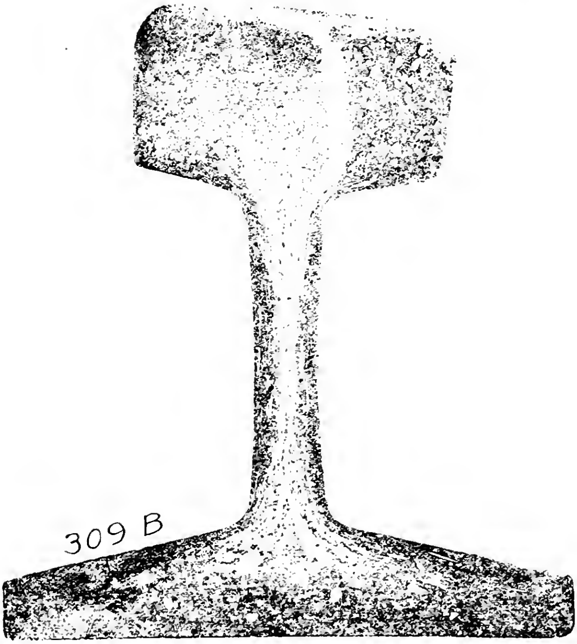


FIG. 309B. DEEP ETCHING OF RAIL 309.

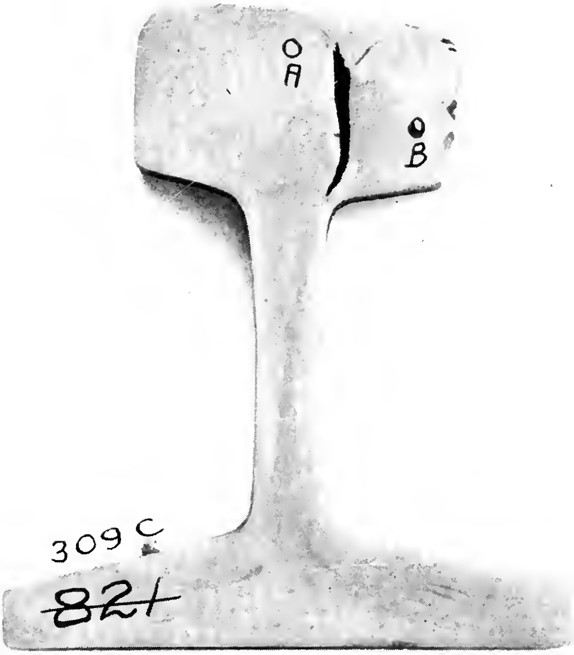


Fig. 309B. Light Etching of Rail 309.

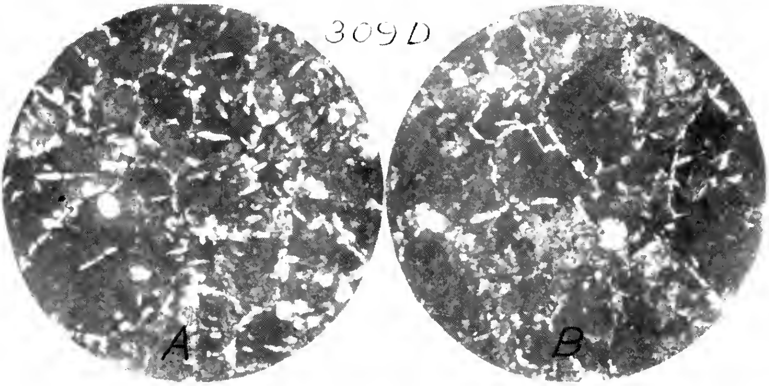


Fig. 309C. Microphotographs of Rail 309, Magnified 65 Diameters. Locations A and B on Fig. 309C.

FIG. 314A. "SPLIT HEAD" RAIL 314.

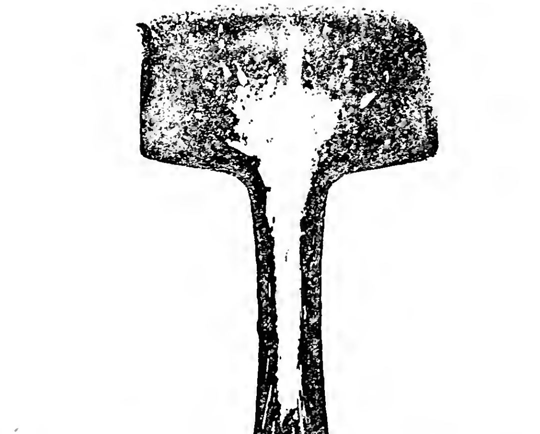


FIG. 314B. DEEP ETCHING OF RAIL 314.

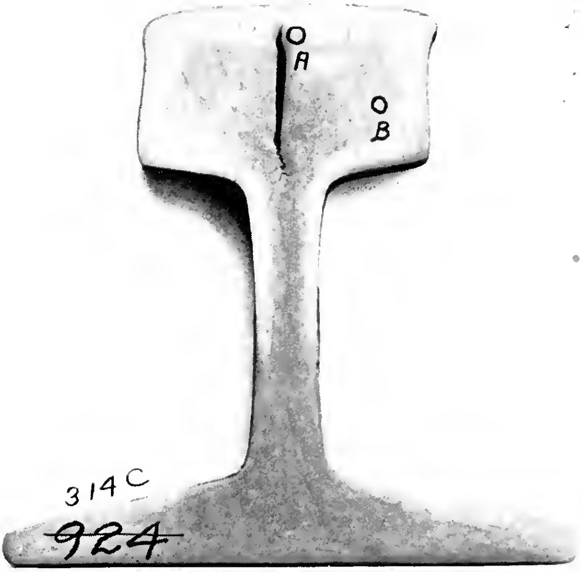


Fig. 314C. Light Etching of Rail 314.

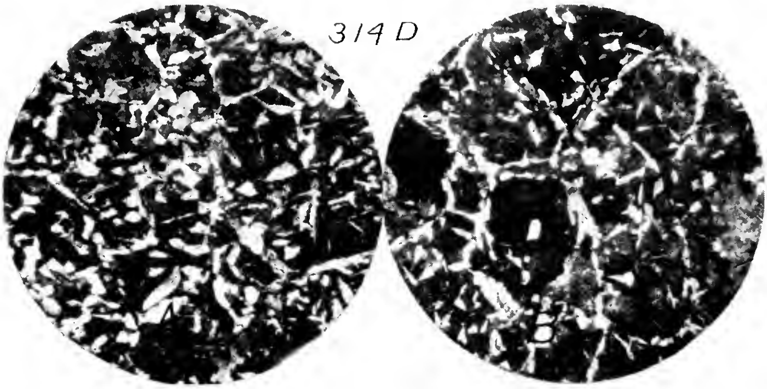


Fig. 314D. Microphotographs of Rail 314, Magnified 65 Diameters. Locations A and B on Fig. 314C.

FIG. 329A. "SPLIT HEAD" RAIL 329.

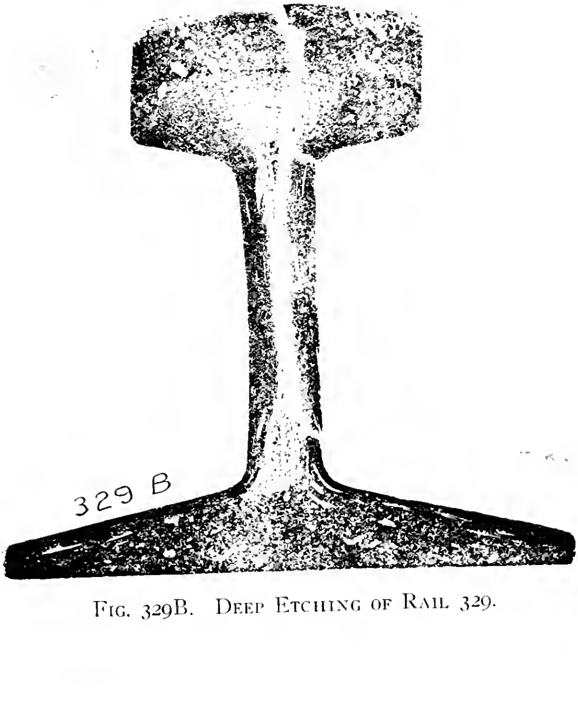


FIG. 329B. DEEP ETCHING OF RAIL 329.

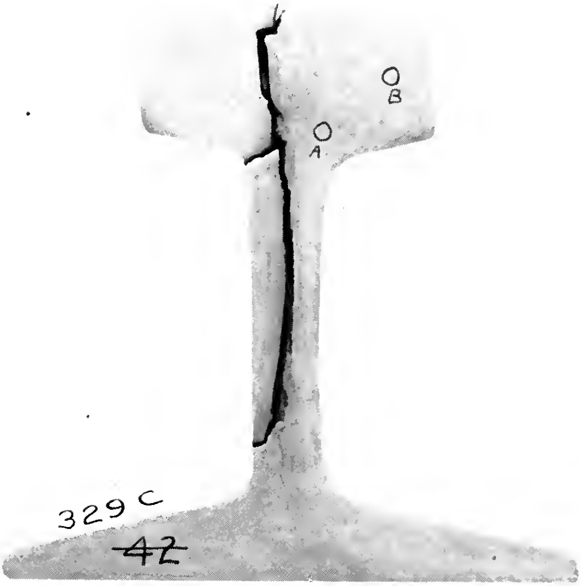


FIG. 329C. LIGHT ETCHING OF RAIL 329.

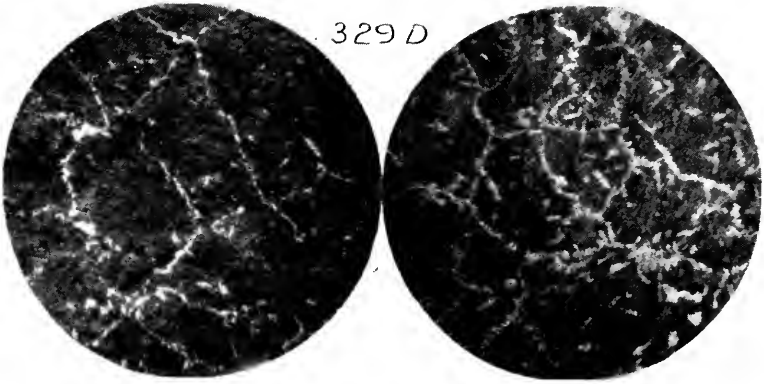


FIG. 329D. MICROPHOTOGRAPHS OF RAIL 329, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 329C.

FIG. 368A. "SPLIT HEAD" RAIL 368.

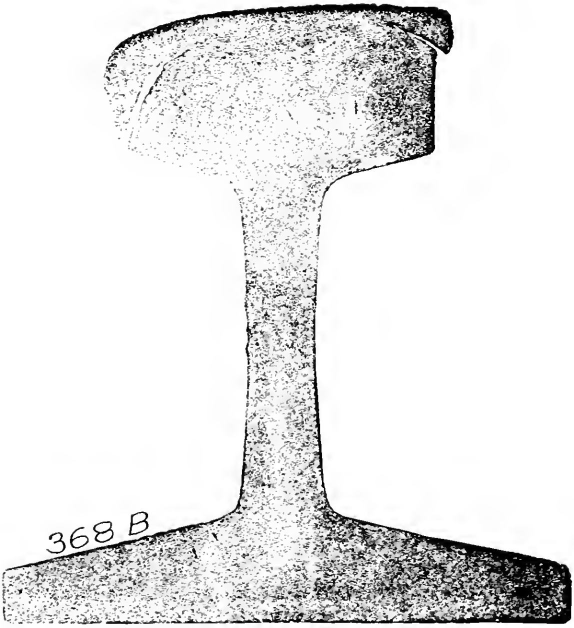


FIG. 368B. DEEP ETCHING OF RAIL 368.
View showing scrap tie-plate in the head.

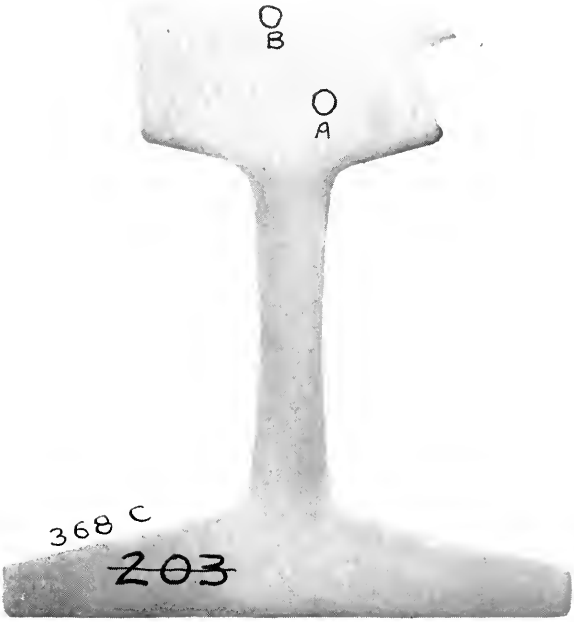


Fig. 368D. Light Etching of Rail 368.

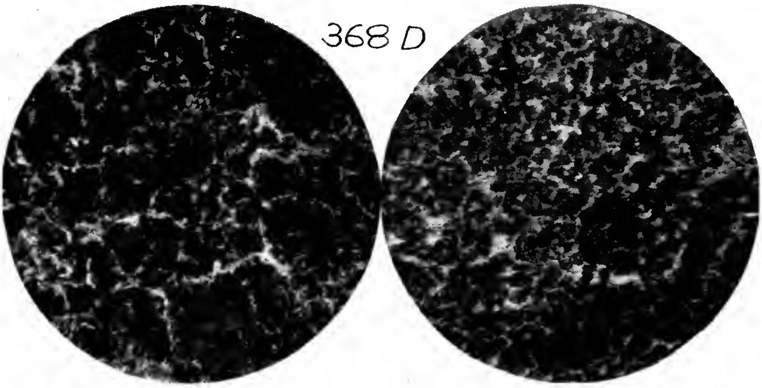


Fig. 368D. Microphotographs of Rail 368, Magnified 65 Diameters. Locations A and B on Fig. 368C.

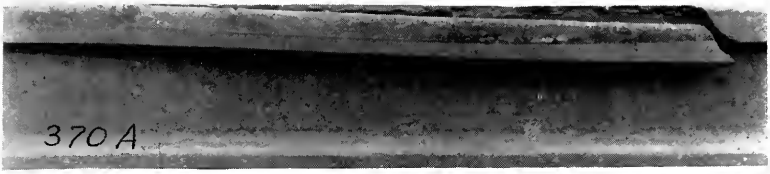


FIG. 370A. "SPLIT HEAD" RAIL 370.

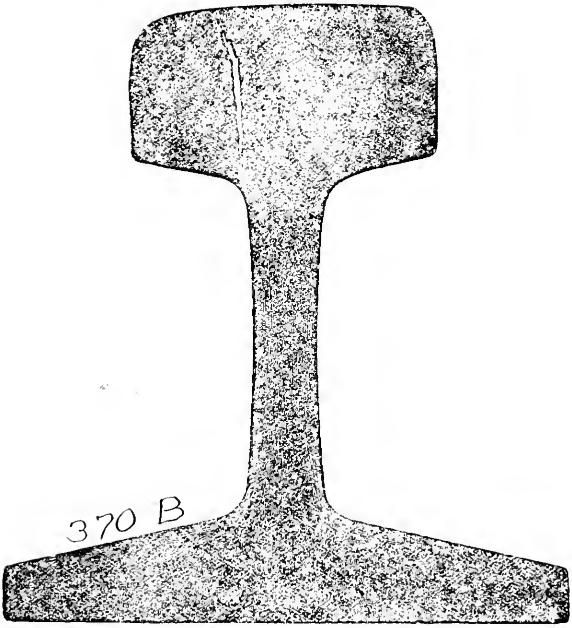


FIG. 370B. DEEP ETCHING OF RAIL 370.

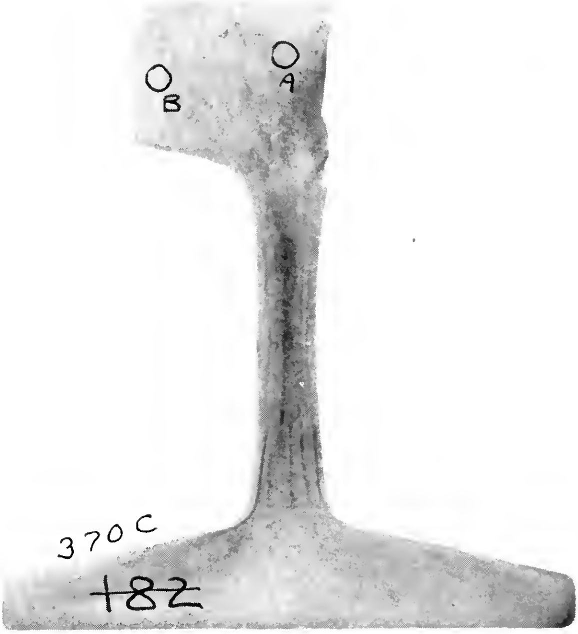


Fig. 370C. Light Etching of Rail 370.

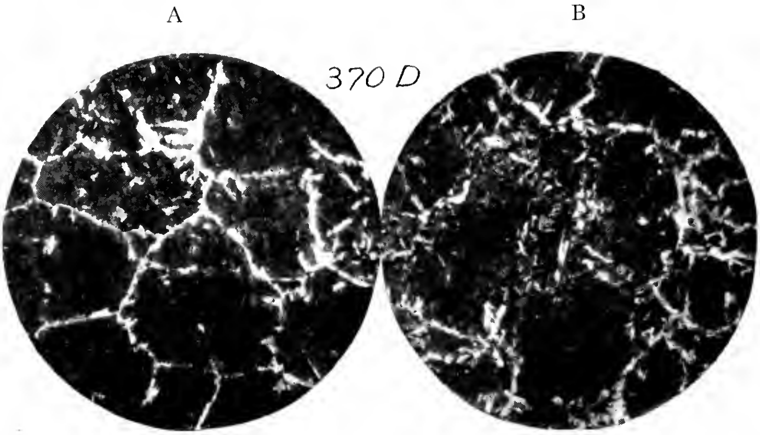


Fig. 370D. Microphotographs of Rail 370, Magnified 65 Diameters. Locations A and B on F.g. 370C.

FIG. 384A. "SPLIT HEAD RAIL 384.

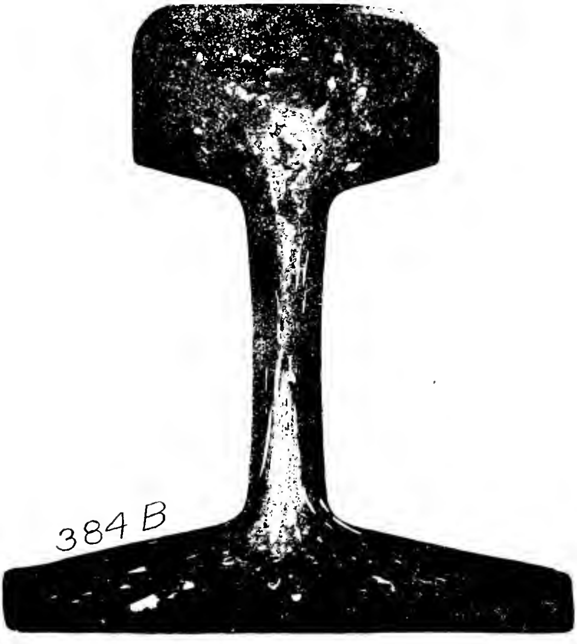


FIG. 384B. DEEP ETCHING OF RAIL 384.

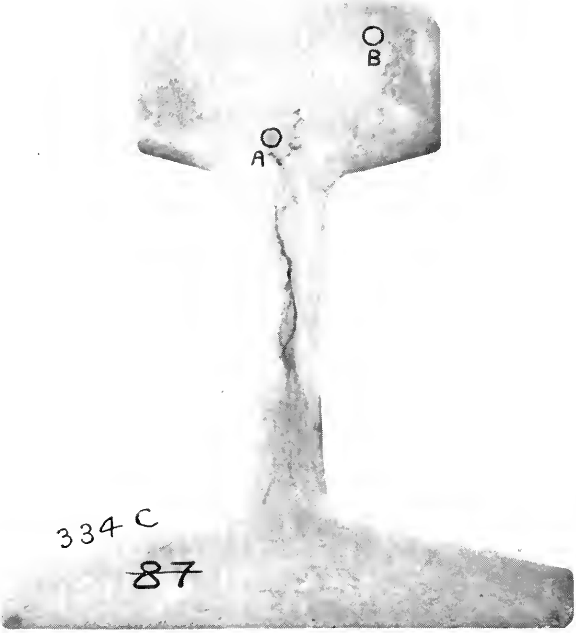


FIG. 384C. LIGHT ETCHING OF RAIL 384.

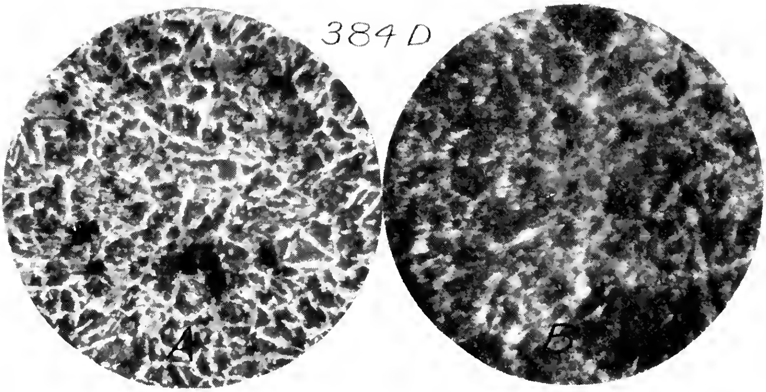
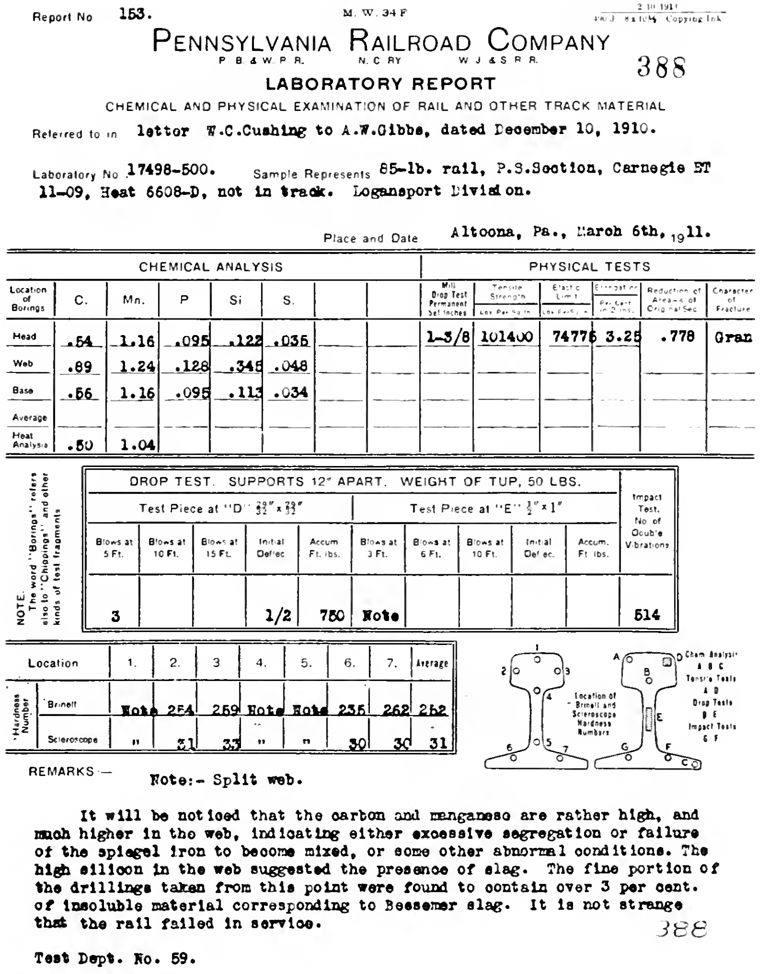


FIG. 384D. MICROPHOTOGRAPHS OF RAIL 384, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 384C.



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PENNSYLVANIA RAILROAD COMPANY

P. B. & W. R. R. N. C. RY. W. J. & S. R. R.

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LABORATORY REPORT

CHEMICAL AND PHYSICAL EXAMINATION OF RAIL AND OTHER TRACK MATERIAL

Referred to in letter W.C.Cushing to A.W.Gibbs, dated December 10, 1910.

Laboratory No. 17498-500. Sample Represents 85-lb. rail, P.S.Section, Carnegie ET 11-09, Heat 6608-D, not in track. Logansport Division.

Place and Date Altoona, Pa., March 6th, 1911.

CHEMICAL ANALYSIS								PHYSICAL TESTS					
Location of Borings	C.	Mn.	P	Si	S.			Mill Drop Test Permanent Set Inches	Tensile Strength Lbs. Per Sq. In.	Elastic Limit Lbs. Per Sq. In.	Elongation Per Cent in 2 ins.	Reduction of Area—% of Original Sec.	Character of Fracture
Head	.54	1.16	.095	.122	.035			1-3/8	101400	74775	3.25	.778	Gran
Web	.89	1.24	.128	.345	.048								
Base	.56	1.16	.095	.113	.034								
Average													
Heat Analysis	.50	1.04											

NOTE. The word "Borings" refers also to "Chippings" and other kinds of test fragments.

DROP TEST. SUPPORTS 12" APART. WEIGHT OF TUP, 50 LBS.										Impact Test. No. of Double Vibrations
Test Piece at "D" $\frac{29}{32}$" x $\frac{29}{32}$"					Test Piece at "E" $\frac{1}{2}$" x 1"					
Blows at 5 Ft.	Blows at 10 Ft.	Blows at 15 Ft.	Initial Deflec.	Accum. Ft. lbs.	Blows at 3 Ft.	Blows at 6 Ft.	Blows at 10 Ft.	Initial Deflec.	Accum. Ft. lbs.	
3			1/2	750	Note					514

Hardness Number	Location	1.	2.	3	4.	5.	6.	7.	Average
	Brinell	Note	254	259	Note	Note	235	262	252
	Scleroscope	"	31	33	"	"	30	30	31

1 2 3 4 5 6 7

Location of Brinell and Scleroscope Hardness Numbers

A B C D E F G

Chem Analysis A B C
Tensile Tests A D
Drop Tests D E
Impact Tests G F

REMARKS — Note:- Split web.

It will be noticed that the carbon and manganese are rather high, and much higher in the web, indicating either excessive segregation or failure of the spiegel iron to become mixed, or some other abnormal conditions. The high silicon in the web suggested the presence of slag. The fine portion of the drillings taken from this point were found to contain over 3 per cent. of insoluble material corresponding to Bessemer slag. It is not strange that the rail failed in service.

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Test Dept. No. 59.

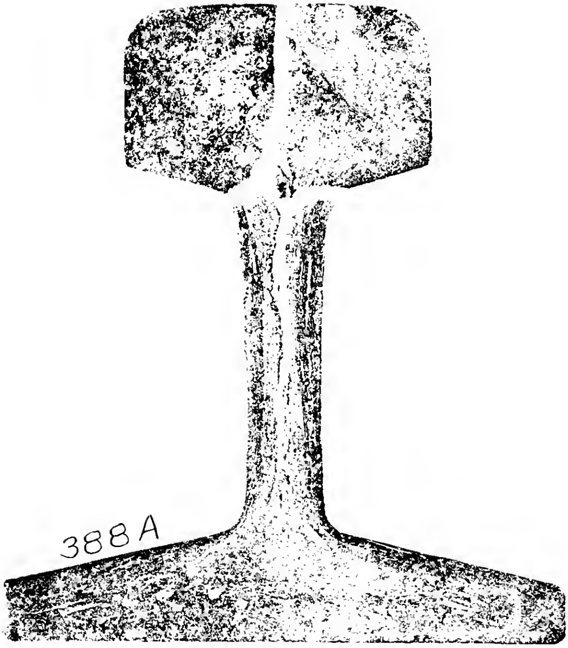


Fig. 388A.

Fig. 388A. Deep Etching of Rail 388.

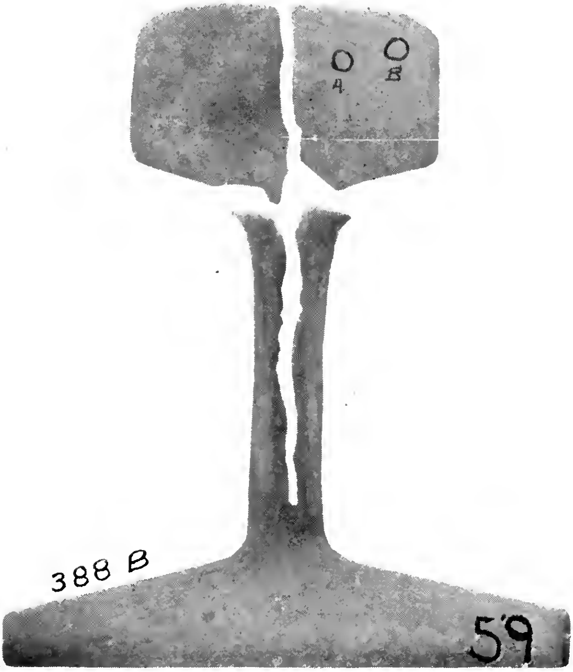


Fig. 388B. Light Etching of Rail 388.

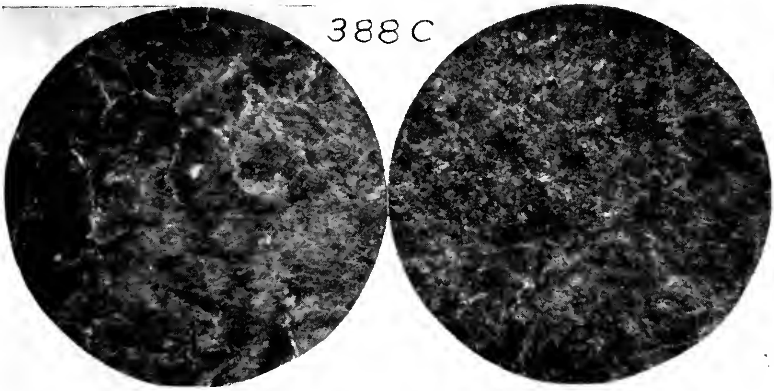


Fig. 388C. Microphotographs of Rail 388, Magnified 65 Diameters. Locations A and B on Fig. 388B.

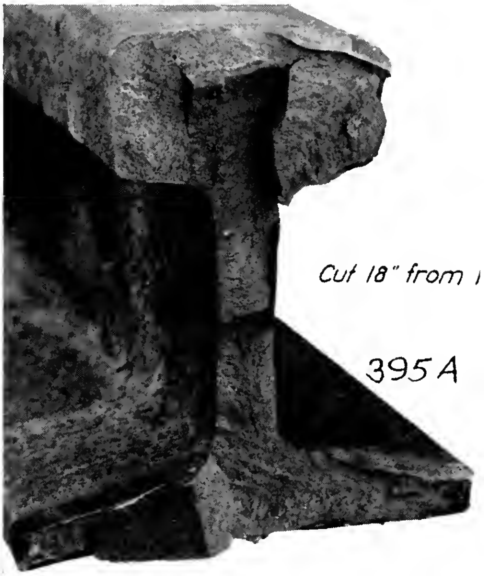


Fig. 395A. "Split Head" Rail 395.

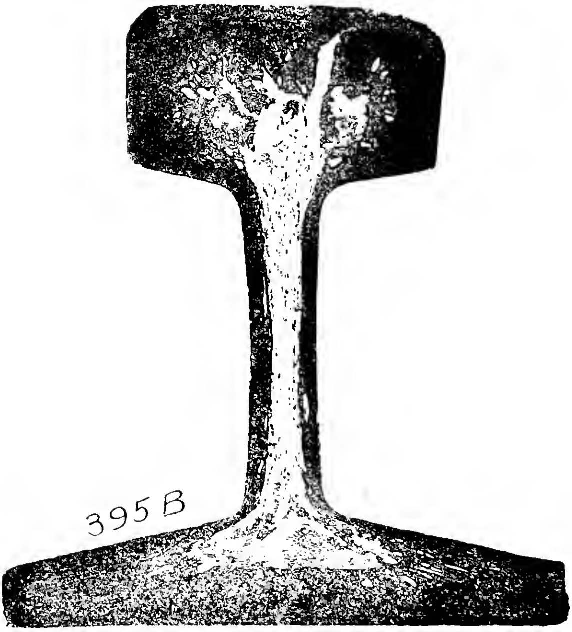


Fig. 395B. Deep Etching of Rail 395.

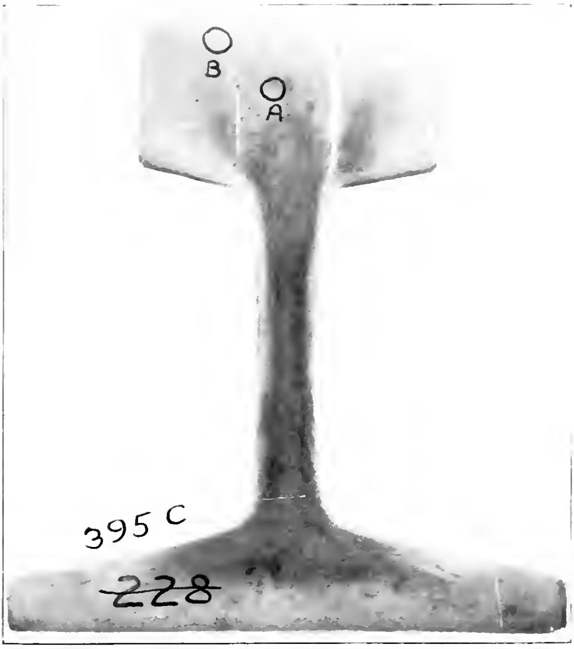


FIG. 395C. LIGHT ETCHING OF RAIL 395.

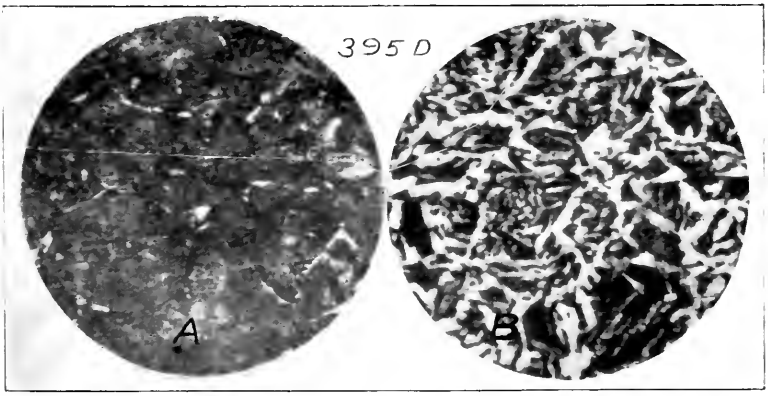


FIG. 395D. MICROPHOTOGRAPHS OF RAIL 395, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 395C.

FIG. 399A. "SPLIT HEAD" RAIL 399.

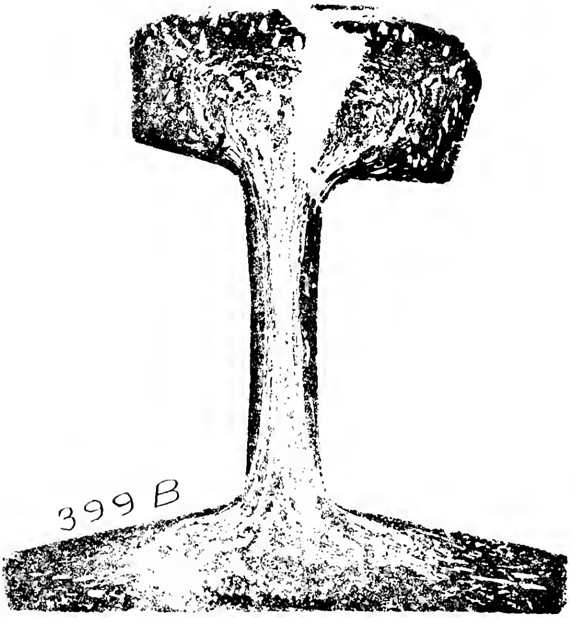


FIG. 399B. DEEP ETCHING OF RAIL 399.

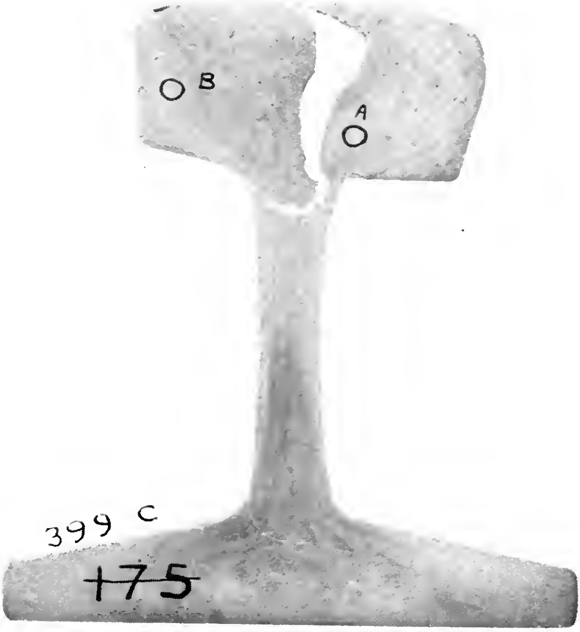


FIG. 399C. LIGHT ETCHING OF RAIL 399.

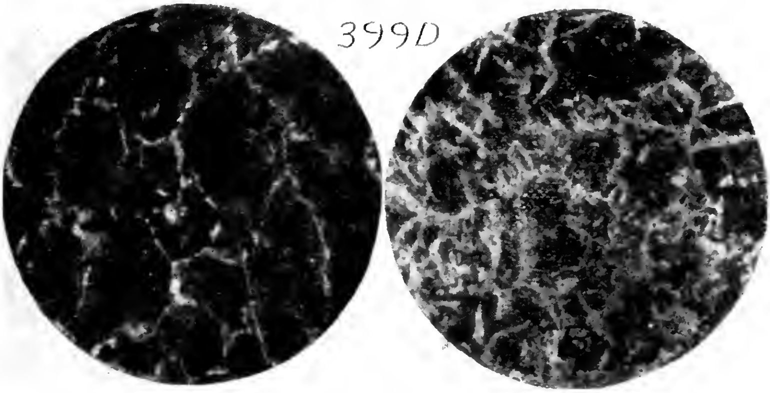


FIG. 399D. MICROPHOTOGRAPHS OF RAIL 399, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 399C.

FIG. 441A. "SPLIT HEAD" RAIL 441.

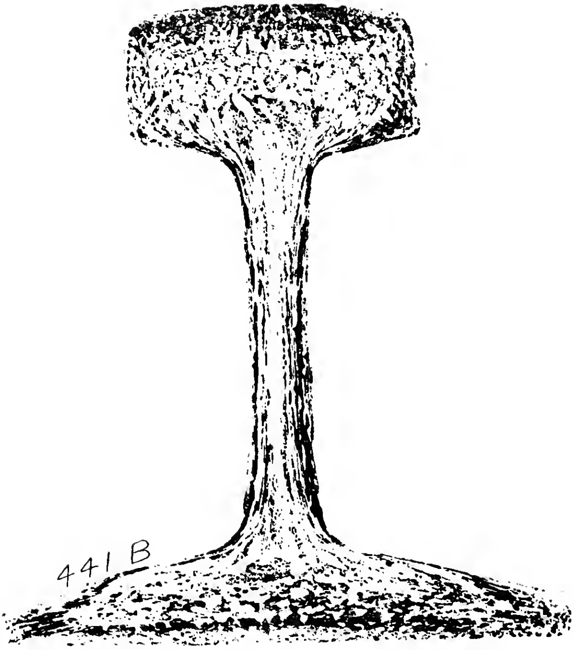


FIG. 441B. DEEP ETCHING OF RAIL 441.

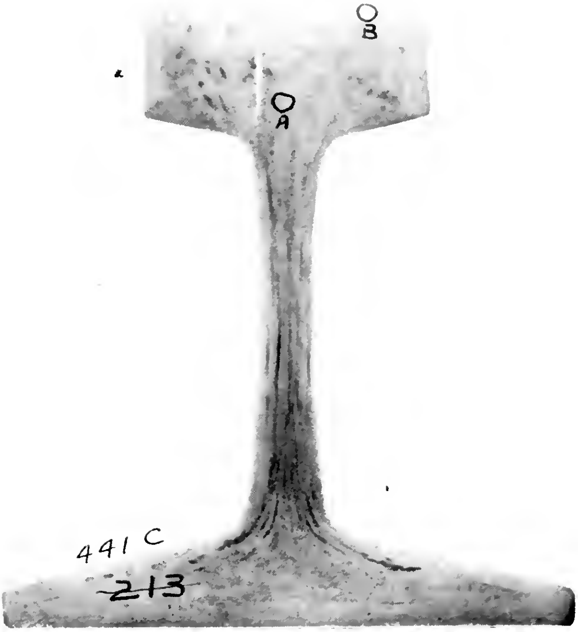


FIG. 441C. LIGHT ETCHING OF RAIL 441.

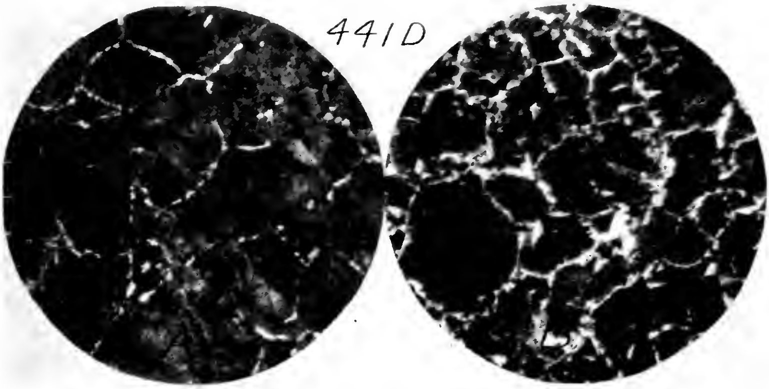
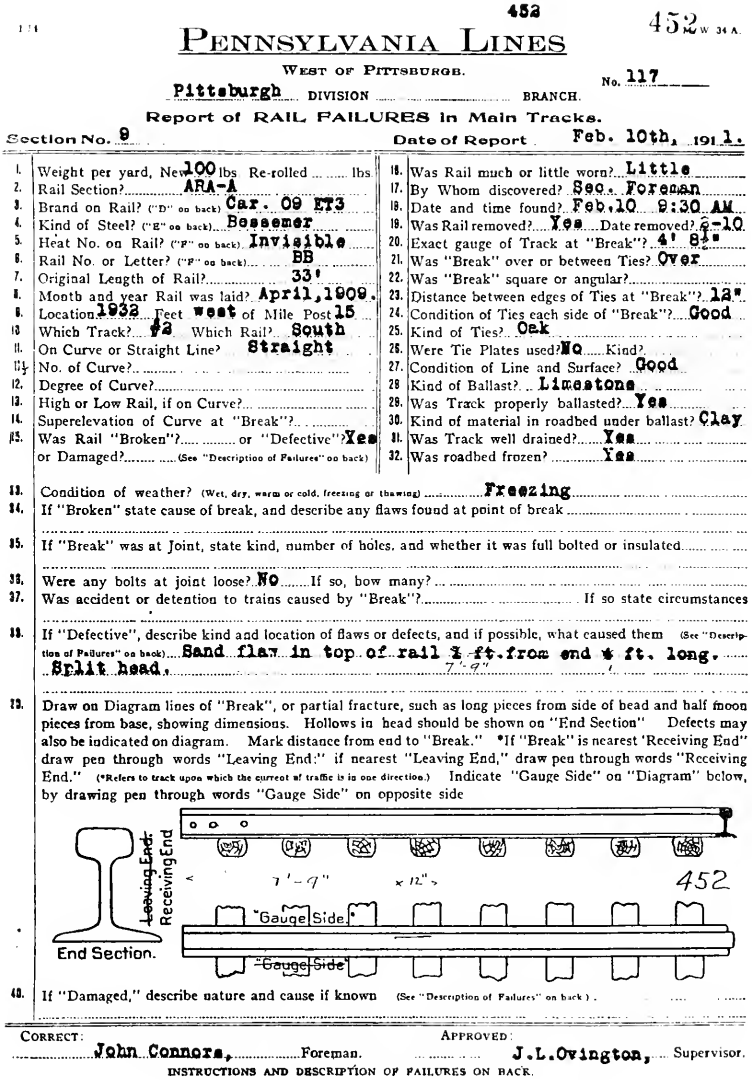


FIG. 441D. MICROPHOTOGRAPHS OF RAIL 441, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 441C.



1 14 452 452 M W 34 A.

PENNSYLVANIA LINES

WEST OF PITTSBURGH.

No. 117

Pittsburgh DIVISION .... BRANCH.

Report of RAIL FAILURES in Main Tracks.

Section No. 9 Date of Report Feb. 10th, 1911.

1. Weight per yard, New 100 lbs Re-rolled .... lbs.
2. Rail Section? ARA-A
3. Brand on Rail? ("D" on back) Car. 09 ET3
4. Kind of Steel? ("E" on back) Bessemer
5. Heat No. on Rail? ("F" on back) Invisible
6. Rail No. or Letter? ("F" on back) BB
7. Original Length of Rail? 33'
8. Month and year Rail was laid? April, 1909.
9. Location 1932 Feet west of Mile Post 15
10. Which Track? #2 Which Rail? South
11. On Curve or Straight Line? Straight
11½ No. of Curve? ....
12. Degree of Curve? ....
13. High or Low Rail, if on Curve? ....
14. Superelevation of Curve at "Break"? ....
15. Was Rail "Broken"? .... or "Defective"? Yes or Damaged? .... (See "Description of Failures" on back)

16. Was Rail much or little worn? Little
17. By Whom discovered? Sec. Foreman
18. Date and time found? Feb. 10 9:30 AM
19. Was Rail removed? Yes Date removed? 2-10
20. Exact gauge of Track at "Break"? 4' 8½"
21. Was "Break" over or between Ties? Over
22. Was "Break" square or angular? ....
23. Distance between edges of Ties at "Break"? 12"
24. Condition of Ties each side of "Break"? Good
25. Kind of Ties? Oak
26. Were Tie Plates used? No Kind? ....
27. Condition of Line and Surface? Good
28. Kind of Ballast? Limestone
29. Was Track properly ballasted? Yes
30. Kind of material in roadbed under ballast? Clay
31. Was Track well drained? Yes
32. Was roadbed frozen? Yes

33. Condition of weather? (Wet, dry, warm or cold, freezing or thawing) Freezing
34. If "Broken" state cause of break, and describe any flaws found at point of break ....
35. If "Break" was at Joint, state kind, number of holes, and whether it was full bolted or insulated ....
36. Were any bolts at joint loose? No If so, how many? ....
37. Was accident or detention to trains caused by "Break"? .... If so state circumstances ....
38. If "Defective", describe kind and location of flaws or defects, and if possible, what caused them (See "Description of Failures" on back) Sand flaw in top of rail ~~1 ft.~~ from end ~~1~~ ft. long.
Split head. 7'-9"
39. Draw on Diagram lines of "Break", or partial fracture, such as long pieces from side of head and half moon pieces from base, showing dimensions. Hollows in head should be shown on "End Section" Defects may also be indicated on diagram. Mark distance from end to "Break." *If "Break" is nearest 'Receiving End" draw pen through words "Leaving End;" if nearest "Leaving End," draw pen through words "Receiving End." (*Refers to track upon which the current of traffic is in one direction.) Indicate "Gauge Side" on "Diagram" below, by drawing pen through words "Gauge Side" on opposite side

40. If "Damaged," describe nature and cause if known (See "Description of Failures" on back) ....

CORRECT: APPROVED:

John Connors, Foreman. J. L. Ovington, Supervisor.

INSTRUCTIONS AND DESCRIPTION OF FAILURES ON BACK.

Report No. 261 M. W. 34 F. 2 10 1913
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PENNSYLVANIA RAILROAD COMPANY

P., B. & W. R. R. N. C. RY W. J. & S. R. R.

LABORATORY REPORT

CHEMICAL AND PHYSICAL EXAMINATION OF RAIL AND OTHER TRACK MATERIAL

Referred to in letter W.C.Cushing to A.W.Gibbs, dated Feb. 18, 1911.

Laboratory No. 18843-5. Sample Represents rail which failed 1932 ft. west of M.P. 15, Pgh. Div., 2-10-11. (100 lb. rail, A.R.A.Sec. Carnegie E.T. 3-09, Heat No. 6719-BB.) Laid April, 1909.

Place and Date Altoona, Pa., May 19, 1911.

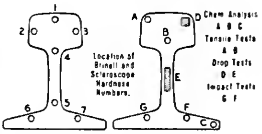
CHEMICAL ANALYSIS								PHYSICAL TESTS					
Location of Borings	C.	Mn.	P	Si.	S.			Mill Drop Test Permanent Set-Inches	Tensile Strength Lbs Per Sq in	Elastic Limit Lbs Per Sq in	Elongation Per Cent. in 2 ins.	Reduction of Area—% of Original Sec	Character of Fracture
Head	.52	0.95	.084	.066	.037				119100	66600	18	28.6	S&G
Web	.62	1.00	.128	.066	.065								
Base	.54	0.97	.094	.066	.048								
Average	.56	0.97	.102	.066	.050								
Heat Analysis													

NOTE
The word ''Borings'' refers also to ''Chippings'' and other kinds of test fragments

DROP TEST. SUPPORTS 12" APART WEIGHT OF TUP, 50 LBS.										Impact Test. No. of Double Vibrations
Test Piece at "D" $\frac{29}{32}$"×$\frac{29}{32}$"					Test Piece at "E" $\frac{1}{2}$"×1"					
Blows at 5 Ft.	Blows at 10 Ft.	Blows at 15 Ft.	Initial Deflec	Accum. Ft. lbs	Blows at 3 Ft.	Blows at 6 Ft.	Blows at 10 Ft.	Initial Deflec.	Accum. Ft. lbs.	
5	1		9/16"	1750	5	5	37	1-1/4"	20750	649

452

Location		1	2	3.	4	5	6.	7	Average
Hardness Number	Brinell	241	235	238	272	249	227	238	243
	Scleroscope	21	18	19	21	22	18	18	19



REMARKS —

A badly segregated rail. The deep etching test shows a structure frequently found in split head rails. The hardness is irregular and very high at point 4.

Test Dept. No. 164.

Fig. 452A. "Split Head" Rail 452.

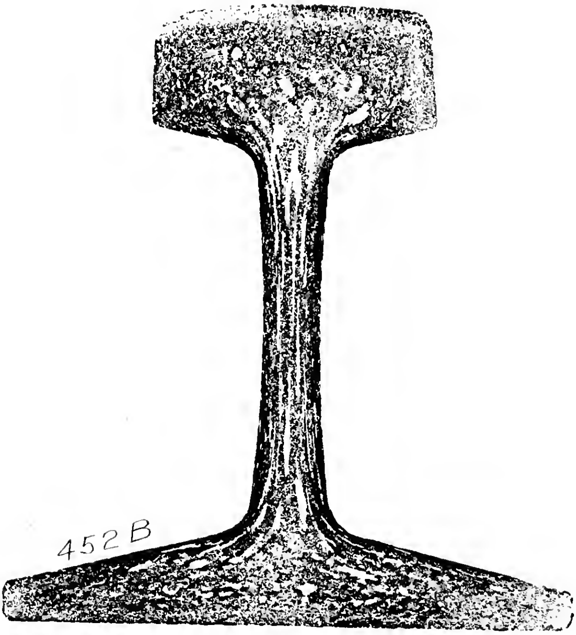


Fig. 452B. Deep Etching of Rail 452.

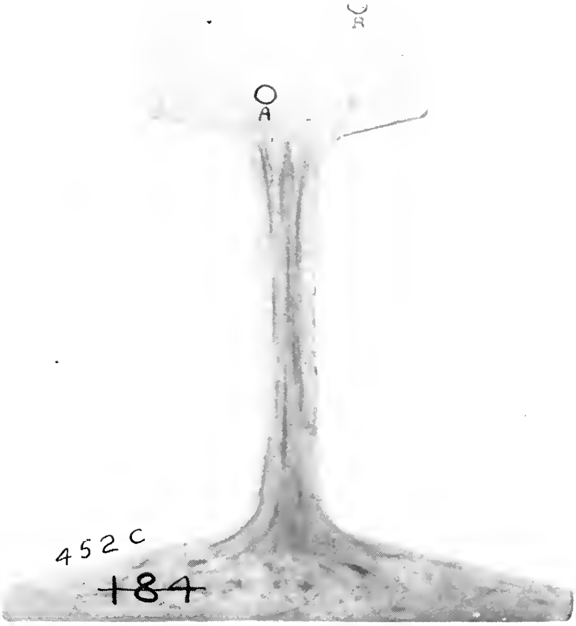


FIG. 452C. LIGHT ETCHING OF RAIL 452.

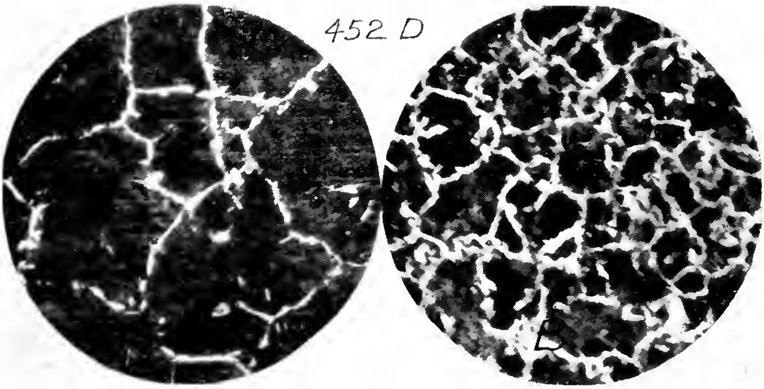
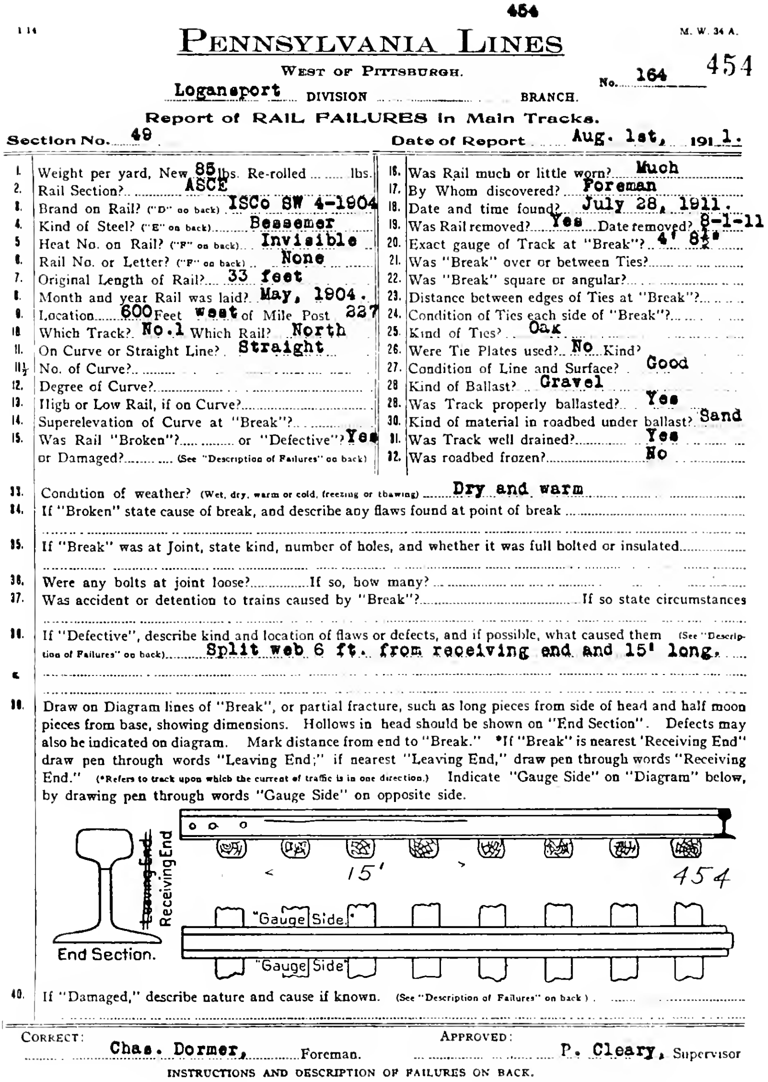


FIG. 452D. MICROPHOTOGRAPHS OF RAIL 452, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 452C.



454

1 14

M. W. 34 A.

PENNSYLVANIA LINES

WEST OF PITTSBURGH.

No. 164 454

Logansport DIVISION .... BRANCH.

Report of RAIL FAILURES in Main Tracks.

Section No. 49 Date of Report Aug. 1st, 1911.

1. Weight per yard, New 85 lbs. Re-rolled .... lbs.
2. Rail Section? ASCE
3. Brand on Rail? ("D" on back) ISCo SW 4-1904
4. Kind of Steel? ("E" on back) Bessemer
5. Heat No. on Rail? ("F" on back) Invisible
6. Rail No. or Letter? ("F" on back) None
7. Original Length of Rail? 33 feet
8. Month and year Rail was laid? May, 1904.
9. Location 600 Feet west of Mile Post 227
10. Which Track? No.1 Which Rail? North
11. On Curve or Straight Line? Straight
11½. No. of Curve? ....
12. Degree of Curve? ....
13. High or Low Rail, if on Curve? ....
14. Superelevation of Curve at "Break"? ....
15. Was Rail "Broken"? .... or "Defective"? Yes or Damaged? .... (See "Description of Failures" on back)
16. Was Rail much or little worn? Much
17. By Whom discovered? Foreman
18. Date and time found? July 28, 1911.
19. Was Rail removed? Yes Date removed? 8-1-11
20. Exact gauge of Track at "Break"? 4' 8½"
21. Was "Break" over or between Ties? ....
22. Was "Break" square or angular? ....
23. Distance between edges of Ties at "Break"? ....
24. Condition of Ties each side of "Break"? ....
25. Kind of Ties? Oak
26. Were Tie Plates used? No Kind?
27. Condition of Line and Surface? Good
28. Kind of Ballast? Gravel
29. Was Track properly ballasted? Yes
30. Kind of material in roadbed under ballast? Sand
31. Was Track well drained? Yes
32. Was roadbed frozen? No
33. Condition of weather? (Wet, dry, warm or cold, freezing or thawing) Dry and warm
34. If "Broken" state cause of break, and describe any flaws found at point of break ....
35. If "Break" was at Joint, state kind, number of holes, and whether it was full bolted or insulated ....
36. Were any bolts at joint loose? .... If so, how many? ....
37. Was accident or detention to trains caused by "Break"? .... If so state circumstances ....
38. If "Defective", describe kind and location of flaws or defects, and if possible, what caused them (See "Description of Failures" on back) Split web 6 ft. from receiving end and 15' long.
39. Draw on Diagram lines of "Break", or partial fracture, such as long pieces from side of head and half moon pieces from base, showing dimensions. Hollows in head should be shown on "End Section". Defects may also be indicated on diagram. Mark distance from end to "Break." *If "Break" is nearest 'Receiving End" draw pen through words "Leaving End;" if nearest "Leaving End," draw pen through words "Receiving End." (*Refers to track upon which the current of traffic is in one direction.) Indicate "Gauge Side" on "Diagram" below, by drawing pen through words "Gauge Side" on opposite side.

~~Leaving End~~

Receiving End

< 15' >

454

"Gauge Side."

"Gauge Side"

End Section.

40. If "Damaged," describe nature and cause if known. (See "Description of Failures" on back) ....

CORRECT: Chas. Dormer, Foreman.

APPROVED: P. Cleary, Supervisor

INSTRUCTIONS AND DESCRIPTION OF FAILURES ON BACK.

Fig. 454A. "Split Head" Rail 454.

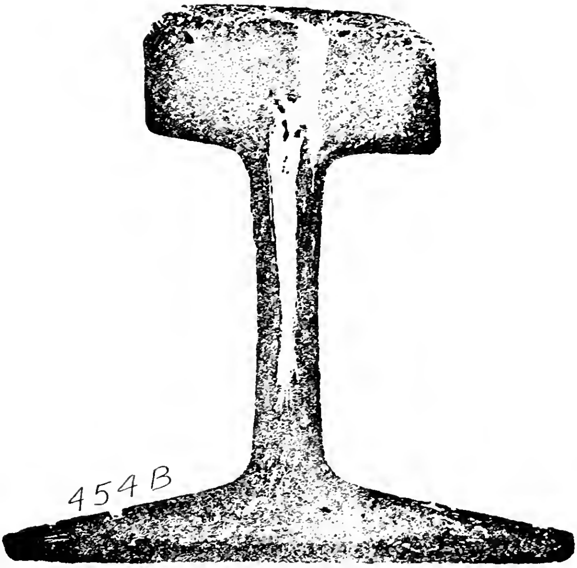


Fig. 454B. Deep Etching of Rail 454.

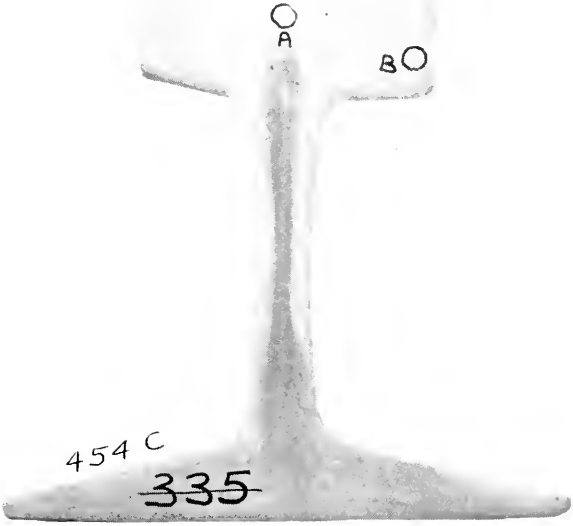


Fig. 454C. Light Etching of Rail 454.

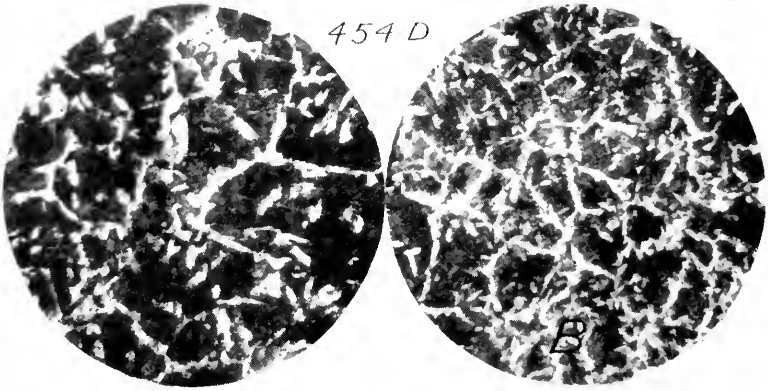
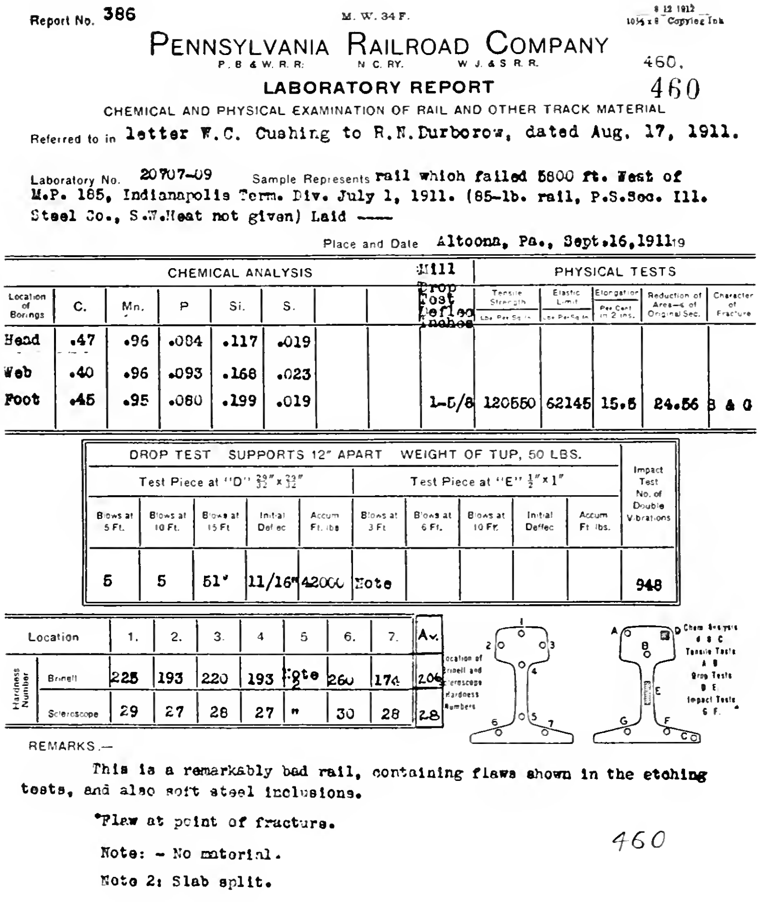


Fig. 454D. Microphotographs of Rail 454, Magnified 65 Diameters. Locations A and B on Fig. 454C.



Report No. 386 M. W. 34 F. 8 12 1912 10½ x 8 Copying Ink

PENNSYLVANIA RAILROAD COMPANY

P. B & W. R. R. N. C. RY. W. J. & S. R. R. 460.

LABORATORY REPORT 460

CHEMICAL AND PHYSICAL EXAMINATION OF RAIL AND OTHER TRACK MATERIAL

Referred to in letter W.C. Cushing to R.N.Durborow, dated Aug. 17, 1911.

Laboratory No. 20707-09 Sample Represents rail which failed 5800 ft. West of M.P. 185, Indianapolis Term. Div. July 1, 1911. (85-lb. rail, P.S.Sec. Ill. Steel Co., S.W.Heat not given) Laid ----

Place and Date Altoona, Pa., Sept.16,1911 19

CHEMICAL ANALYSIS								Mill	PHYSICAL TESTS				
Location of Borings	C.	Mn.	P	Si.	S.			Drop Test Deflec Inches	Tensile Strength Lbs. Per Sq. In.	Elastic Limit Lbs. Per Sq. In.	Elongation Per Cent in 2 ins.	Reduction of Area—% of Original Sec.	Character of Fracture
Head	.47	.96	.084	.117	.019								
Web	.40	.96	.093	.168	.023								
Foot	.45	.95	.080	.199	.019			1-5/8	120550	62145	15.5	24.56	S & C

DROP TEST SUPPORTS 12″ APART WEIGHT OF TUP, 50 LBS.

Test Piece at "D" $\frac{29}{32}''\times\frac{29}{32}''$					Test Piece at "E" $\frac{1}{2}''\times1''$					Impact Test No. of Double Vibrations
Blows at 5 Ft.	Blows at 10 Ft.	Blows at 15 Ft.	Initial Deflec	Accum Ft. lbs	Blows at 3 Ft.	Blows at 6 Ft.	Blows at 10 Ft.	Initial Deflec	Accum Ft. lbs.	
5	5	51*	11/16"	42000	Note					948

Hardness Number	Location	1.	2.	3.	4	5	6.	7.	Av.
	Brinell	225	193	220	193	Note 2	260	174	206
	Scleroscope	29	27	28	27	"	30	28	28

REMARKS.—

This is a remarkably bad rail, containing flaws shown in the etching tests, and also soft steel inclusions.

*Flaw at point of fracture.

Note: - No material.

Note 2: Slab split.

460

Fig. 460A. "Split Head" Rail 460.

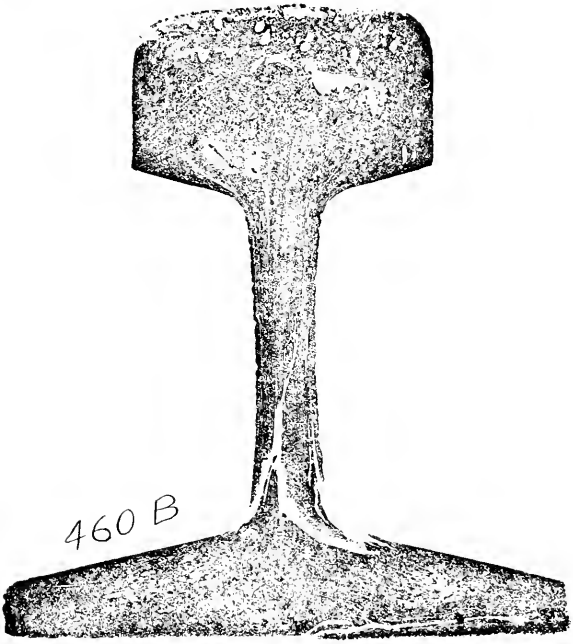


Fig. 460B. Deep Etching of Rail 460.
View showing scrap steel embedded.

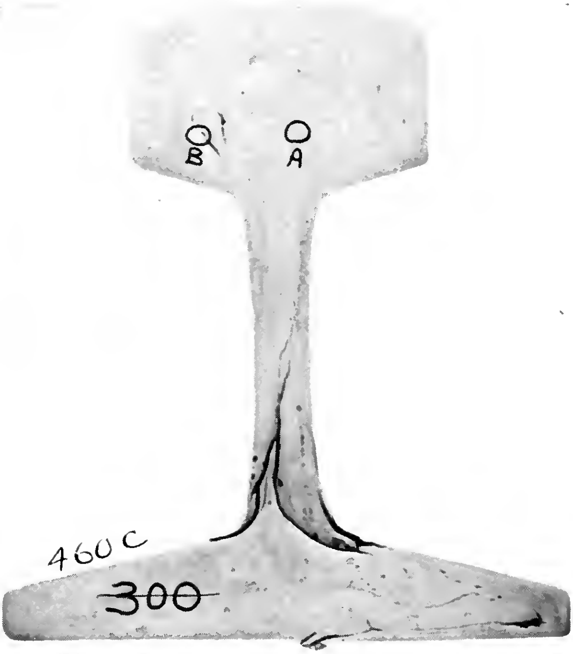


FIG. 460C. LIGHT ETCHING OF RAIL 460.

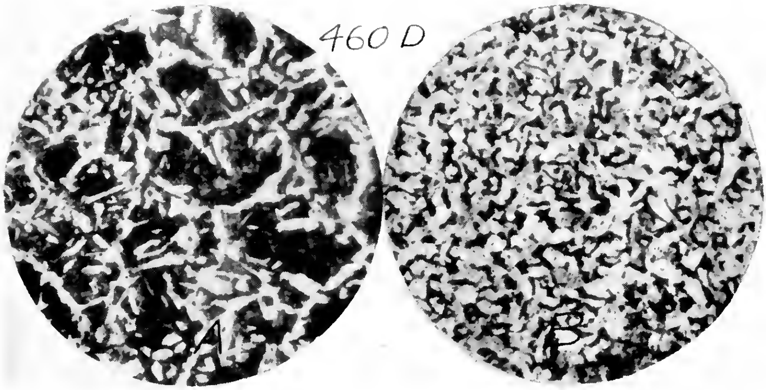


FIG. 460D. MICROPHOTOGRAPHS OF RAIL 460, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 460C.

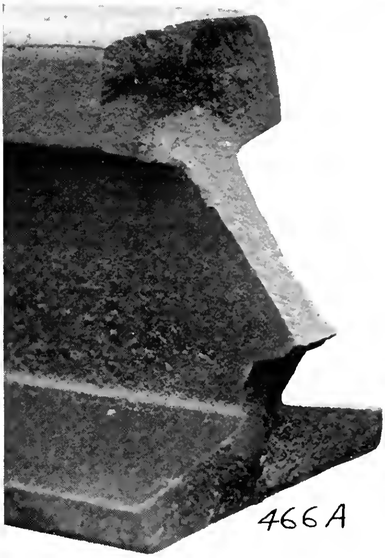


Fig. 466A. "Split Head" Rail 466.

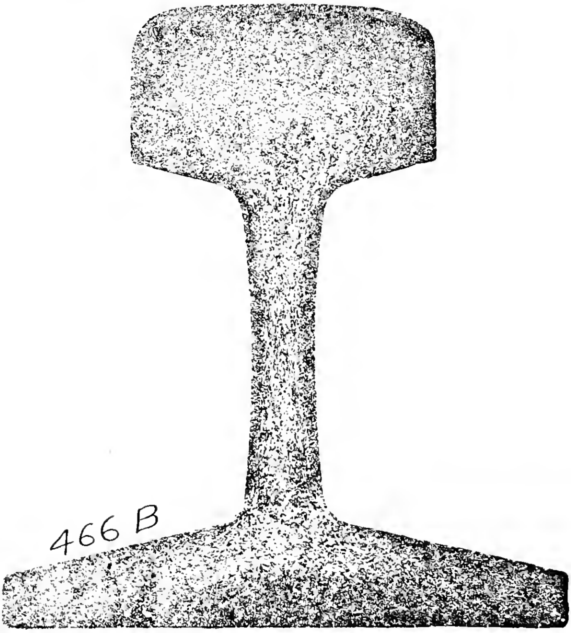


Fig. 466B. Deep Etching of Rail 466.

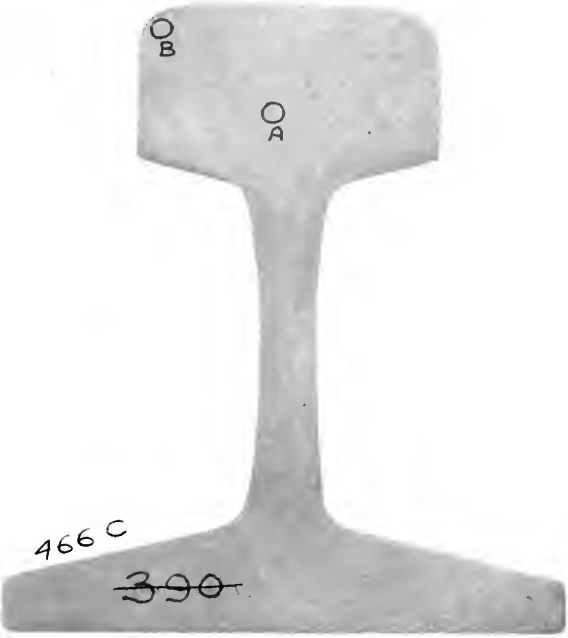


Fig. 466C. Light Etching of Rail 466.

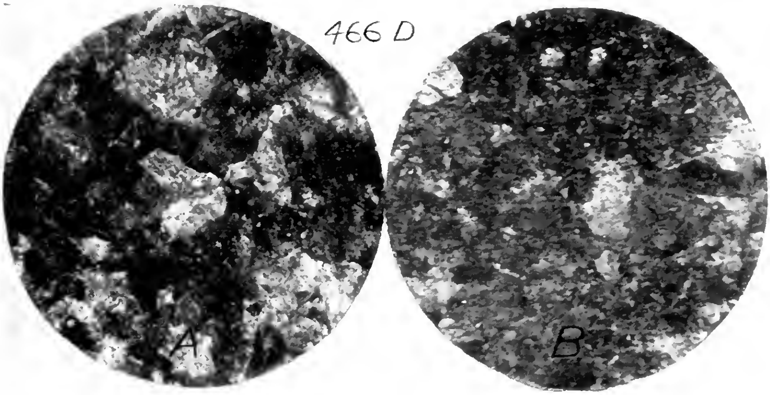


Fig. 466D. Microphotographs of Rail 466, Magnified 65 Diameters. Locations A and B on Fig. 466C.

Fig. 505A. "Broken Base" Rail 505.

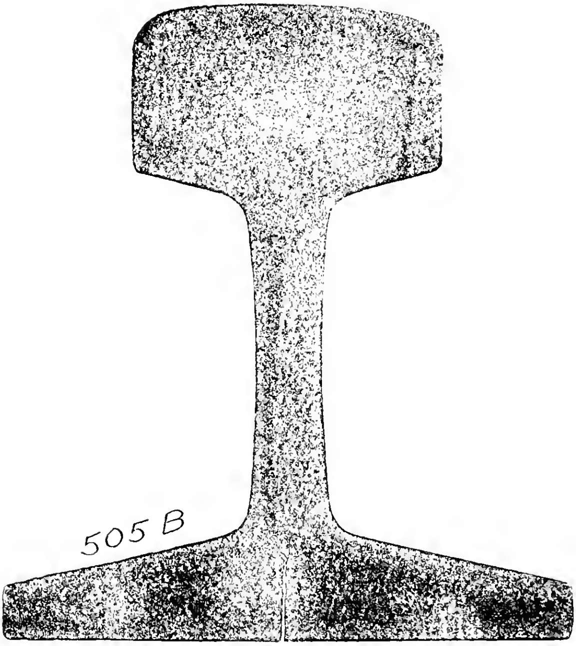


Fig. 505B. Deep Etching of Rail 505.

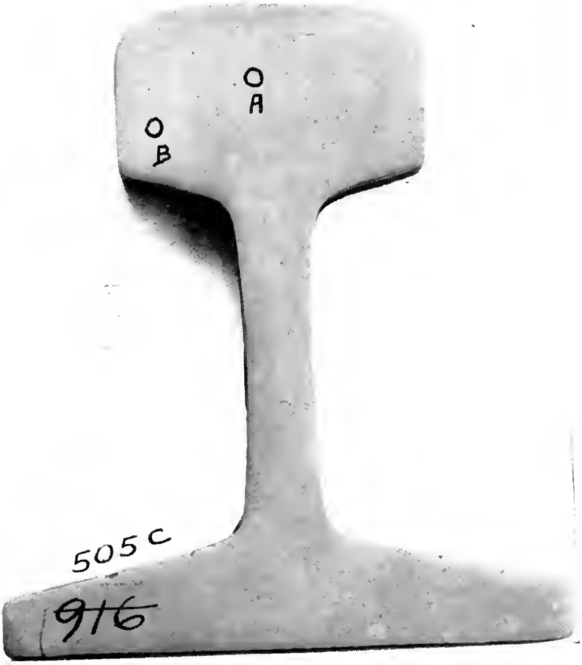


FIG. 505C. LIGHT ETCHING OF RAIL 505.

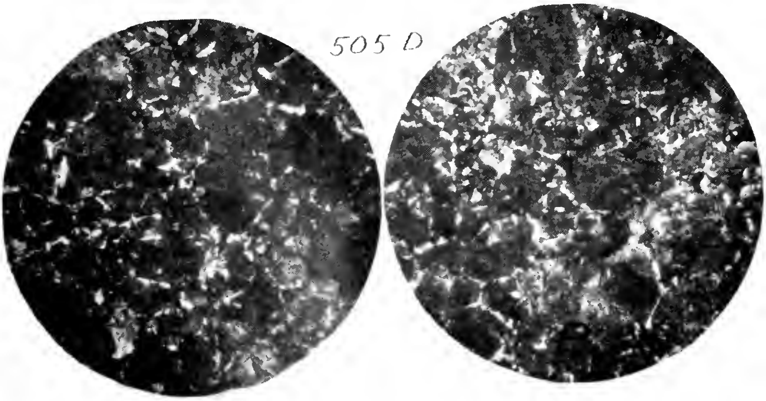


FIG. 505D. MICROPHOTOGRAPHS OF RAIL 505, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 505C.

Report No. **1156.** M. W. 34 F.

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T.D.No.1051.

PENNSYLVANIA RAILROAD COMPANY

P., B. & W. R. R. N. C. RY. W. J. & S. R. R.

LABORATORY REPORT 522

CHEMICAL AND PHYSICAL EXAMINATION OF RAIL AND OTHER TRACK MATERIAL

Referred to in W.O.Cushing's letter of 11-4-12 to J.T.Wallis.

Laboratory No. 28961-2-3 Sample Represents 100-lb. rail from C.T.Div. Canal St. Curve. 8-24-12. P.S.Sec. Ill.S.Co. Gary Wks. 2-10. Heat No. 1805. Split head.

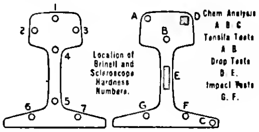
Place and Date Altoona, Pa., December 5, 1912.

CHEMICAL ANALYSIS								PHYSICAL TESTS					
Location of Borings	C	Mn.	P	Si.	S.			Mill Drop Test Permanent Set-Inches	Tensile Strength Lbs Per Sq In	Elastic Limit Lbs Per Sq In	Elongation Per Cent in 2 ins.	Reduction of Area—% of Original Sec.	Character of Fracture
Head	.67	.60	.019	.127	.030				90600	42278	14	17.7	G&S
Web	.66	.60	.024	.118	.034						Note A		
Base	.69	.60	.018	.122	.031								
Average	.67	.60	.019	.122	.032								
Heat Analysis													

NOTE The word "Borings" refers also to "Chippings" and other kinds of test fragments

DROP TEST SUPPORTS 12″ APART WEIGHT OF TUP, 50 LBS.										Impact Test, No. of Double Vibrations
Test Piece at "D" $\frac{29}{32}$″ x $\frac{29}{32}$″					Test Piece at "E" ½″ x 1″					
Blows at 5 Ft.	Blows at 10 Ft.	Blows at 15 Ft.	Initial Deflec.	Accum. Ft. lbs	Blows at 3 Ft.	Blows at 6 Ft.	Blows at 10 Ft.	Initial Deflec.	Accum. Ft. lbs.	
5	5	34	5/8	29250	Note:					703

Location		1	2	3.	4	5.	6.	7	Average
Hardness Number	Brinell	210	206	181	206	210	212	216	206
	Scleroscope	33	34	31	33	33	32	34	33



REMARKS— Note: No Material.
Note A: One tensile sample split at fracture.

522

A split head failure due to an inclusion of soft steel, the location of which is evident in the etching tests.

FIG. 522A. "FLOW OF METAL" RAIL 522.

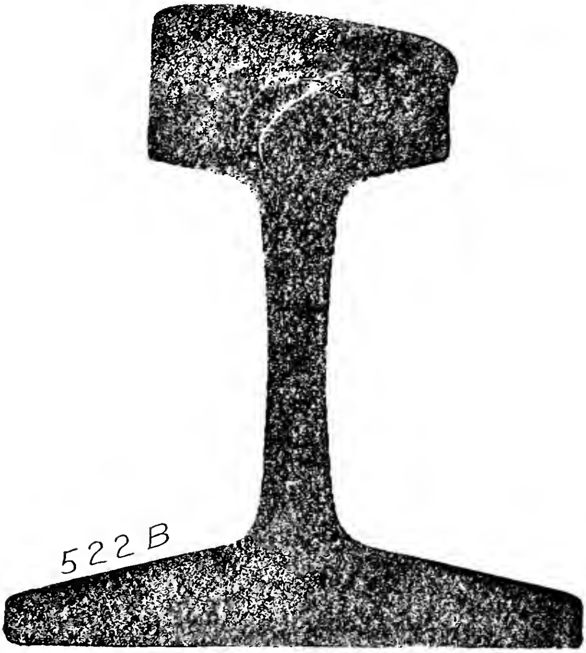


FIG. 522B. DEEP ETCHING OF RAIL 522.

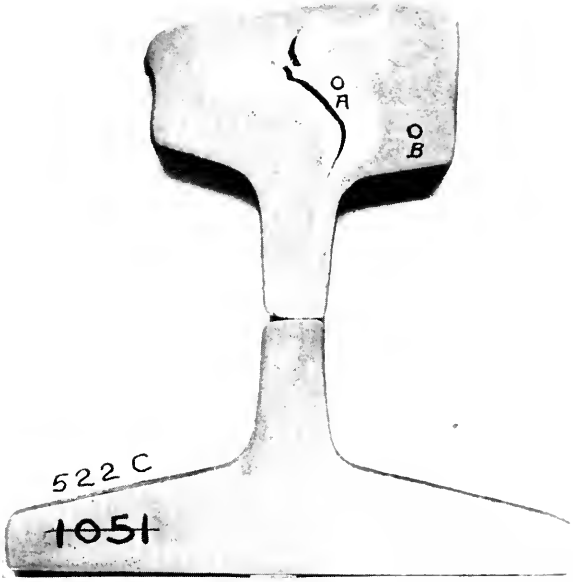


FIG. 522C. LIGHT ETCHING OF RAIL 522.
View showing scrap tie-plate in head.

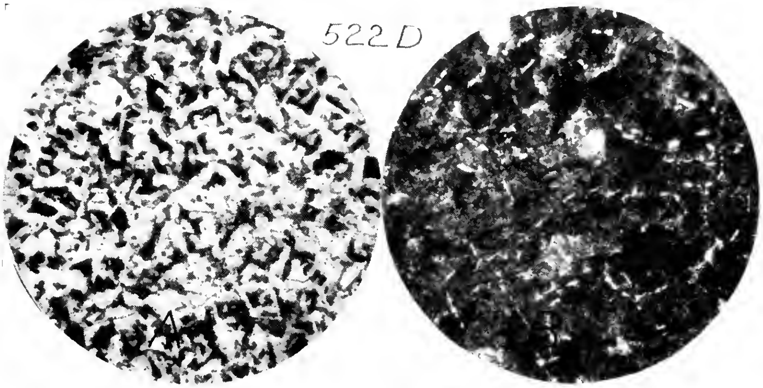


FIG. 522D. MICROPHOTOGRAPHS OF RAIL 522, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 522C.

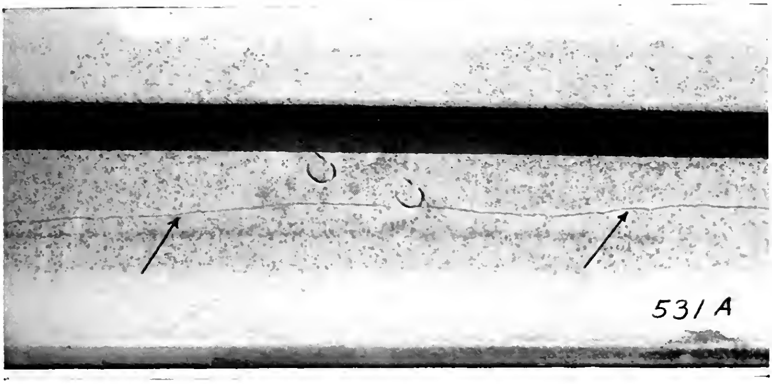


FIG. 531A. "SPLIT WEB" RAIL 531.

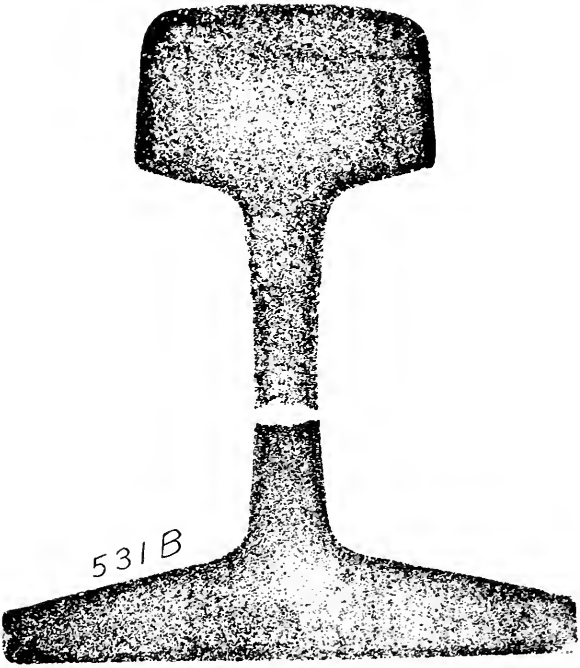


FIG. 531B. DEEP ETCHING OF RAIL 531.

FIG. 531C. LIGHT ETCHING OF RAIL 531.

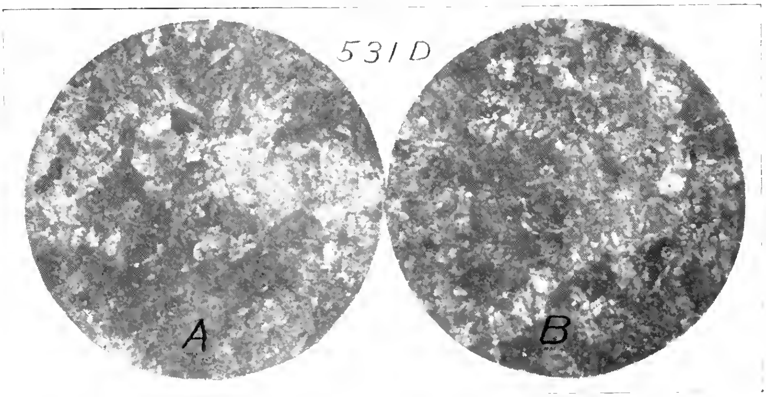
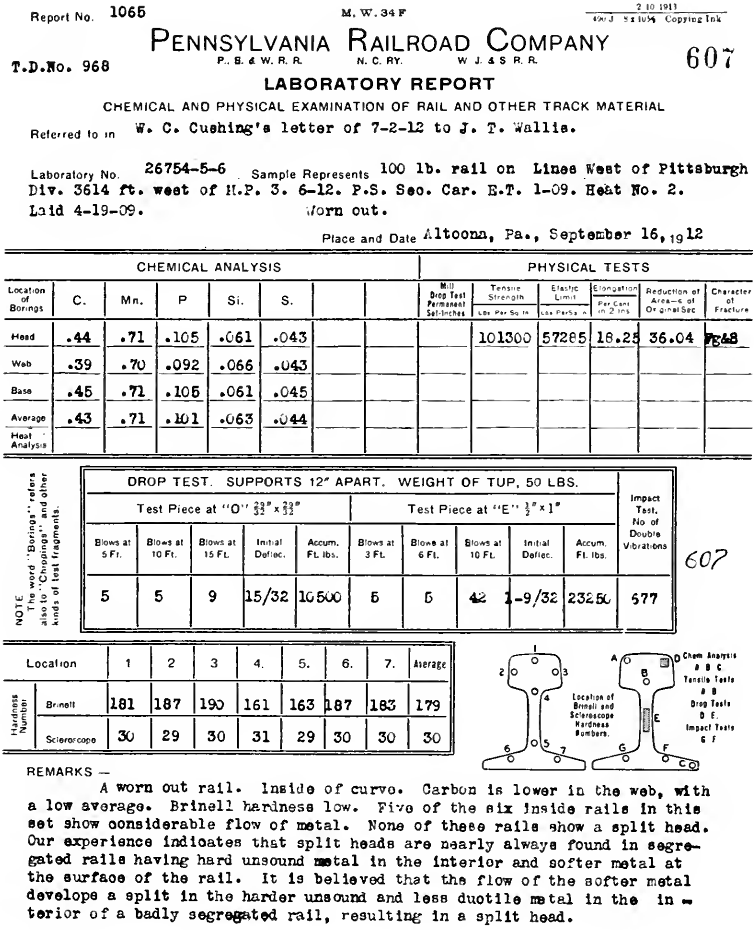


FIG. 531D. MICROPHOTOGRAPHS OF RAIL 531, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 531C.



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PENNSYLVANIA RAILROAD COMPANY

T.D.No. 968 P., B. & W. R. R. N. C. RY. W. J. & S. R. R. 607

LABORATORY REPORT

CHEMICAL AND PHYSICAL EXAMINATION OF RAIL AND OTHER TRACK MATERIAL

Referred to in W. C. Cushing's letter of 7-2-12 to J. T. Wallis.

Laboratory No. 26754-5-6 Sample Represents 100 lb. rail on Lines West of Pittsburgh Div. 3614 ft. west of M.P. 3. 6-12. P.S. Sec. Car. E.T. 1-09. Heat No. 2. Laid 4-19-09. Worn out.

Place and Date Altoona, Pa., September 16, 1912

CHEMICAL ANALYSIS								PHYSICAL TESTS					
Location of Borings	C.	Mn.	P	Si.	S.			Mill Drop Test Permanent Set-Inches	Tensile Strength Lbs Per Sq In	Elastic Limit Lbs Per Sq In	Elongation Per Cent in 2 Ins	Reduction of Area—% of Original Sec	Character of Fracture
Head	.44	.71	.105	.061	.043				101300	57285	18.25	36.04	Fg&8
Web	.39	.70	.092	.066	.043								
Base	.45	.71	.105	.061	.045								
Average	.43	.71	.101	.063	.044								
Heat Analysis													

NOTE
The word ''Borings'' refers also to ''Chippings'' and other kinds of test fragments.

DROP TEST. SUPPORTS 12″ APART. WEIGHT OF TUP, 50 LBS.										
Test Piece at ''O'' $\frac{29}{32}$″ x $\frac{29}{32}$″					Test Piece at ''E'' ½″ x 1″					Impact Test. No of Double Vibrations
Blows at 5 Ft.	Blows at 10 Ft.	Blows at 15 Ft.	Initial Deflec.	Accum. Ft. lbs.	Blows at 3 Ft.	Blows at 6 Ft.	Blows at 10 Ft.	Initial Deflec.	Accum. Ft. lbs.	
5	5	9	15/32	10500	5	5	42	1-9/32	23250	577

607

Location		1	2	3	4.	5.	6.	7.	Average
Hardness Number	Brinell	181	187	190	161	163	187	183	179
	Scleroscope	30	29	30	31	29	30	30	30

REMARKS —

A worn out rail. Inside of curve. Carbon is lower in the web, with a low average. Brinell hardness low. Five of the six inside rails in this set show considerable flow of metal. None of these rails show a split head. Our experience indicates that split heads are nearly always found in segregated rails having hard unsound metal in the interior and softer metal at the surface of the rail. It is believed that the flow of the softer metal develops a split in the harder unsound and less ductile metal in the interior of a badly segregated rail, resulting in a split head.

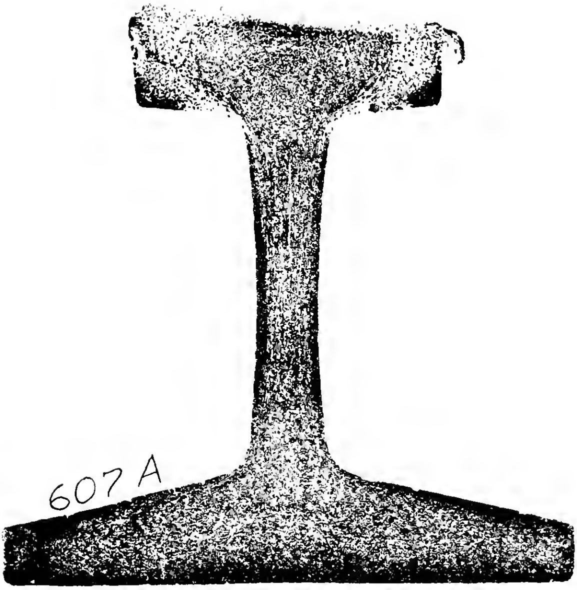


Fig. 607A. Deep Etching of Rail 607.

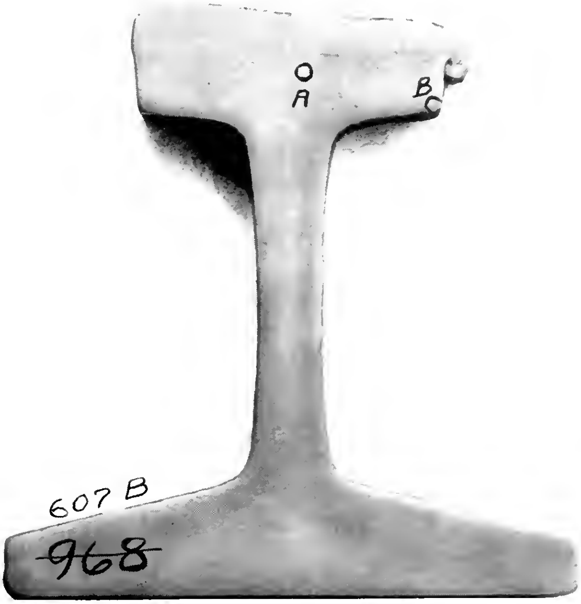


FIG. 607B. LIGHT ETCHING OF RAIL 607.

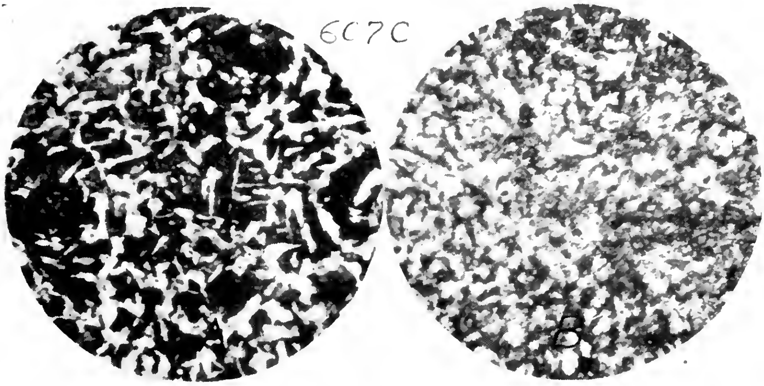


FIG. 607C. MICROPHOTOGRAPHS OF RAIL 607, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 607B.

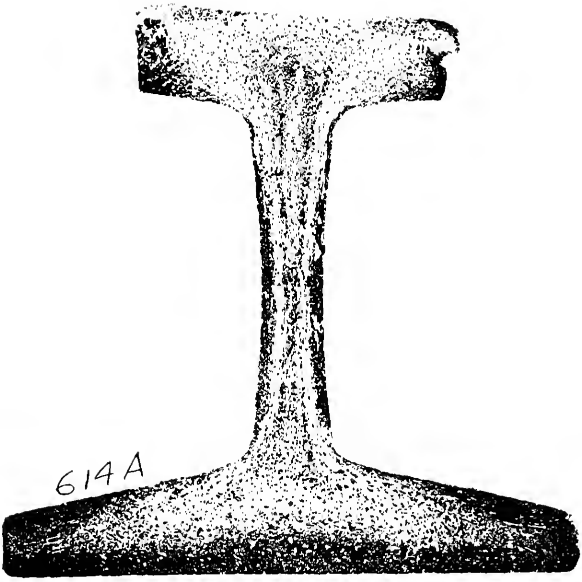


Fig. 614A. Deep Etching of Rail 614.

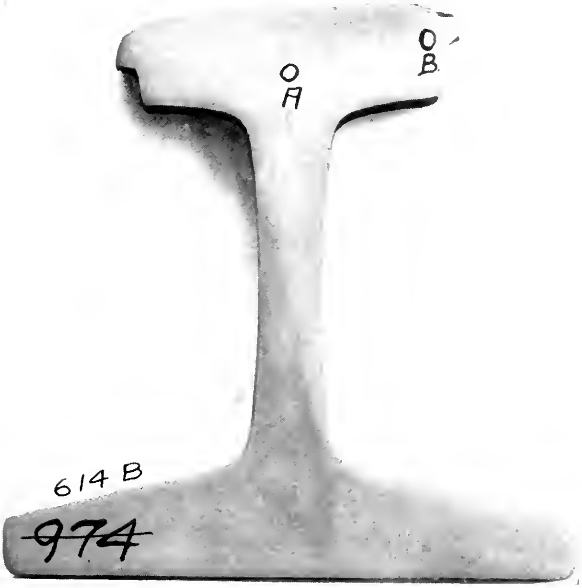


Fig. 614B. Light Etching of Rail 614.

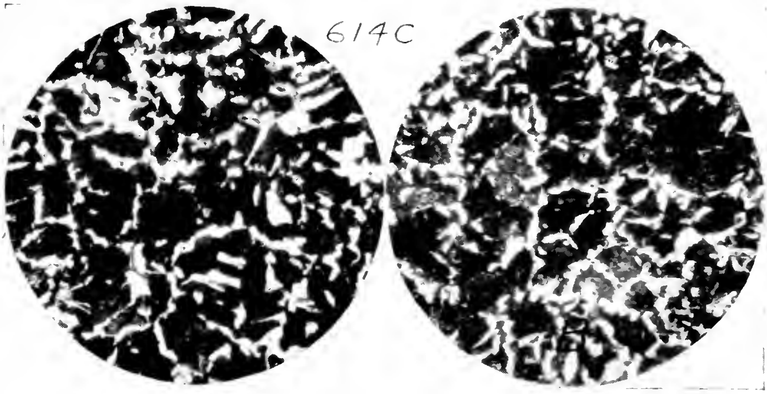


Fig. 614C. Microphotographs of Rail 614, Magnified 65 Diameters. Locations A and B on Fig. 614B.

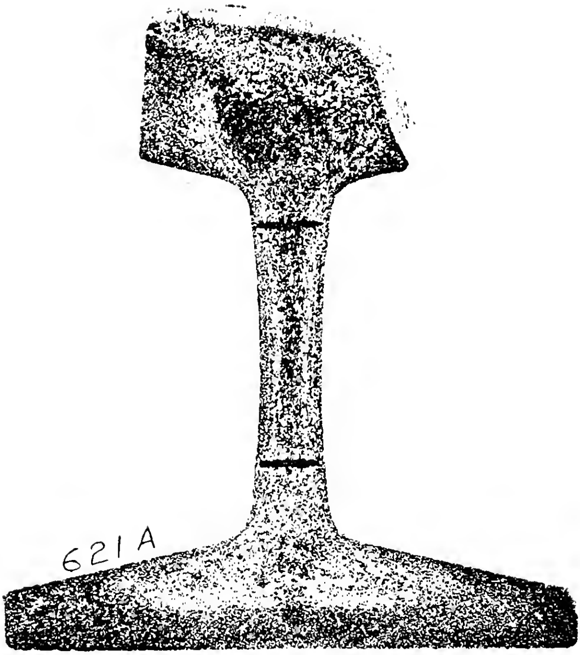


FIG. 621A. DEEP ETCHING OF RAIL 621.

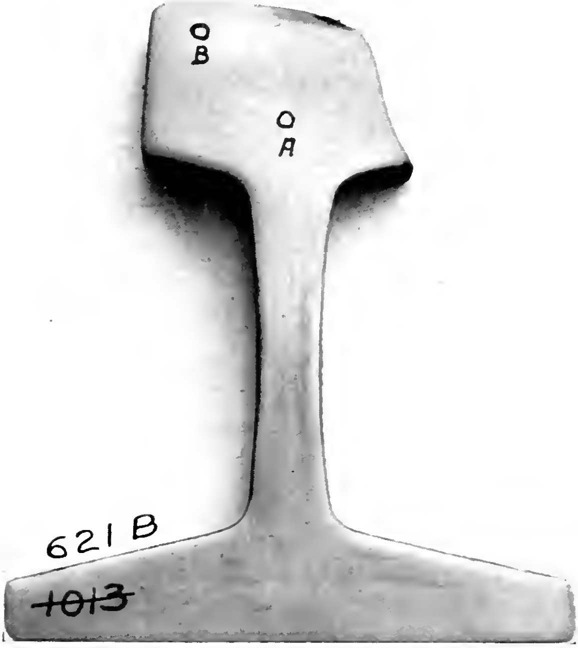


FIG. 621B. LIGHT ETCHING OF RAIL 621.

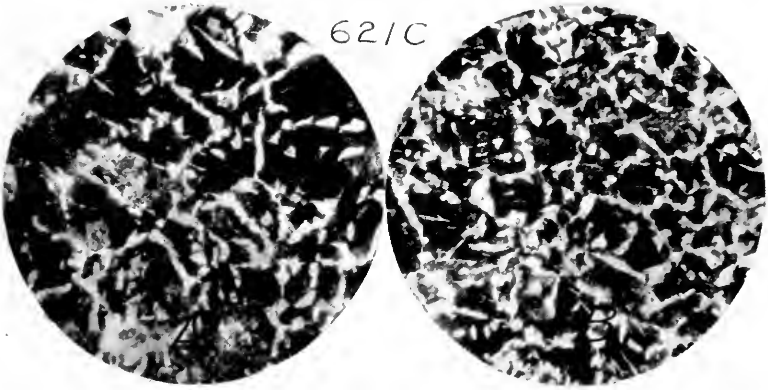


FIG. 621C. MICROPHOTOGRAPHS OF RAIL 621, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 621B.

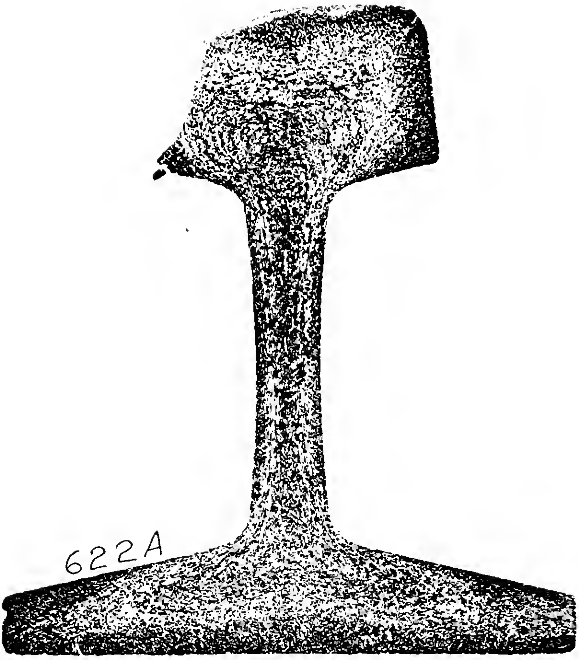


Fig. 622A. Deep Etching of Rail 622.

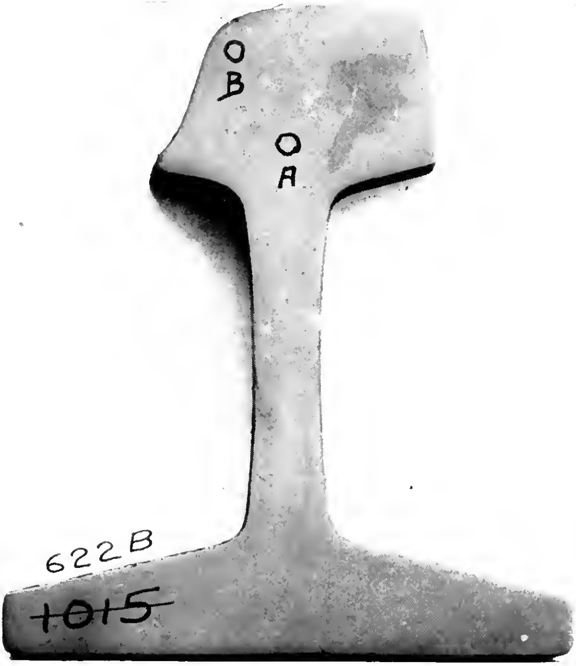


Fig. 622B. Light Etching of Rail 622.

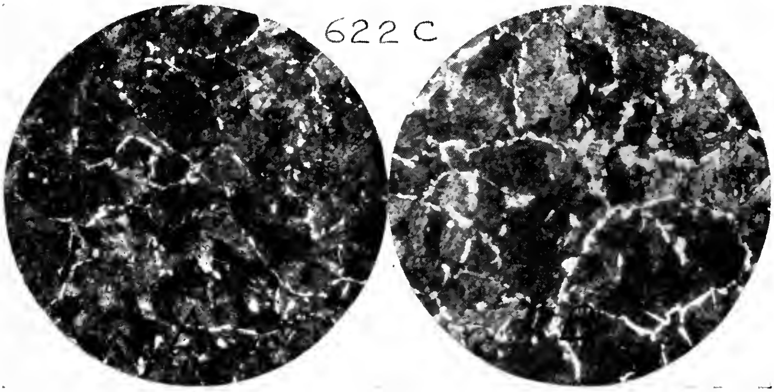


Fig. 622C. Microphotographs of Rail 622, Magnified 65 Diameters. Locations A and B on Fig. 622B.

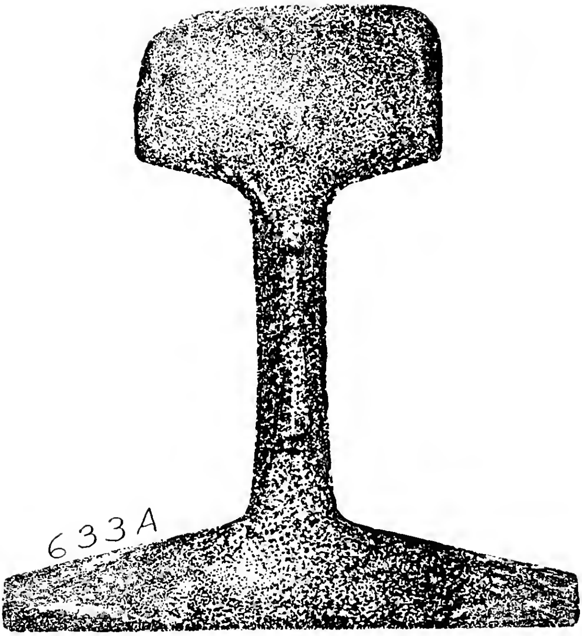


FIG. 633A. DEEP ETCHING OF RAIL 633.

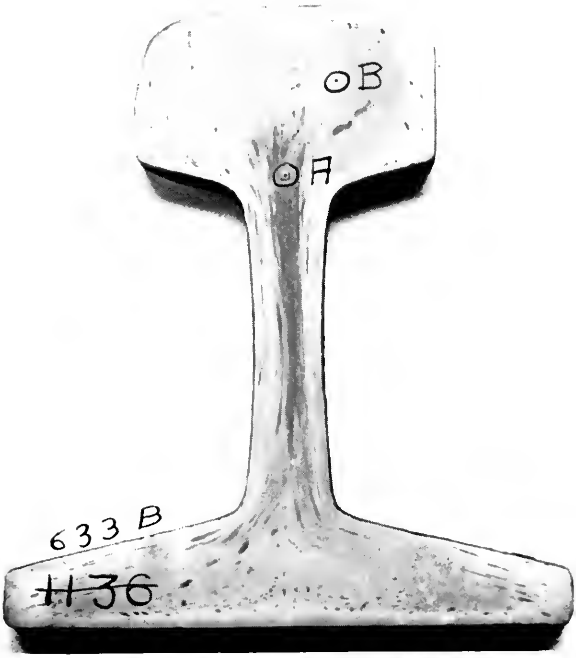


Fig. 633B. Light Etching of Rail 633.

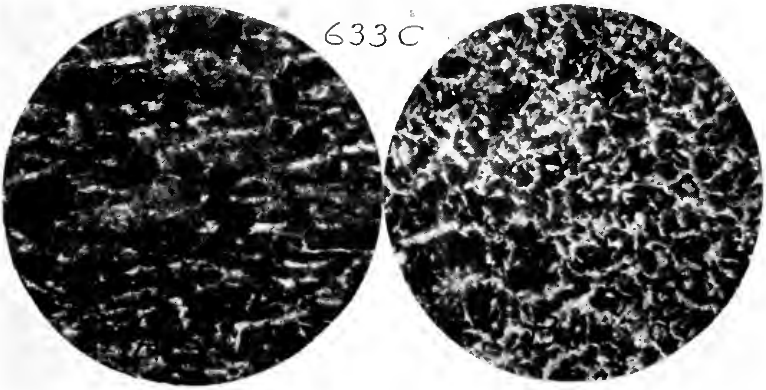


Fig. 633C. Microphotographs of Rail 633, Magnified 65 Diameters. Locations A and B on Fig. 633B.

A—Shows microstructure of segregated area.

B—Average structure of head, showing an unusually fine grain.

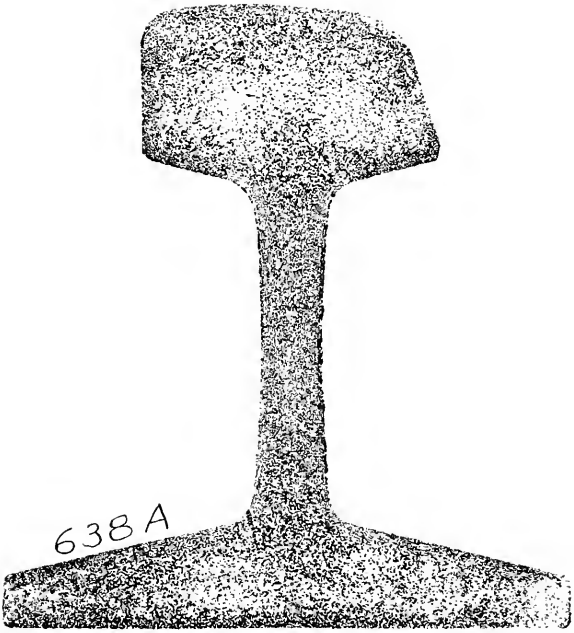


Fig. 638A. Deep Etching of Rail 638.

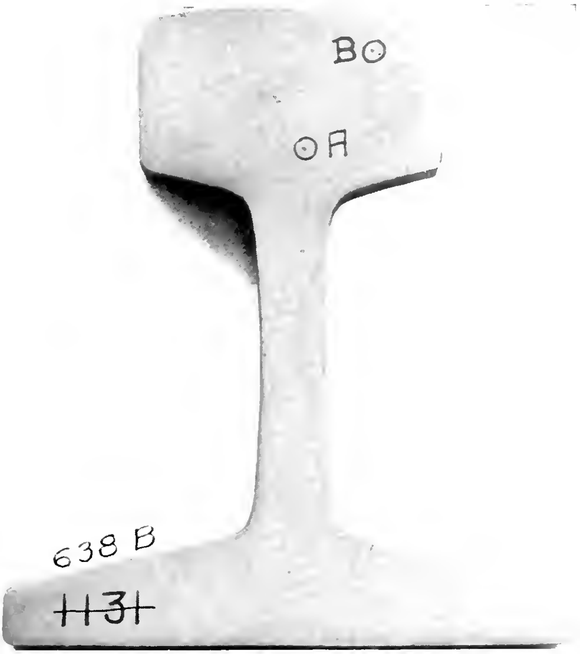


Fig. 638B. Light Etching of Rail 638.

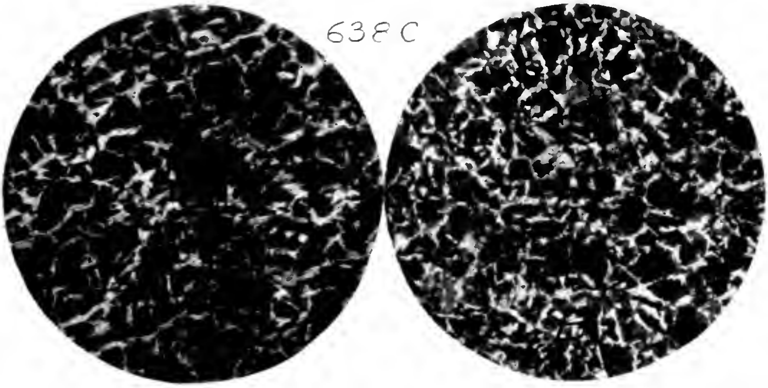


Fig. 638C. Microphotographs of Rail 638, Magnified 65 Diameters. Locations A and B on Fig. 638B.

A—Average structure consisting of ferrite and pearlite.
B—Ferrite-pearlite structure of finer grain than center of head.

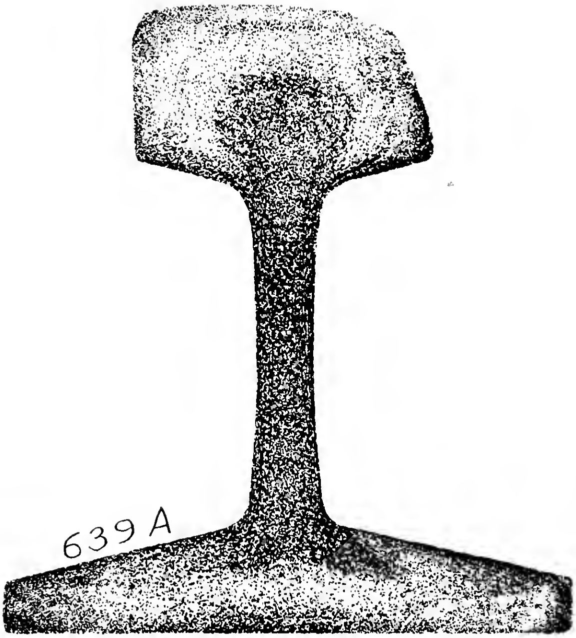


Fig. 639A. Deep Etching of Rail 639.

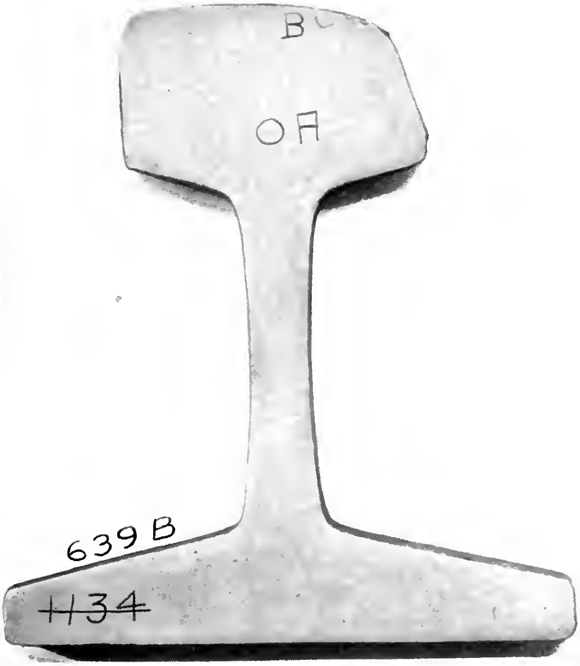


FIG. 639B. LIGHT ETCHING OF RAIL 639.

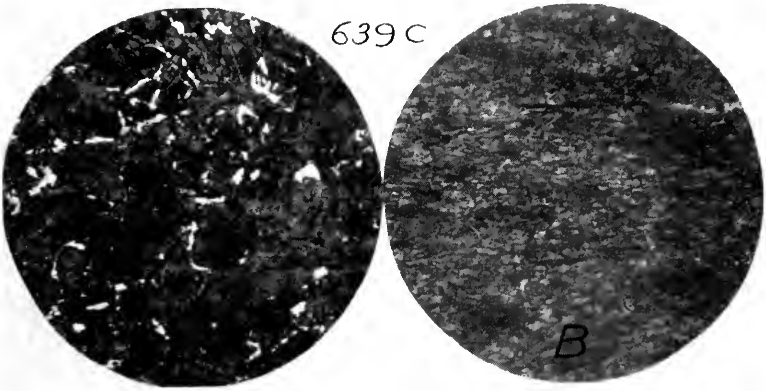


FIG. 639C. MICROPHOTOGRAPHS OF RAIL 639, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 639B.

A—Average structure, pearlite with small amount of ferrite.
B—Distortion of grain on top of head due to wheel load.

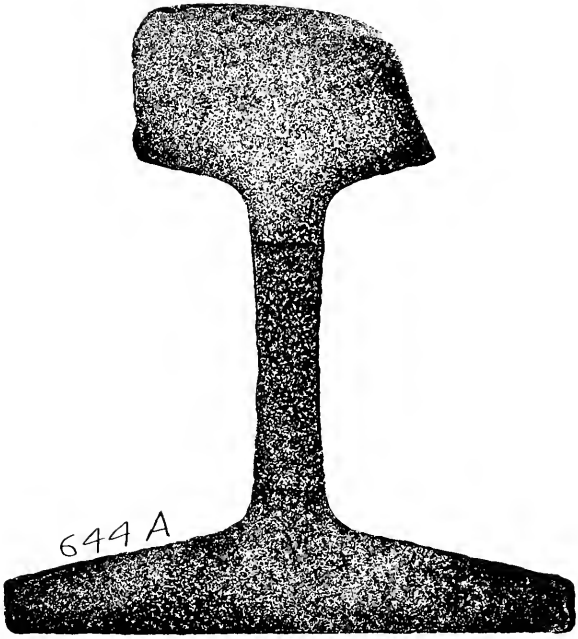


Fig. 644A. Deep Etching of Rail 644.

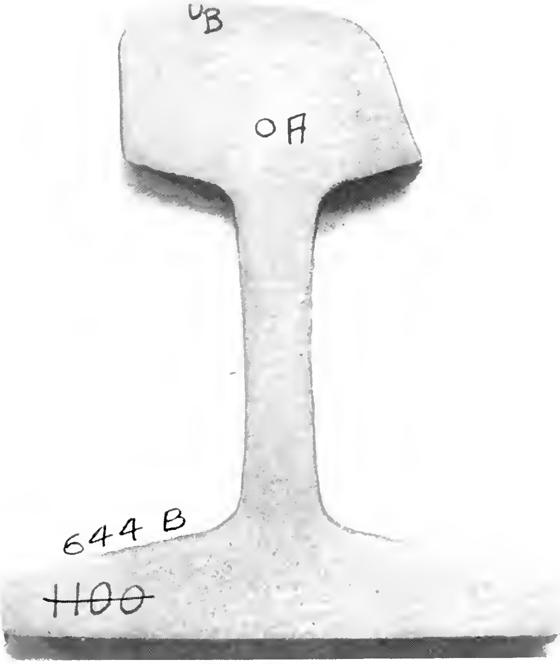


FIG. 644B. LIGHT ETCHING OF RAIL 644.

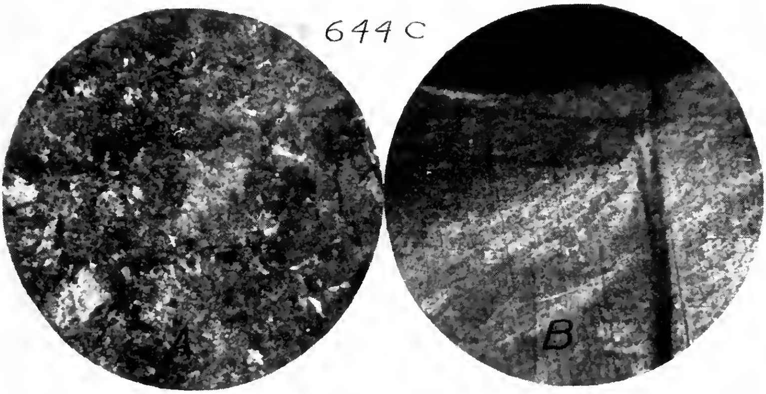


FIG. 644C. MICROPHOTOGRAPHS OF RAIL 644, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 644B.

A—Average structure.

B—Shows structure of hardened area on top of head, probably caused by slipping engine drivers. This spot is about 3/8-inch wide and 1/32-inch deep, and is very brittle, as is shown by cracks in this portion.

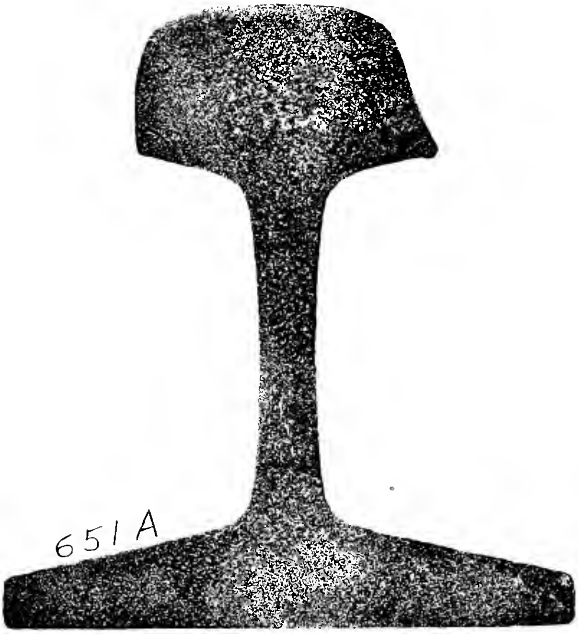


Fig. 651A. Deep Etching of Rail 651.

FIG. 651B. LIGHT ETCHING OF RAIL 651.

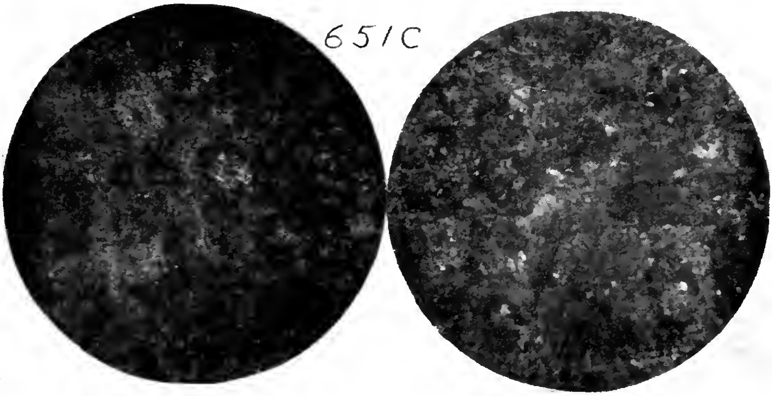


FIG. 651C. MICROPHOTOGRAPHS OF RAIL 651, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 651B.
A and B—Good average structure.

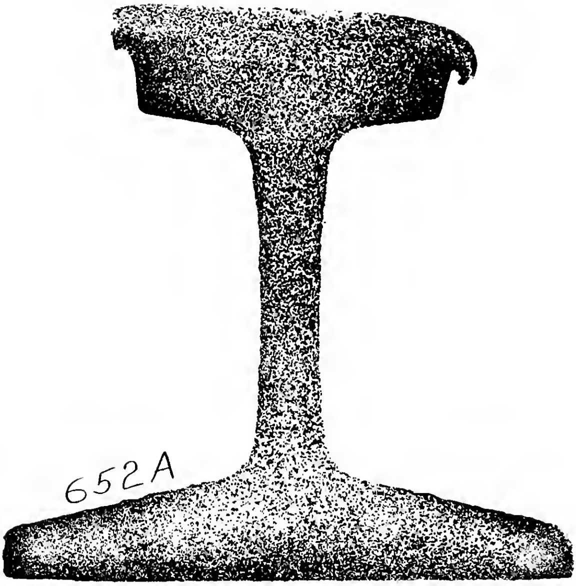


FIG. 652A. DEEP ETCHING OF RAIL 652.

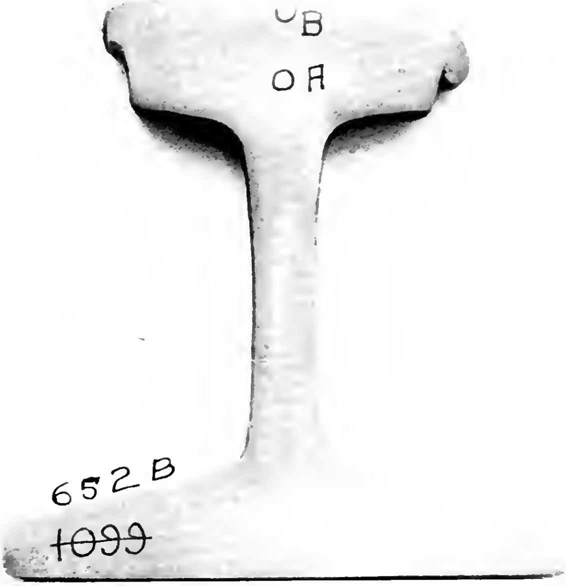


FIG. 652B. LIGHT ETCHING OF RAIL 652.

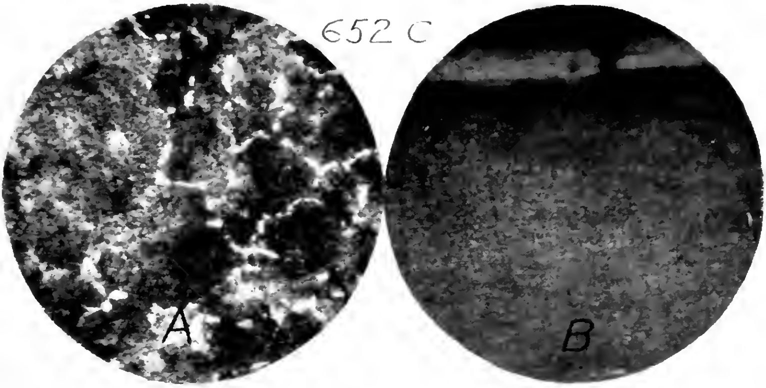


FIG. 652C. MICROPHOTOGRAPHS OF RAIL 652. MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 652B.

A—Average structure showing a small amount of ferrite.

B—Distorted grain and narrow hardened surface on top of head, probably caused by slipping engine drivers.

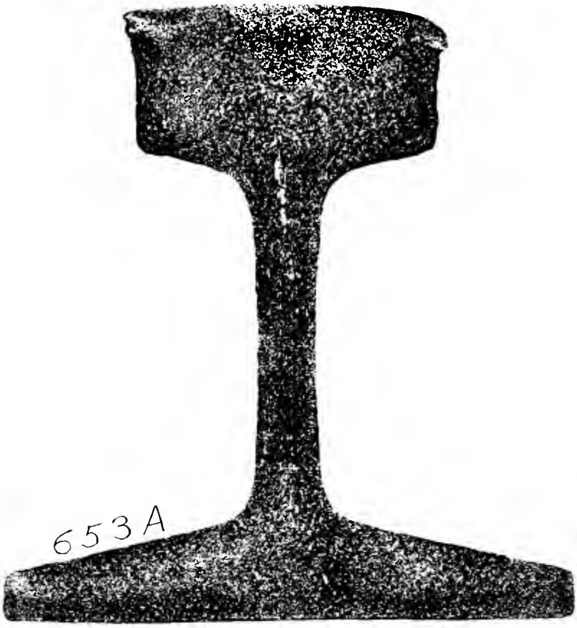


Fig. 653A. Deep Etching of Rail 653.

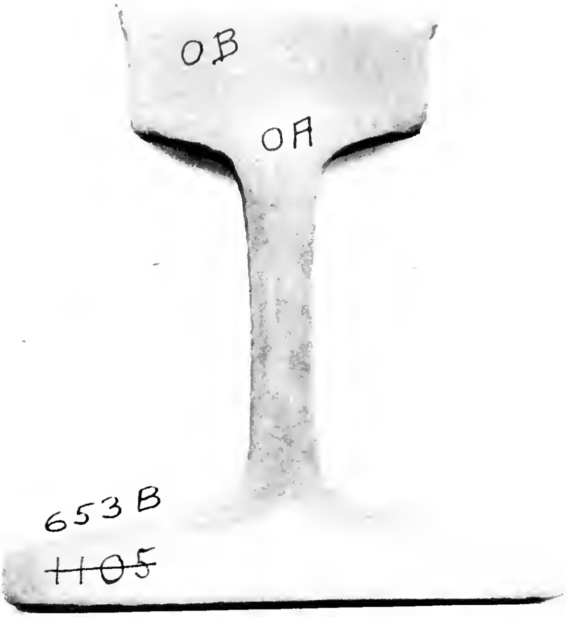


Fig. 653B. Light Etching of Rail 653.

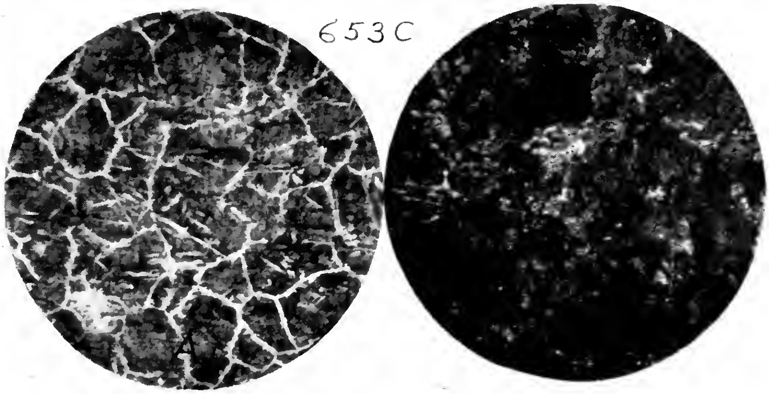


Fig. 653C. Microphotographs of Rail 653, Magnified 65 Diameters. Locations A and B on Fig. 653B.

A—Shows brittle cementite structure. This stream is about ½-inch long and $\frac{1}{32}$-inch wide, located at junction of head and web.

B—Average structure.

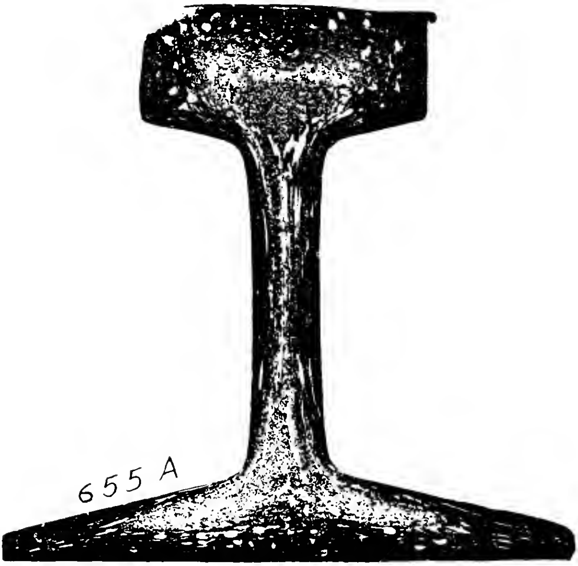


FIG. 655A. DEEP ETCHING OF RAIL 655.

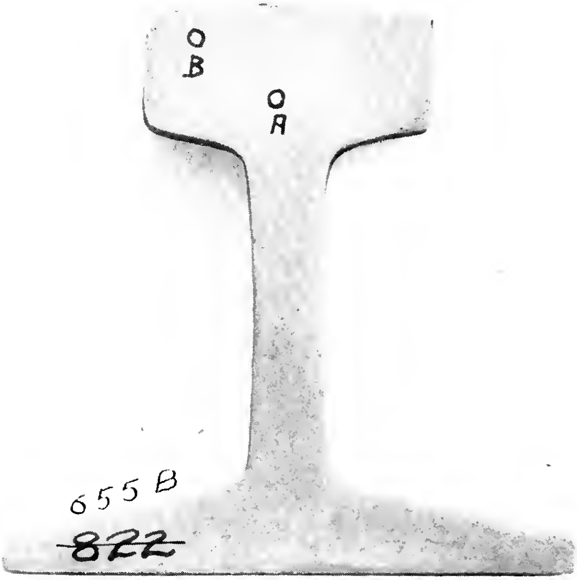
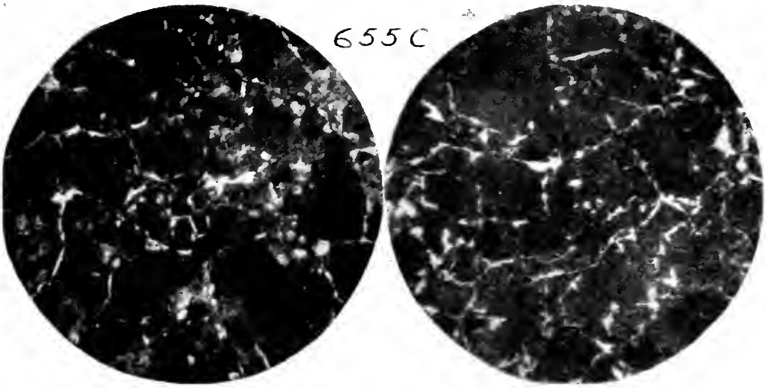
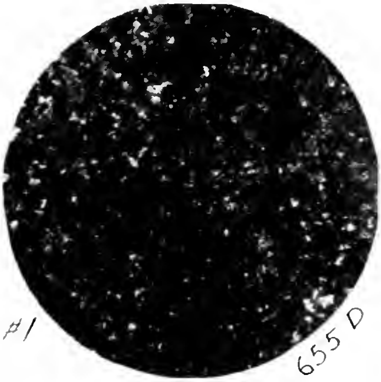


FIG. 655B. LIGHT ETCHING OF RAIL 655.



655 C

FIG. 655C. MICROPHOTOGRAPHS OF RAIL 655, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 655B.



#1

655 D

FIG. 655D. MICROPHOTOGRAPHS OF RAIL 655, $\frac{1}{16}$-INCH BELOW SURFACE, MAGNIFIED 65 DIAMETERS.

(Etched with nitric amyl alcohol.)

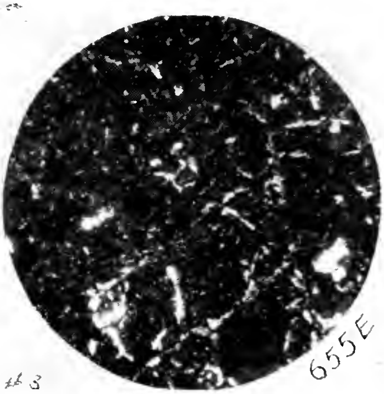


Fig. 655E. Microphotographs of Rail 655, ⅛-Inch Below Surface, Magnified 65 Diameters.

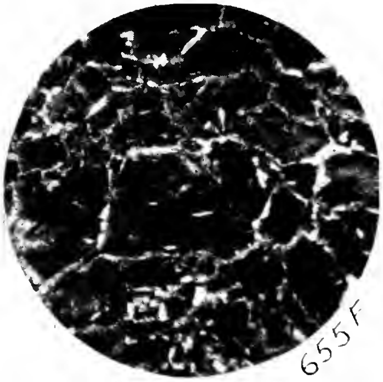


Fig. 655F. Microphotographs of Rail 655, ½-Inch Below Surface, Magnified 65 Diameters.
(Both etched with nitric amyl alcohol.)

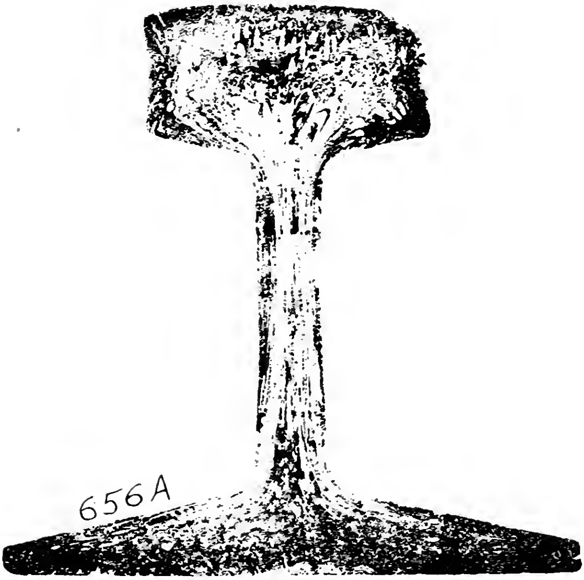


Fig. 656A. Deep Etching of Rail 656.

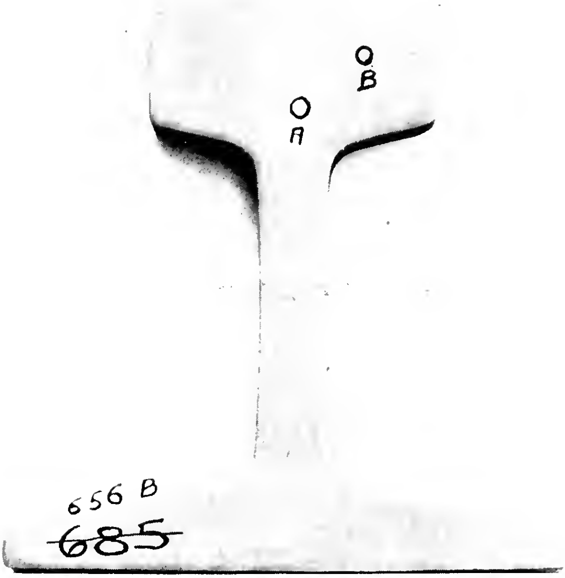


FIG. 656B. LIGHT ETCHING OF RAIL 656.

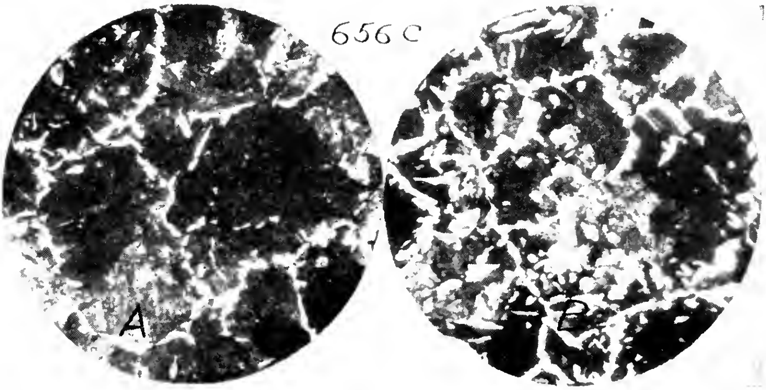


FIG. 656C. MICROPHOTOGRAPHS OF RAIL 656, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 656B.

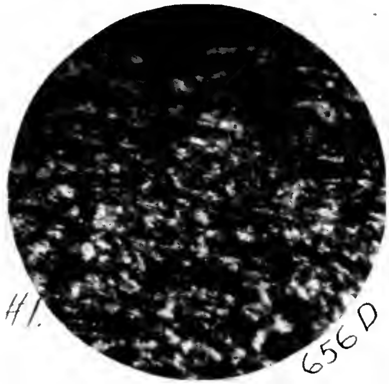


Fig. 656D. Microphotographs of Rail 656, Running Face, Magnified 65 Diameters, Where Struck by Flat Wheel.

Fig. 656E. Microphotographs of Rail 656, Magnified 65 Diameters. Presumably Below Surface.
General Structure of Steel in Rail.
(Both etched with nitric amyl alcohol.)

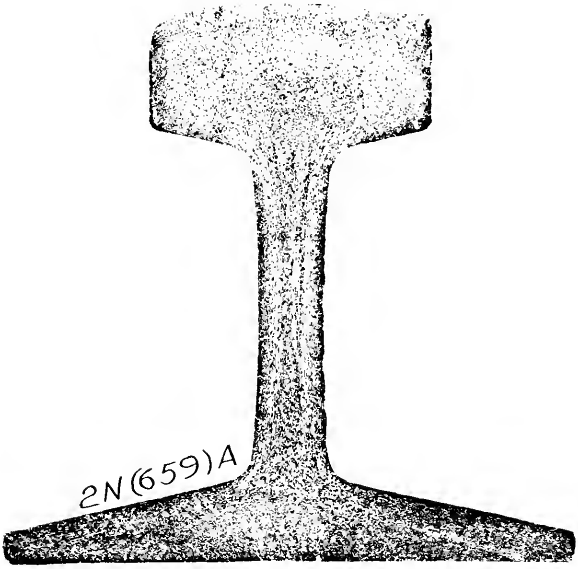


Fig. 2N(659)A. Deep Etching of Rail 659.

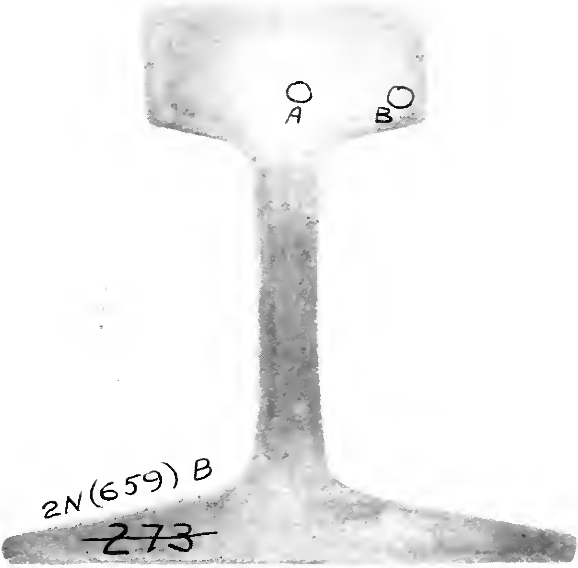


FIG. 2N(659)B. LIGHT ETCHING OF RAIL 659.

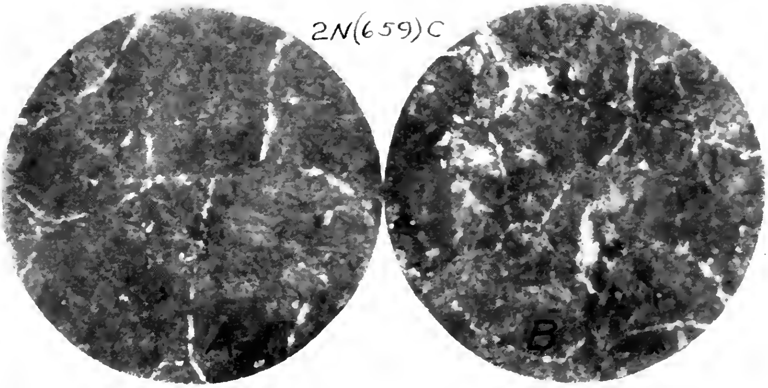


FIG. 2N(659)C. MICROPHOTOGRAPHS OF RAIL 659, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 2N(659)B.

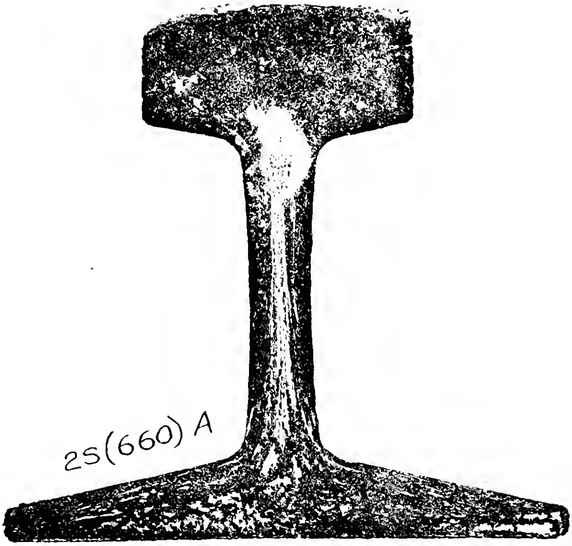


Fig. 2S(660)A. Deep Etching of Rail 660.

FIG. 2S(660) B. LIGHT ETCHING OF RAIL 660.

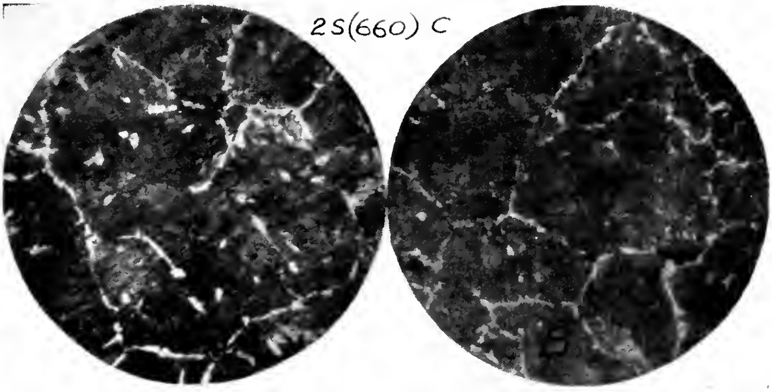


FIG. 2S(660) C. MICROPHOTOGRAPHS OF RAIL 660, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 2S(660) B.

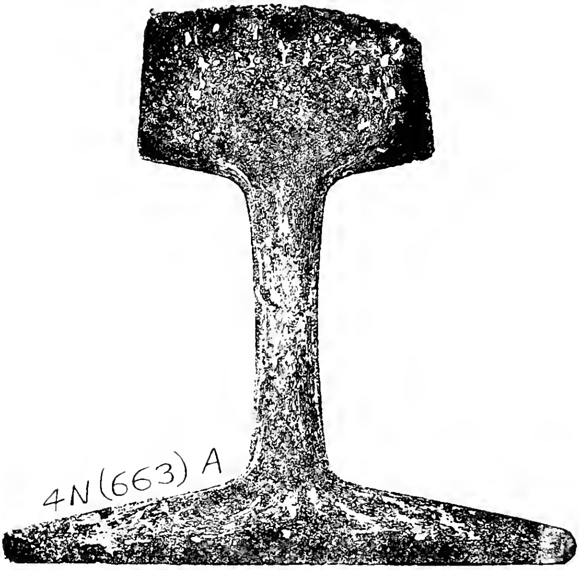


Fig. 4N(663)A. Deep Etching of Rail 663.

FIG. 4N(663)B. LIGHT ETCHING OF RAIL 663.

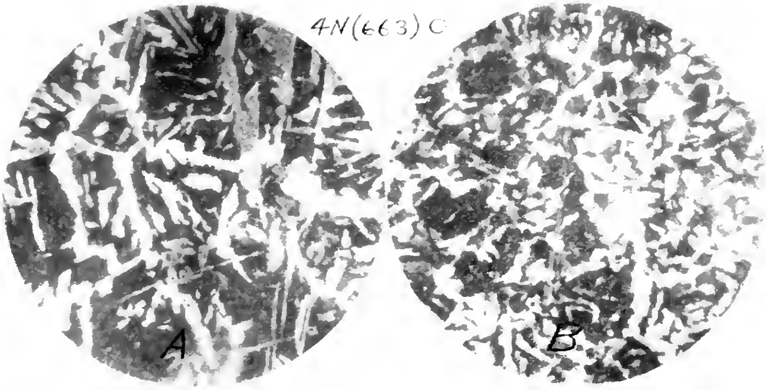


FIG. 4N(663)C. MICROPHOTOGRAPHS OF RAIL 663, MAGNIFIED 65 DIAMETERS. LOCATIONS A AND B ON FIG. 4N(663)B.

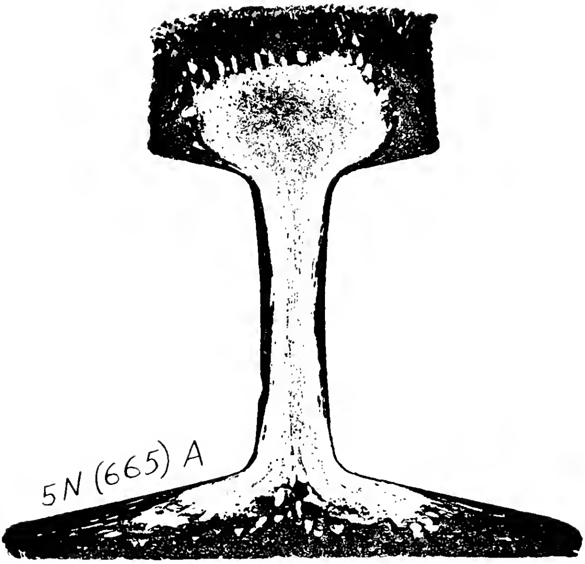


FIG. 5N (665) A. DEEP ETCHING OF RAIL 665.

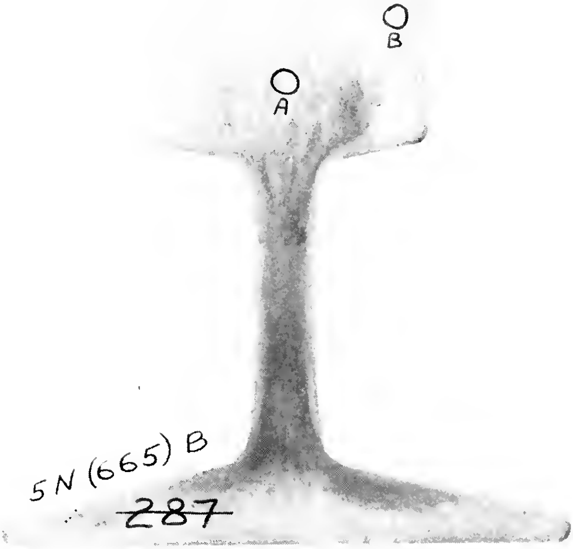


FIG. 5N (665) B. LIGHT ETCHING OF RAIL 665.

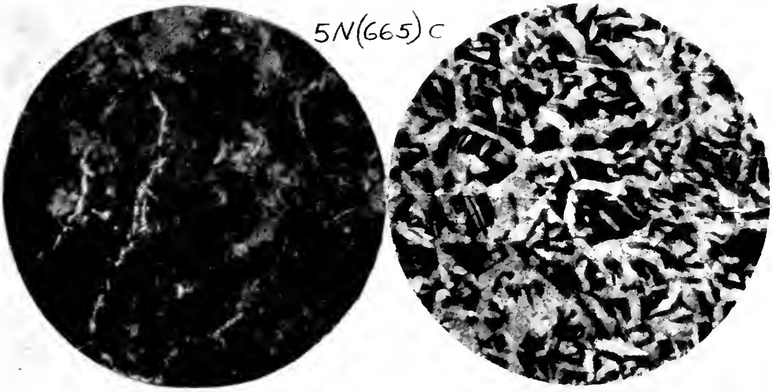


Fig. 5N(665)C. Microphotographs of Rail 665, Magnified 65 Diameters. Locations A and B on Fig. 5N(665)B.

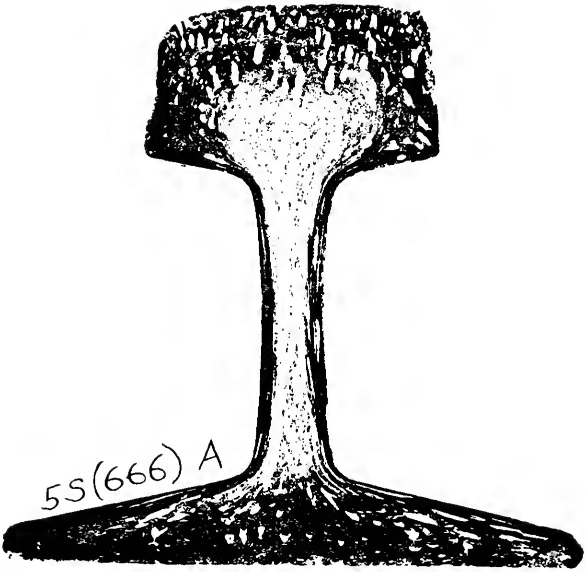


Fig. 5S(656)A. Deep Etching of Rail 666.

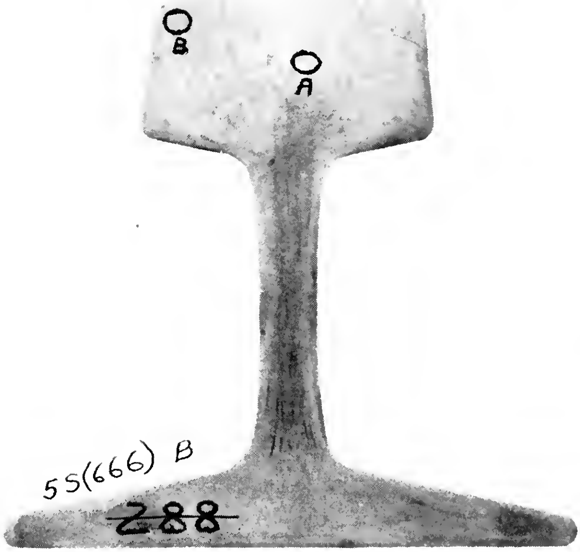


Fig. 5S(666)B. Light Etching of Rail 666.

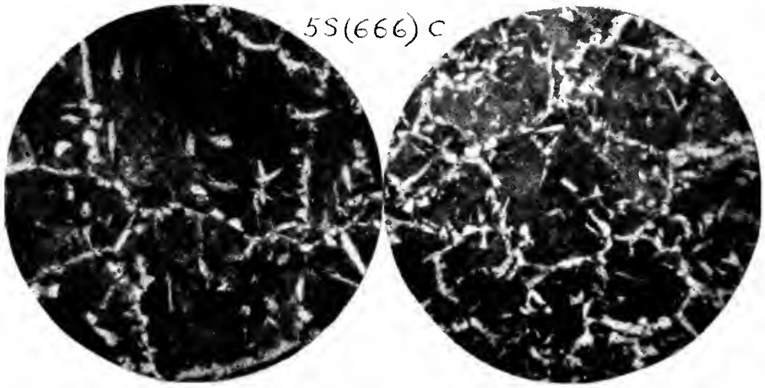


Fig. 5S(666)C. Microphotographs of Rail 666, Magnified 65 Diameters. Locations A and B on Fig. 5S(666)B.

(For Sheets and Plates, see inserts in back of Volume.)

THE NICK AND BREAK TEST IN THE INSPECTION OF STEEL RAILS.

By Robert W. Hunt and C. W. Gennet, Jr.

Steel metallurgists will recall that prior to the general dependence upon the services of the analytical chemist, that is, in the days when but few steel works had their own laboratories, the grading of crucible steel in the ingot, and before it was drawn down into bars, was based upon the appearance of the fracture of each separate ingot. After the ingots became cold, a piece was broken off one corner and an expert workman judged of the hardness of the metal by the exposed fracture, and marked the ingot accordingly. Thus one would be used for tool, another for drill, another for spring steel, and so on.

In later years, when the dissatisfaction with the results given by steel rails led to much discussion as to what changes should be made in the specifications governing their manufacture, the Rail Committee of the American Railway Association called in consultation the late William Metcalf, Past-President of the American Institute of Mining Engineers, 1881; Past-President of the American Society of Civil Engineers, 1898-99, and for years a steel maker. Previous to that time drop tests of pieces of rail representing each heat of steel had been included in some of the specifications, but the object of such tests had been limited to determining the ductility of the steel. There had not been any prescribed breaking tests with a view of disclosing the internal structure of the rail.

Mr. Metcalf, based no doubt upon his experience as a maker of crucible steel, urged that the then current testing did not go far enough, and that several pieces of rail from each heat should be broken, and by the disclosed fractures the rails from that heat accepted or rejected. The Committee, when reporting, did not adopt his suggestions, but, based largely upon his insistence that the drop testing as then conducted did not go far enough, many railroad engineers gradually enlarged the scope of their drop-testing requirements until it became the general practice to break, say, three pieces from each heat of Open-Hearth steel and to accept or reject certain rails according to whether or not interior defects were revealed. It was argued that the practice should be extended to include the breaking of a piece of rail from the top end of each

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Rail Report 54, March, 1916.

ingot rolled, and in fact some experimental rollings were made under such provisions, but opposition to the plan of making this fracture test on a piece of rail from each ingot developed among rail makers, with the result that what seems to us to be a perfectly logical method of testing rails to insure against acceptance of defective material, failed to have a fair working trial; and thus it remained, about a year ago, for the Algoma Steel Corporation, whose mill is at Sault Ste. Marie, Canada, to open the door commercially, so to speak, to the possibilities of a specification for rails, marking, we believe, a distinct step forward in the direction of safer and better wearing rails.

A contract for 10,000 tons of rails made by the Canadian Pacific Railway with the Algoma company was the first to require what has been commonly termed "the nick and break test on each ingot," and this was quickly followed by others for rails to be shipped to this country under similar conditions of testing. In justice to the Algoma company it may be said that they have become so appreciative of the logic, as well as the economy, of the nick and break test that they have seen fit to have it incorporated freely and without extra compensation in many of their specifications. One contract for rails to be shipped to one of the leading railroads of the Middle West was given special attention at the time of rolling, and it is essentially the results obtained on it that we desire to record, at the same time drawing attention to various phases of the matter of specifications and their application and interpretation.

The contract in question covered a large tonnage of 90-lb. American Railway Association type "A" section of rail, the dimensions of which are as shown in Fig. 1. The specification under which the rails were rolled was that adopted March 17, 1915, by the American Railway Engineering Association, but so modified in detail as to provide for nicking and breaking the top crop end of the top rail of each ingot rolled, and accepting or rejecting it (with the subsequent ones of the same ingot) as a result of conditions revealed by the fracture produced. The important parts of the specification are as follows, and the corresponding parts of the present American Railway Engineering Association specification are also shown to render easy comparison possible:

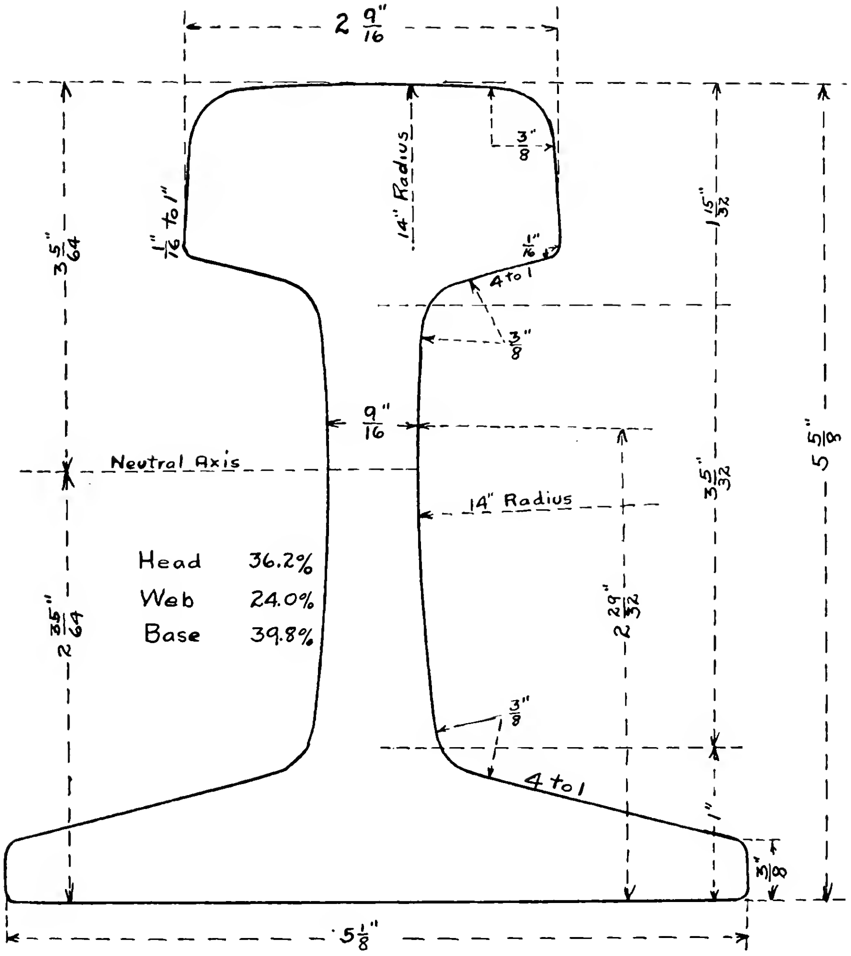


Fig. 1.
90-Lb. A.R.A. Type "A" Rail.

NICK AND BREAK TEST SPECIFICATION, 1915. For 90-Lb. Open-Hearth Steel Rails.	A. R. E. A. SPECIFICATION, ADOPTED MARCH 17, 1915. For 90-Lb. Open-Hearth Steel Rails.
Chemical Composition. Same.	**Chemical Composition.** Per cent. carbon...... .62 to .75 Per cent. phosphorus not to exceed .... .04 Per cent. manganese.. .60 to .90 Per cent. silicon, not less than .10
Physical Qualities. Same.	**Physical Qualities.** Tests shall be made to determine ductility or toughness as opposed to brittleness; and soundness.
Method of Testing. Same.	**Method of Testing.** The physical qualities shall be determined by the drop test.
Drop Testing Machine. Same.	**Drop Testing Machine.** The drop testing machine used shall be the standard of the American Railway Engineering Association. (a) The tup shall weigh 2,000 lbs. and have a striking face with a radius of five inches. (b) The anvil block shall weigh 20,000 lbs. and be supported on springs. (c) The supports for the test pieces shall be spaced three feet between centers and shall be a part of, and firmly secured to the anvil. The bearing surfaces of the supports shall have a radius of five inches.
Pieces for Drop Test. Same.	**Pieces for Drop Test.** Drop tests shall be made on pieces of rail not less than four feet and not more than six feet long. These test pieces shall be cut from the top end of the top rail of the ingot, and marked on the base or head with gage marks one inch apart for three inches each side of the center of the test piece, for measuring the ductility of the metal.
Temperature of Test Pieces. Same.	**Temperature of Test Pieces.** The temperature of the test pieces shall be between 60 and 100 degrees Fahrenheit.
Height of Drop. Same.	**Height of Drop.** The test piece shall preferably be placed base upwards on the supports, and be subjected to impact of the tup falling free from a height of 17 feet.

NICK AND BREAK TEST SPECIFICATION, 1915. For 90-Lb. Open-Hearth Steel Rails.	A. R. E. A. SPECIFICATION, ADOPTED MARCH 17, 1915. For 90-Lb. Open-Hearth Steel Rails.
Elongation, or Ductility. Same.	**Elongation, or Ductility.** (a) Under these impacts the rail under one or more blows shall show at least 6 per cent. elongation for one inch, or five per cent. each for two consecutive inches of the six-inch scale, marked as described. (b) A sufficient number of blows shall be given to determine the complete elongation of the test piece of one out of every three test pieces of a heat.
Permanent Set. Same.	**Permanent Set.** It is desired that the permanent set after one blow under the drop test shall not exceed 1.65 inches, and a record shall be made of this information.
Test to Destruction. The test pieces which do not break under the first or subsequent blows shall be nicked and broken to determine whether the interior metal is sound. The words "interior defect" used below shall be interpreted to mean seams, laminations, cavities or interposed foreign matter, or a bright fine-grained center evidencing segregation, made visible by the destruction tests, the saws or the drills.	**Test to Destruction.** The test pieces which do not break under the first or subsequent blows shall be nicked and broken to determine whether the interior metal is sound. The words "interior defect" used below shall be interpreted to mean seams, laminations, cavities or interposed foreign matter made visible by the destruction tests, the saws or the drills.
Open-Hearth Process Drop Tests. Same.	**Open-Hearth Process Drop Tests.** Test pieces shall be selected from the second, middle and last full ingot of each Open-Hearth heat.
(a) If two of these test pieces do not break at the first blow, and if both show the required elongation, all of the rails of the heat shall be accepted, except as provided by section (g).	(a) If two of these test pieces do not break at the first blow, and if both show the required elongation, all of the rails of the heat shall be accepted, provided that none of the three test pieces when broken show interior defect.
(b) If two of the test pieces break at the first blow, or do not show the required elongation, all of the top rails from that heat shall be rejected.	(b) If two of the test pieces break at the first blow, or do not show the required elongation, or if any of the three test pieces when broken show interior defect, all of the top rails from that heat shall be rejected.
(c) Second tests shall then be made from three test pieces selected by the Inspector from the top end of any second rails of the same heat, preferably of the same	(c) Second tests shall then be made from three test pieces selected by the Inspector from the top end of any second rails of the same heat, preferably of the same

NICK AND BREAK TEST SPECIFICATION, 1915. FOR 90-LB. OPEN-HEARTH STEEL RAILS.	A. R. E. A. SPECIFICATION, ADOPTED MARCH 17, 1915. FOR 90-LB. OPEN-HEARTH STEEL RAILS.
ingots. If two of these test pieces do not break at the first blow, and if both show the required elongation, all of the remainder of the rails of the heat shall be accepted, except as provided by section (g).	ingots. If two of these test pieces do not break at the first blow, and if both show the required elongation, all of the remainder of the rails of the heat shall be accepted, provided that none of the three test pieces when broken shows interior defect.
(d) If two of these test pieces break at the first blow, or do not show the required elongation, all of the second rails of the heat shall be rejected.	(d) If two of these test pieces break at the first blow, or do not show the required elongation, or if any of the three test pieces when broken show interior defect, all of the second rails of the heat shall be rejected.
(e) Third tests shall then be made from three test pieces selected by the Inspector from the top end of any third rails of the same heat, preferably of the same ingots. If two of these test pieces do not break at the first blow, and if both show the required elongation, all of the remainder of the rails of the heat shall be accepted, except as provided by section (g).	(e) Third tests shall then be made from three test pieces selected by the Inspector from the top end of any third rails of the same heat, preferably of the same ingots. If two of these test pieces do not break at the first blow, and if both show the required elongation, all of the remainder of the rails of the heat shall be accepted, provided that none of the three test pieces when broken show interior defect.
(f) If two of these test pieces break at the first blow, or do not show the required elongation, all of the remainder of the rails from that heat shall be rejected.	(f) If two of these test pieces break at the first blow, or do not show the required elongation, or if any of the three test pieces when broken show interior defect, all of the remainder of the rails from that heat shall be rejected.
(g) The test pieces which have successfully withstood the drop test and also a piece representing the top end of all other top rails shall be nicked and broken. If the fracture shows interior defect the "A," or top rail of the ingot, shall be rejected, and a piece cut from its bottom end to represent the "B," or second rail of the same ingot. This piece shall then be nicked and broken, and if its fracture shows interior defect, the rail represented shall be rejected. The testing by nicking and breaking shall proceed progressively in this manner on all the rails of each ingot, if necessary, and they shall be accepted or rejected according as the fracture of the test piece representing them shows interior defect.	Omitted.
Note.—Each rail must be stamped with a number to indicate the ingot from which it was rolled, so as to permit of identification with the other rails of the same ingot.	*Note.*—Omitted.

TABLE 1. COMPARISON OF RESULTS UNDER VARIOUS SPECIFICATIONS.

	Nick and Break Specification	A.R.E.A. Specification
No. of Rollings	10	
No. of Heats Rolled	1002	
No. of Ingots Rolled	16297	
No. of Rails Rolled	69826	
No. Heats rejected at Drop Test	0	0
No. Heats of "A" Rails rejected at Drop Test	15	15
No. "A" Rails rejected at Drop Test	267	267
No. "A" Rails in addition rejected account Pipe	934	2393
No. "A" Rails in addition rejected account Segregated	829	1189
No. "A" Rails in addition rejected account other reasons	12	0
Total "A" Rails rejected	1775	3582
No. "B" Rails in addition rejected account Pipe	31	28
No. "B" Rails in addition rejected account Segregated	7	11
No. "B" Rails in addition rejected account other reasons	0	0
Total "B" Rails rejected	38	39
No. "C" Rails in addition rejected account Pipe	3	0
No. "C" Rails in addition rejected account Segregated	0	0
No. "C" Rails in addition rejected account other reasons	0	0
Total "C" Rails rejected	3	0
Total all Rails rejected on Fracture	1816	3621
Total all Rails rejected on Physical Test	2083	3888
Per Cent. Rails rolled and rejected on Test	2.98	5.56
Total Rails rejected account Pipe	968=1.4%	2421=3.4%
Total Rails rejected account Segregated	836=1.2%	1200=1.7%
Total Rails rejected account other reasons	12= .01%	0= 0%

NUMBER OF RAILS REJECTED UNDER NICK AND BREAK SPECIFICATION WHICH WOULD HAVE BEEN ACCEPTED UNDER A. R. E. A. SPECIFICATION.

	"A" Rails.	"B" Rails.	"C" Rails.	Total.
Piped	409	21	2	432
Segregated	492	3	0	495
Other reasons	3	0	0	3
Total	904	24	2	930

Per cent. rails rolled that were rejected under the Nick and Break Specification that would have been accepted under the A. R. E. A. Specification........ 1.33

One of the most important questions that has been raised in connection with the nick and break test specification is with regard to the relative number of rejections occurring under it and some other, particularly the American Railway Engineering Association above quoted; and that this point could be solved, record was made of each condition that did actually occur, with corresponding conditions, in so far as possible, that would have occurred had the nick and break test on each ingot been waived and the straight American Railway Engineering Association specification applied. The comparison of the results are shown in Table 1.

The most important facts and conclusions which can be deduced from Table are:

(1) That the application of the nick and break test specification results in a distinct saving to the mill in the number of rails rejected as against those that would be rejected under the American Railway Engineering Association specification. These rejections have been reduced from 5.56 per cent. to 2.98 per cent., resulting, therefore, in a saving to the mill of rejected rails amounting to 46.4 per cent.

(2) That the application of the nick and break test specification is of greater protection to the railroad than would be the American Railway Engineering Association specification, for the rejections under the former include 1.33 per cent. of the total number of rails rolled, which would have been accepted under the American Railway Engineering Association specification. Thus, of the total number of rails rejected under the nick and break specifications, 44.6 per cent. would not have been rejected under the American Railway Engineering Association specification, so that practically one-half of the rails rejected under the nick and break test specification would have been accepted under the American Railway Engineering Association, and obviously been laid in the track.

(3) If, as has been shown by published records, the number of rails which fail in service and have to be replaced because of unsound or unhomogeneous metal, represents nearly one-half of the total number of failures occurring on the railroads each year, obviously, then, by the application of the nick and break test specification, which is a protection against unsound and unhomogeneous metal, a material reduction in the number of these rail failures easily would be effected.

To our minds a serious defect of most specifications is the disregard for the individuality of each ingot cast from a heat. Large heats and large ingots, at present so common to modern mill practice, aggravate conditions which in the old days of Bessemer steel were not so important, and while it is the usual practice to select drop test pieces from three different ingots from an Open-Hearth heat, still it often happens that the three selected are what might be termed good ingots as against some others cast from the same heat which are not. Specifications usually control the location in the heat of the ingots from which pieces of rail are to be taken for drop tests, which may lead to special care in the casting of those particular ingots, thus preventing them from being truly representative ones, and tending toward many a defective rail being accepted and put into service, a condition which frequently would be averted if the prescribed test had been made on a piece of rail from some other ingot of the heat. As illustrative of the efficacy of the nick and break test specification in eliminating some of the bad rails referred to, Fig. 2 is given. It shows fractures made on an "A" or top rail of an ingot which was so located in the heat that under no ordinary specification would it have been selected for test purposes. Careful examination of the sawed ends of the rail failed to detect any signs of a pipe, yet as

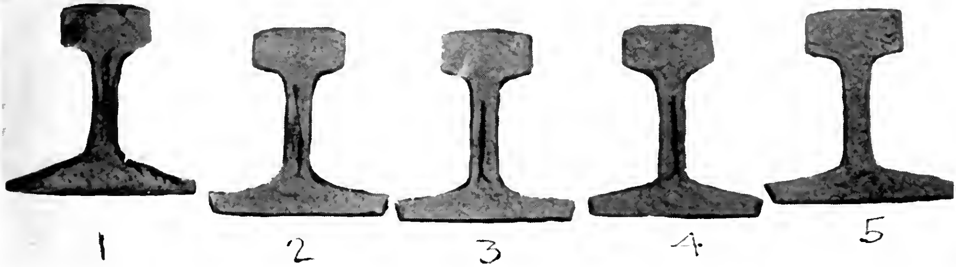


FIG. 2. SHOWING THE EFFICACY OF THE NICK AND BREAK TEST.

The crop end of an "A" rail from an ingot so located in a heat that under no ordinary specification would it have been selected for drop testing, was regularly tested by nicking and breaking. It showed a large pipe which caused rejection of the "A" rail. The regular drop tests and their fractures of the heat represented were satisfactory in every respect. The "A" rail was then carefully examined, especially on its ends, and no sign of pipe was found, the hot saw marks probably obliterating signs of the pipe. Under customary specifications, the rail would therefore have been accepted and ultimately laid in track. The rejected rail was then broken into short pieces with the results shown.

1. Shows original nick and break test fracture which was piped.
2. Shows a fracture 2 ft. 9 in. from the top end of the "A" rail which was also piped.
3. Shows a fracture 6 ft. 8 in. from the top end, also piped.
4. Shows a fracture 9 ft. 8 in. from the top end, also piped.
5. Shows a fracture 12 ft. from the top end and clear of signs of interior defect.

Other fractures at greater distances from the top end showed no signs of interior defects, so that this rail was actually piped for about 30 per cent. of its length.

will be seen from the photograph, the rail was piped, and very badly so, for about ten feet of its length. There can be no question but that this rail, under ordinary circumstances, would have been accepted and ultimately laid in the track on practically any railroad of the United States, but under the nick and break test specification, by which each ingot is virtually considered a unit by itself, the crop end of this rail was found piped and the rail was rejected.

The reasons for the disparity in the number of rails rejected under the two specifications are plainly shown by the results obtained on two different heats selected at random from among those rolled:

Ingot No.	Heat X			Heat Y		
	Fracture of nick and break test on			Fracture of nick and break test on		
	A Rail	B Rail	C Rail	A Rail	B Rail	C Rail
1	O. K.			O. K.		
2	O. K.			Piped	Piped	O. K.
3	*O. K.			O. K.		
4	O. K.			*O. K.		
5	O. K.			Piped	O. K.	
6	O. K.			O. K.		
7	O. K.			*O. K.		
8	O. K.			Piped	O. K.	
9	O. K.			O. K.		
10	O. K.			*O. K.		
11	O. K.			O. K.		
12	O. K.			O. K.		
13	*Piped	O. K.		Segreg.	O. K.	
14	*O. K.			Segreg.	O. K.	
15	O. K.			O. K.		
16	O. K.			O. K.		
17				Piped	O. K.	
18				O. K.		
19				O. K.		
20				O. K.		

*Refers to what would have been the regular drop test pieces under the American Railway Engineering Association specification.

Thus, on Heat X, piece No. 13 was piped, and under the American Railway Engineering Association specification, therefore, a total of 16 rails would have been condemned as against the single one lost under the nick and break test specification. On Heat Y, the three regular American Railway Engineering Association test pieces were good in all respects, and yet 4 "A" rails and 1 "B" rail actually were piped, while 2 other "A" rails were segregated, and, therefore, 7 defective rails would have been accepted and put in service under the American Railway

Engineering Association specification, but all were rejected under the nick and break test specification.

By the nick and break test mentioned above is meant, firstly, the nicking; and secondly, the breaking, by some mechanical means, of a short length of rail selected as required by the specification. This, it will be noted, must be, for the first, or the original test, the top end of the top rail of each ingot rolled, and naturally for this sample, the crop end, which must be cut by the hot saws, from the top of the "A" rail was used. These crop ends were ordinarily from 18 in. to 24 in. long, and after being stamped with the heat and ingot number, to permit of identification, were allowed to cool for a little over thirty minutes, and were then quenched in water, pains being taken to insure quenching from a temperature color of near black or natural cold steel, so as to render no appreciable change in steel structure possible. Then the pieces were nicked as desired; and, for the purpose of breaking, inserted in a specially designed anvil of a bulldozer (Fig. 3) so arranged that the ram readily broke the rail where it had been nicked, giving, without trouble in most cases, the square character of fracture desired for examination. Thus the fractures were ready for judging in an average time of about one hour after the rails were rolled, and in many cases long before the actual drop test pieces were cold enough to test, and even before the rails represented had reached the cold straightening presses. It is interesting to observe that the bulldozer actually broke the rails at a rate of about 3 per minute, or at a rate, say, of 2000 pieces in twelve hours; and, as each piece represented an ingot, the rate of break-

FIG. 3. VIEW OF BULLDOZER USED AT ALGOMA FOR BREAKING CROP ENDS OF "A" RAILS, SHOWING ALSO THE QUENCHING TANK.

ing possible shows it to be well in excess of any probable tonnage that could be rolled with any present mill equipment. In case of the fracture on this original test showing bad, thus incurring the rejection of the top rail of the particular ingot represented, it was necessary to locate that rail in front of the straightening presses by identifying the heat and ingot number and rail letter on it, and from its bottom end to break a piece to represent the second rail of the same ingot. This requirement continued to all of the rails of the ingot as far as necessary, and it was found possible to accomplish the desired end easily. A little care in the distribution in front of the straightening presses of the rails from the hot beds made the identification possible without the necessity for extended searching, and when the particular rail for retest was located, it was marked and in due course taken to the nearest straightening press, where a piece readily was broken from its lower or back end and the fracture scrutinized by the inspector without delay or trouble to the regular operation of the mill. In fact, no greater trouble arose with regard to locating and making the necessary retests than is demanded in any mill when all the top rails of a heat, or even a whole heat, have to be located and identified in order to comply with rejection requirements, a matter of more or less everyday occurrence in some mills.

Undeniably the judging of the fractures produced by the nick and break test is a matter of great importance, and requires the services of experienced and competent men; but so do all the detailed parts of intelligent and efficient rail inspection; in fact, the same statement can be truthfully made in regard to every detail of steel rail making. The trend of all matters pertaining to rails is indisputably toward obtaining a safer and better wearing product, railroad officials and manufacturers alike being more appreciative of conditions in this respect than ever before; this attitude, no doubt, being stimulated because of the activities of the different Governmental and State Commissions. Recent improvements in mill practice have been acknowledged, and it is equally true that railroads are taking greater pains than formerly with the maintenance of their tracks and equipment, and thus of greatly increased importance is the employment of experienced and competent inspectors with whom to entrust the duties of rail inspection. Any specification and any detail of inspection becomes a hardship to the manufacturer and wasted expenditure to the purchaser when inexperienced and incapable inspectors are employed, and under such circumstances the nick and break test specification is of no greater assurance against accepting bad rails than it is against making bad steel.

Among the questions that have been raised, in the discussion of the nick and break test specification, has been that as to how well the fracture of the crop end of the top rail of each ingot predicated the conditions as to soundness and homogeneity, considered in either a chemical or physical sense, which would exist in the rails which were accepted under this specification. For the purpose of investigating this phase of the matter, a series of special tests were made, the idea in mind being to examine fractures made in rails which had been accepted under the specification, and which, therefore, represented conditions occurring farther down from the top of the ingots where it might be presumed secondary pipes or possible segregation could exist. These tests were made in the following order and with the results shown:

First:

The top 9 ft. of 25 "A" rails that had successfully passed the nick and break test, and been accepted for shipment, were each broken into four pieces, producing, therefore, 100 fractures, all of which were found free from signs of interior defects, except in one case where each of the four fractures from the same rail showed traces of slight segregation, limited in extent to the area of the web. (This case was No. 7451-11, the photographs of picric acid etchings with analyses of which follow.)

A careful record was taken as to the amount of top discard originally occurring on the ingots from which these "A" rails were rolled, and it was found that the fractures thus produced represented amounts of from 8 to 25 per cent. from the top of the ingots. Chemical analyses for carbon (by combustion) were made on the pieces originally used for the nick and break test on these rails, so that a comparison could be obtained of the inspector's judgment as to segregation as evidenced by the fracture, and that indicated by analyses of the drillings taken from the junction of the head and web and the corner of the head. The chemical results obtained were:

TABLE 2.

Sample No.	Carbon (by combustion)		Per Cent. of Segregation.
	At corner of head.	At junction of head and web.	
1533–12	.66	.73	10.6
3366– 4	.63	.728	15.5
–11	.60	.81	35.0
3367– 7	.67	.636	–5.0
4433–17	.657	.724	10.2
5490– 4	.62	.727	17.2
– 5	.635	.70	10.2
– 6	.666	.656	–1.5
– 8	.63	.67	6.3
5497– 1	.643	.683	6.2
– 5	.65	.65	0.0
– 6	.66	.61	–7.6
– 8	.64	.686	7.2
– 9	.636	.645	1.4
–11	.636	.666	4.7
–14	.645	.635	–1.5
7451– 1	.66	.63	–4.5
– 4	.64	.65	1.5
– 8	.62	.62	0.0
–11	.63	.64	1.6
7452– 7	.64	.63	–1.5
–13	.62	.67	8.0
–16	.625	.643	2.8
7460– 9	.623	.60	–3.6
–16	.636	.61	–4.1

Second:

In order to demonstrate more fully the possibility of interior defects occurring even farther down in "A" rails, three of the accepted "A" rails were entirely broken up into short pieces, and each fracture was carefully examined. No fracture thus produced showed the presence of interior defect.

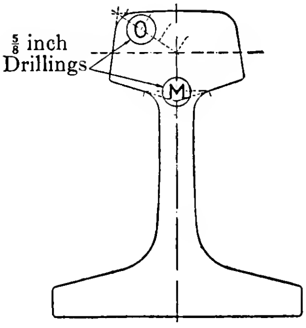
Third:

In order to more fully investigate this important matter, three "B" rails were selected, which had been rolled directly adjoining some of the "A" rails mentioned above in "First," and the top 9 ft. of each was broken into four pieces, with the result that none of the 12 fractures thus obtained at distances approximating 40 per cent. from the top of the ingots from which these rails were rolled, showed any signs of interior defect.

It will be noted that the nick and break test specification does not require a specific amount of discard from the top of the ingots, that matter being left, as it is under the A. R. E. A. specification, to the judgment of the mill management for regulating. The practice at Algoma in this respect was to continue shearing from the top of each ingot until the appearance of the front end of the blooms indicated that sound metal had been reached, and some ingots, therefore, showed more top discard than others. Bearing this practice in mind, the above special tests are, we think, fairly convincing of the fact that the fracture examined under the nick and break test specification is admirably indicative of conditions occurring in the rails directly represented. As illustrative of the above mentioned results of these special tests, we show photographs of picric acid etchings, with analyses, of representative rails that were tested as described, and these are especially interesting and worthy of close study, particularly in view of some conditions which will later be touched upon.

(See photographs of etchings, etc., on insertions.)

Early in 1915 the Pennsylvania Railroad System brought out a specification for rails which was later adopted, and a large tonnage subsequently rolled under its provisions. It contained, in addition to the drop test requirements, virtually the same as those above given for the A. R. E. A. specification, the following requirements as to chemical composition:



For Open-Hearth process, a check analysis will be made by the purchaser of a piece of rail representing a melt, after the rails from that melt have passed the physical requirements. On request of the inspector, and in his presence, the manufacturer shall furnish from one of the drop test pieces representing the melt, drillings satisfactory to the inspector, taken with a ⅝-inch drill, parallel to the axis of the rail, at a point one-third of the distance from the upper corner to the center of the head, as shown at location

"O." The analysis from these drillings shall conform to the chemical requirements specified, viz.:

Elements.	Per Cent.
Carbon	0.60 to 0.75
Phosphorus	Not to exceed 0.04
Manganese	0.60 to 0.90
Silicon	0.10 to 0.30

and failure to meet these requirements shall be sufficient cause for the rejection of the entire melt.

After the rail has passed the physical requirements, additional drillings will be taken from the same rail, and in the same manner as specified above, at the junction of the head and web, as shown by location "M." The carbon determination from these drillings shall be within 12 per cent. of the amount found at location "O." If the test from the top rail fails to meet this requirement, all top rails from the melt shall be rejected, and a similar determination shall be made from location "M" of a second rail. If this test fails, all the second rails from the melt shall be rejected, and a similar determination shall be made from location "M" of a third rail. If this test fails, all the remaining rails from the melt shall be rejected.

If, however, the segregation found at location "M" in any rail in a rolling exceeds 25 per cent., when determined as provided for above, the progressive testing of the second and third rails will not be permitted on any subsequent melts; but on such melts the failure of the top rail to pass the requirements provided for above will cause the rejection of the entire heat.

The intent of this specification is, obviously, to protect against the acceptance of segregated rails, such as are found among those rolled from the top of the ingot. The Pennsylvania practice regarding the physical test pieces is based on the principle that the fracture must show an actual pipe in order for rejection on account of interior defect to be made, it being considered that the above-mentioned chemical stipulations are sufficient to prevent shipment of rails whose fractures might also show segregation. The wisdom of these specifications has been questioned, because, as will be seen at a glance, the chemical analysis, whereby the degree of segregation is determined, is made on a piece of rail selected from an individual ingot of a heat. Thus it may happen that the one ingot selected may be the only one in the heat which was sufficiently bad to have required rejection, while, on the other hand, the assumption is equally possible that the ingot represented may have been the only good one in the heat.

It was but natural that a discussion of the merits of the nick and break test specification versus the Pennsylvania specification should ensue. Questions arose as to whether or not the examination of the fractures obtained under the nick and break test specification for the presence of segregation was sufficient to be used in lieu of the expensive plan adopted by the Pennsylvania, and to thus serve as protection against acceptance of segregated rails. As has been previously pointed out, there is nothing particularly new in the matter of judging the quality of steel from its fracture, and while we do not presume to say at this time that it is possible to judge accurately of the carbon content of the steel from an examination of a rail fracture, still we think it possible for a careful examination by an experienced man to reveal such a possible disparity in the distribution of the carbon of the metal throughout the section as to determine whether or not the rail is harmfully segregated. Thus we again emphasize the importance of the accurate judging of the fractures produced by the nick and break test, and the necessity of having experienced and competent men for that duty.

In order to compare the results obtained by judging segregation from the fracture with those obtained by the method laid down by the Pennsylvania specification, the following analyses for carbon by combustion were made on nick and break test pieces selected at random, the fractures of which in some cases showed no signs of segregation to the eye, while in other cases they did. The drillings for analyses were taken from locations approximating those laid down by the Pennsylvania specification, but it should be noted that because of a considerable difference

TABLE 3.

ANALYSES OF NICK AND BREAK TEST FRACTURES NOT SHOWING SEGREGATION, AND ON WHICH "A" RAILS WERE ACCEPTED.

Sample No.	Carbon (combustion) Penn. location.		Per Cent. Segregation.	Carbon at center of web.
	O	M		
1577– 1	.55	.707	28.5	.76
– 2	.52	.73	40.4	.76
– 5	.51	.60	17.6	.67
– 8	.503	.645	20.7	.75
–10	.50	.76	52.0	.80
–12	.525	.593	12.9	.57
–15	.52	.69	32.6	.785
–16	.534	.73	36.7	.695
2509–10	.62	.64	3.2	.69
–12	.62	.645	4.0	.66
–13	.62	.645	4.0	.62
3367– 1*	.65	.75	15.4	...
– 2	.58	.64	10.3	...
3426– 2	.59	.66	11.8	.71
– 5	.522	.715	36.9	.74
–11	.637	.66	3.6	.66
–15	.572	.593	3.6	.60
–16	.61	.655	7.3	.66
3427– 1	.59	.614	4.0	.62
– 7	.59	.62	5.0	.64
–12	.593	.61	2.8	.66
6446– 8	.61	.59	3.2	.60
–10	.61	.66	8.2	.705
–11	.60	.61	1.6	.64
–13	.62	.66	6.4	.64
7460– 1*	.686	.64	–6.7	...

*Regular drop test pieces as would have been analyzed under the Pennsylvania specification.

TABLE 4.

ANALYSES OF NICK AND BREAK TEST FRACTURES WHICH SHOWED SEGREGATION AND ON WHICH "A" RAILS WERE REJECTED.

Sample No.	Carbon (combustion) Penn. location		Per Cent. Segregation
	O	M	
1578- 3	.63	.73	15.8
-16	.65	.73	12.3
2510- 5	.675	.70	3.7
3427- 5	.604	.645	6.8
-13	.574	.62	8.1
3428-10	.68	.80	17.6
3429- 1	.59	.94	59.3
6445- 3	.64	.735	14.8
- 9	.637	.71	11.4
-11	.61	.77	26.2
-12	.65	.71	9.2
6447-16	.543	.81	49.1

between the section of the Pennsylvania rail and that which was being tested, there is a slight, but probably immaterial, difference with respect to the location of drillings called "M"; with the result that on the rails tested, the two holes, "O" and "M," are slightly nearer together than would be the case on the Pennsylvania section of rail.

It will be observed that in some cases the chemical analyses for carbon made on drillings taken in practical accord with the Pennsylvania plan as to location and shown in Tables 3 and 4 (to which can also be added Table 2), do not sustain the inspector's judgment on the question of segregation as evidenced by the fracture of the nick and break test; for some samples showed segregation by chemical analyses, while their fractures were considered good, and vice versa. The analyses of all the samples taken that have the percentage of carbon at the junction of the head and web more than 12 per cent. of that at the corner of the head (this being the adopted limit of the Pennsylvania specification) are repeated in Table 5 for reference; and those analyses representing the contrary of the case, that is, where the fracture showed segregation, but which condition was not confirmed by the analyses, are also shown.

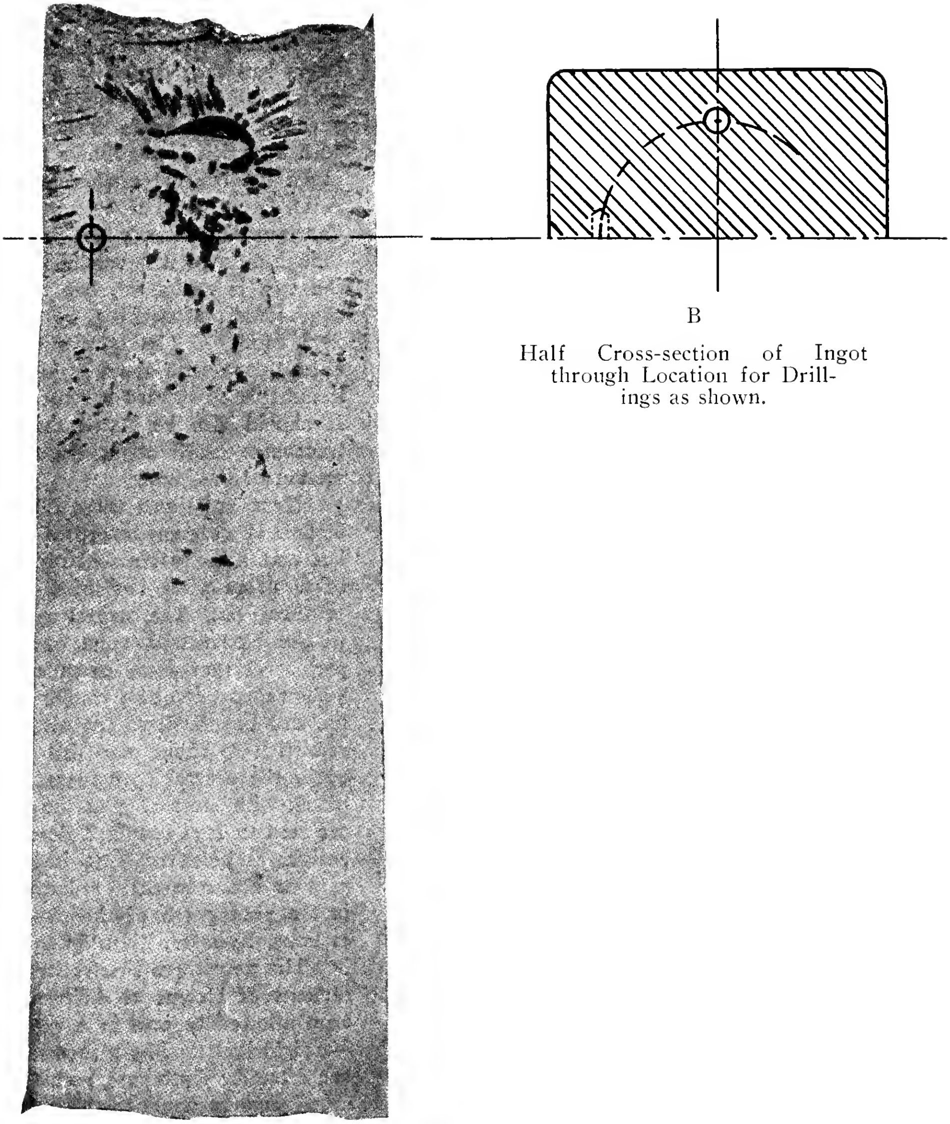
This condition of affairs seemingly would show that the nick and break test specification is unreliable on the ground that it is impossible to positively depend on the fractures obtained under it to evidence the question of segregation; and so it would appear that, based on the character of the fracture, some rejections were made that should not have been made; while, on the other hand, some rails were accepted that should have been rejected, bearing in mind, of course, the limitations regarding segregation as adopted by the Pennsylvania specification. Assuming that this was the case, and it is not unreasonable to expect that a few errors would be made in the judging of something like 20,000 fractures, it is worthy of note that the loss of rejected rails to the manufacturer, and the additional protection afforded to the purchaser are respectively so little and so great by comparison with the A. R. E. A. specification, as to more than offset any objections raised on this ground. Notwithstanding, we do not believe that the seemingly paradoxical situation, as forecasted by Table 5, exists to the extent indicated, and we feel confident that a further study of the facts will throw new light on the situation and tend to dispel the presumption of inaccuracy. At the outset we submit that the taking of drillings and the making of analyses from as few as two definitely prescribed locations on the cross-section of a rail, does not by any means positively determine the presence of harmful or dangerous segregation.

TABLE 5.

Representing	Sample No.	Carbon (combustion) Penn. location		Per Cent. Segregation.
		O	M	
Original nick and break tests of accepted "A" rails. See Table 2.	3366- 4	.63	.728	15.5
	-11	.60	.81	35.0
	5490- 4	.62	.727	17.2
Original nick and break tests of accepted "A" rails. See Table 3.	1577- 1	.55	.707	28.5
	- 2	.52	.73	40.4
	- 5	.51	.60	17.6
	- 8	.503	.645	20.7
	-10	.50	.76	52.0
	-12	.525	.593	12.9
	-15	.52	.69	32.6
	-16	.534	.73	36.7
	3367- 1	.65	.75	15.4
	3426- 5	.522	.715	36.9
Original nick and break tests which showed segregation causing rejection of "A" rails. See Table 4.	2510- 5	.675	.70	3.7
	3427- 5	.604	.645	6.8
	-13	.574	.62	8.1
	6445- 9	.637	.71	11.4
	-12	.65	.71	9.2

Many investigations as to piping and segregation in ingots have been made, and many published reports are available showing the results and conclusions reached. Invariably, these investigations have been primarily for the purpose of finding the extent of piping and segregation, especially with respect to the depth in the ingot to which these conditions may extend, and, in addition, the general shape and size of the localities affected. Such studies commonly have been made on vertical longitudinal sections of ingots; that is, the ingots or blooms have been split near their vertical axes, and probably one plane of the axial section etched, while the other plane has been carefully analyzed by taking a large number of drillings from various locations. Among the conclusions reached is the fact that the pipe is a kind of inverted bell-shaped cavity more or less frequently bridged over in places and extending to various depths in different ingots. Further, it has been concluded that the region of segregation is largely complementary to the cavity or pipe, that is, the mass of segregated metal is chiefly a belly-shaped portion enclosing the cavity and other parts of the physically unsound metal generally existing in the top of ingots and extending downward to various depths. Strangely, these conclusions have been reached, as the published investigations would indicate, without a consideration or study by chemical survey of cross-sections of ingots at various distances from their tops, and the lack of such studies would appear to raise an important question involving segregation.

To make clear the question now raised, Fig. 4 is submitted, in which "A" shows an ingot originally examined at the Watertown Arsenal, and reported in their "Tests of Metals" for 1909. It is a vertical longitudinal section one inch from the axis. With customary methods of making a chemical survey, we will assume that the carbon at the location shown by the circle (viz., on drillings taken at right angles to the plane of the section of the ingot) is .70 per cent. Assuming now that a half cross-section of the ingot was taken through this circle as shown at "B" in Fig. 4, and it by no means follows that the carbon content at a point equidistantly located from the axis on the cross-section, as shown by the circle there, would also be .70 per cent.; in fact, we think conditions are very much against such being the case. In the first place, the fact that most ingots cast are not strictly square, and that the rate of cooling is retarded more in one direction than in the other, would no doubt tend to prevent anything like a uniform distribution of, for example, carbon, on cross-sections near the top, and with respect to equal distances from the axes. In the second place, steel solidfying in the molds does not always show the effects of such complete deoxidation as to make it lie entirely quiet, a condition frequently resulting in the boiling or raising up of a portion of the top of the ingots and producing the commonly styled "boiled" or "horny topped" ingots. With such ingots it seems reasonable to assume that there must be strong eddies or currents created in a vertical direction in parts of the solidifying steel, with the result that those metalloids possessing the segregating characteristics would seek, as long as it is possible for them to do so, the paths of least resistance, and would ultimately become solidified in the vertical channels so formed. Thus the conclusion is reached that the cross-section of an ingot, if critically examined chemically, would be found to show largely varying amounts of carbon, phosphorus, and sulphur in very small areas, arranged in some manner entirely impossible of predetermination, and dependent on unforeseen and uncontrollable conditions, for which each ingot would of course be a unit unto itself.



A

Vertical Longitudinal Section of Watertown Ingot.

B

Half Cross-section of Ingot through Location for Drillings as shown.

Fig. 4.

That such conditions do actually exist is evident from a chemical survey of a cross-section of a rail, being No. 4433-17, sample No. 5, shown among the photographs of etchings. The results of this survey are shown on Fig. 5. The amounts of carbon and phosphorus are given for each location, the small holes having been made with a ¼-inch drill, and the large holes, which were the original locations of the drillings, having been made with the customary ⅝-inch drill. Regardless of the characteristic segregated core, the lack of a uniform distribution of carbon and phosphorus is plainly seen, showing that within reasonably small areas the segregating elements may vary considerably. It will be observed that the average carbon for the major portion of the head is .04 per cent. less than the average carbon of a similar portion of the base, a condition probably often created, and which, if as in this case, was possible of a definite reversal, would result in producing rails with hard steel heads and somewhat softer steel bases, theoretically making very desirable rails.

As further proof of the peculiar segregating conditions in cross-sections, we give Fig. 6, in which "X" represents the base of a rail which broke at the drop test without exhibiting the slightest sign of segregation, but which showed a fracture seeming to indicate by radiating lines its progress from a common point, something after the fashion shown. Fractures showing these characteristics are of almost daily occurrence, sometimes the lines radiating from a common point in the head of the rail, and at other times, as shown, from a common point in the base of the rail. "Y" shows the locations on this piece of rail of drillings for analyses taken with a ⅛-inch drill all within the area of a ⅝-inch circle, and from the results of carbon obtained on these samples it will be seen that there is a maximum difference of .14 per cent. in the five samples. If drillings had been taken with a ⅝-inch drill with the central hole as a center, it is reasonable to assume that the carbon of such would have been the average of all, which was .835 per cent., notwithstanding that more careful examination shows that within the small area of this ⅝-inch drill, the carbon actually did vary .14 per cent. No doubt the small area of high carbon was the actual nucleus of the original fracture.

Thus it will be seen that the elements which segregate in ingots doubtless occur to a large extent in vertical lines or striations, after the manner of stalactites hanging from an imaginary roof which is really the top of the ingot. The question of segregation then as determined by drillings taken, for example, from the corner of the head of a rail and the junction of the head and web, may or may not be representative of the actual conditions, depending upon whether the drills happen to find striæ of the segregating metalloids.

Going back to the question raised by Table 5, we had several new nick and break test fractures made on pieces of the original crop ends used by the inspector, and we found that in every case the inspector's judgment as to the appearance of segregation on the fractures was correct. Similarly, the analyses of several pieces were duplicated carefully,

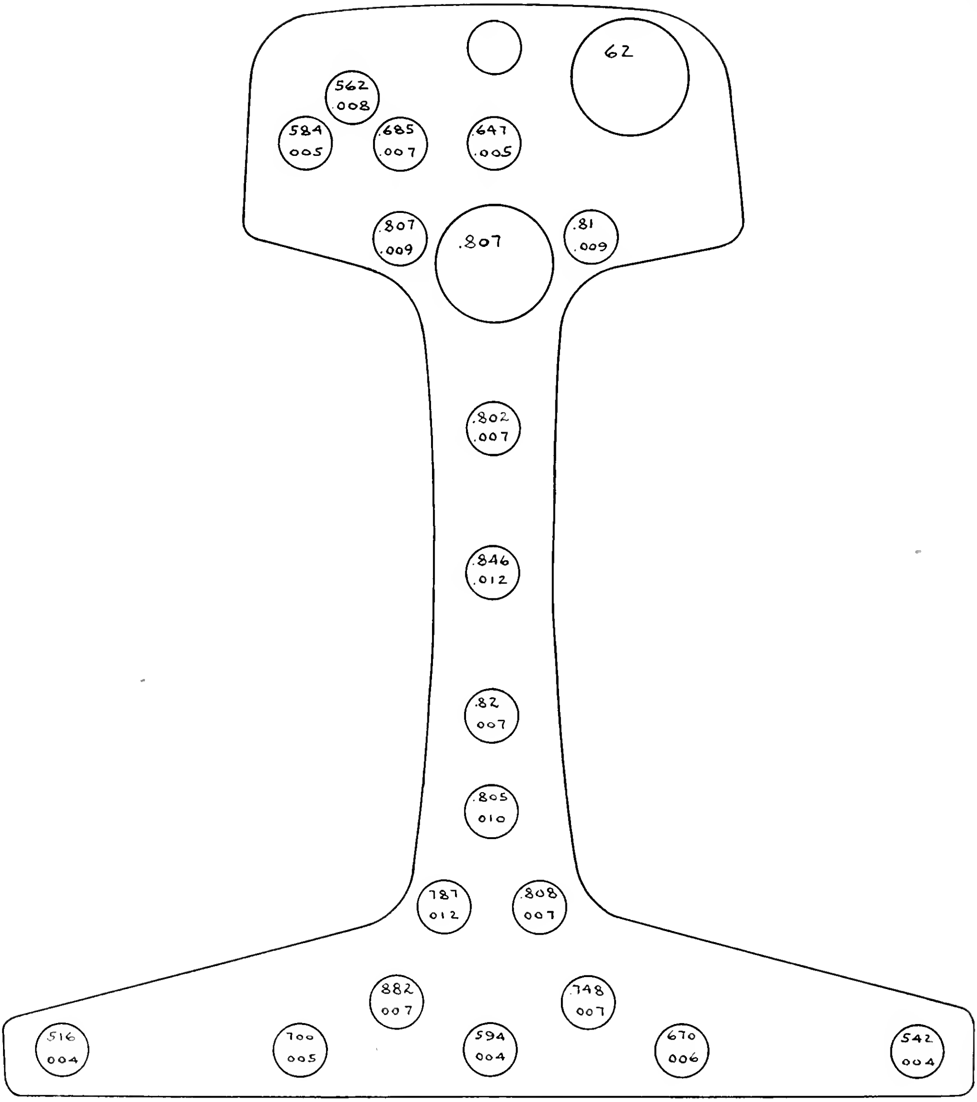
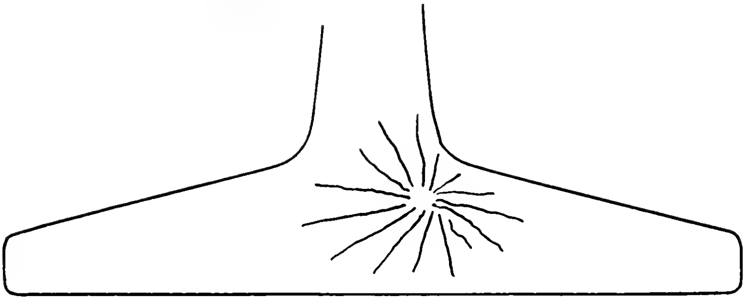
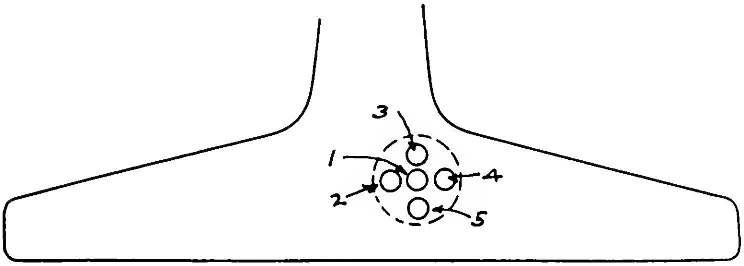


Fig. 5.

Carbon and Phosphorus at Locations Shown on Section of Rail from Heat 4433; 16 Per Cent. from Top of Ingot No. 17.



"X"—showing a characteristic fracture of rails broken under the drop test which seemingly has lines radiating from a nucleus.



"Y"—showing how drillings were taken with an ⅛-in. drill, with No. 1 at the above-mentioned nucleus and Nos. 2, 3, 4 and 5 surrounding it. All of the 5 holes would have been enclosed by a ⅝-in hole.

The carbon at No. 1 was .816 per cent.
The carbon at No. 2 was .76 per cent.
The carbon at No. 3 was .908 per cent.
The carbon at No. 4 was .883 per cent.
The carbon at No. 5 was .812 per cent.
Average carbon .... .835 per cent.

Fig. 6.

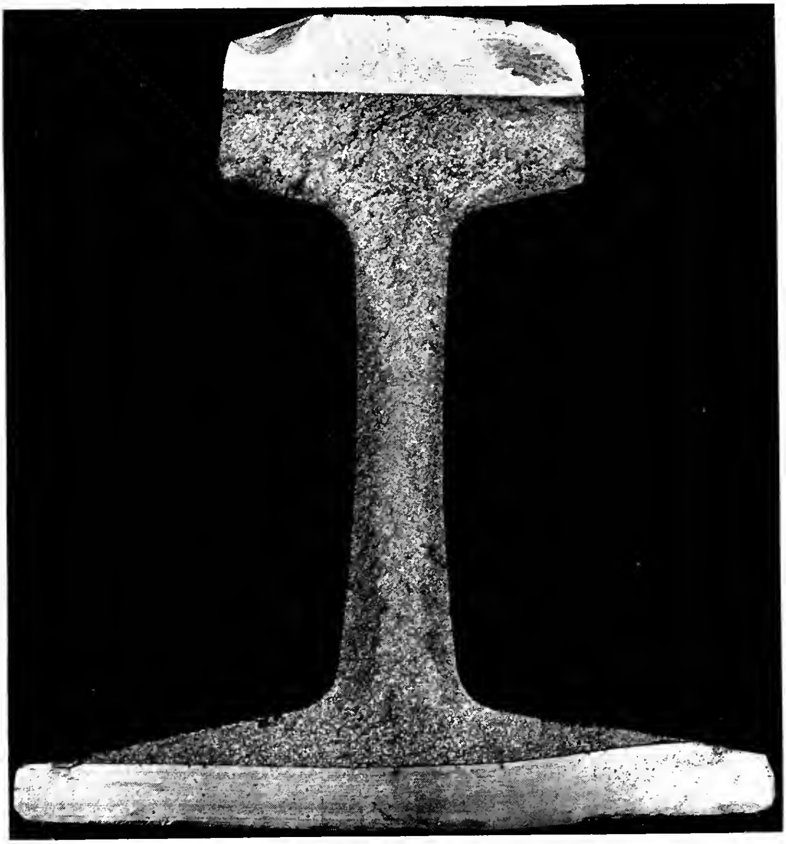


Fig. 7.

Photograph No. 1057. Fracture of Sample Rail No. 6445-9, Showing Segregation in the Center of the Web, but Which Does Not Extend Into the Head.

Pennsylvania Location.	Per Cent. Carbon by Combustion.	
Corner of head	.637	
Junction of head and web	.71	
Per cent. of segregation		11.4
Center of web	.78	
Per cent. of maximum segregation		22.4

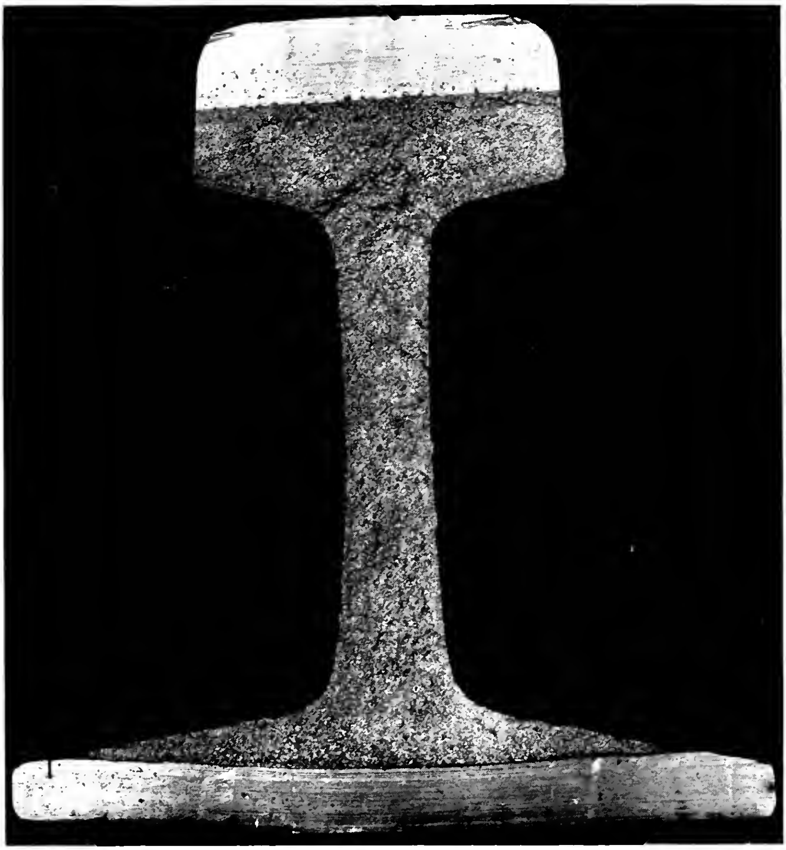


Fig. 8.

Photograph No. 1058. Sample No. 1577-2. Fracture Shows Absolutely Clear of Segregation.

Pennsylvania Location.	Per Cent. Carbon by Combustion.	
Corner of head	.52	
Junction of head and web	.73	
Per cent. of segregation		40.4
Center of web	.76	
Per cent. of maximum segregation		46.1

with no appreciable difference in the results as above reported. With respect especially to the pieces representing "A" rails that were rejected on the original nick and break test, it was found that the evidence of segregation seen in the fracture was localized in the area of the web, and plainly did not extend into the head sufficiently to be reached when taking drillings for analyses from the prescribed locations. Thus the Pennsylvania specification would fail to detect segregation in those instances, yet the rails plainly were segregated.

This condition is shown by Fig. 7, which is a photograph of an actual fracture of the second nick and break test made as above mentioned, and on which the fine grained metal in the web plainly shows segregation. The analysis of this sample shows that the segregation evidently tapers off near the junction of the head and web so that the drillings taken from the prescribed locations do not reveal the true extent of the segregation as manifested when taking drillings from the center of the web.

With respect to the contrary condition, that is, where the fracture is clear of segregation, but where chemical analysis shows it to exist, attention is directed to Fig. 8, which is also a photograph of an actual fracture as produced by the second nick and break test above mentioned. It is absolutely clear of signs of segregation, but chemical analysis shows it to be segregated to the extent of 40.4 per cent. for carbon as between the corner of the head and the junction of the head and web, while the maximum segregation, considering drillings from the center of the web, amounts to 46.1 per cent. The results obtained indicate that the drilled locations happened to contain striations of the segregating elements, particularly carbon, and that, as in the case covered in connection with Fig. 6, the high percentage of carbon exists in such minute areas as to fail to be detected by a close examination of the original fracture.

In conclusion, we express the hope that further investigation and study of the cross-sectional results of segregation will be made, and the effects of segregation in rail sections more fully established. We appreciate, of course, the importance of having any accepted test an accurate gage of the degree of segregation that might be harmful to the serviceability of the rails; and, at the same time, based on the observation of the application of the nick and break test to so large a production of rails, we consider that it has clearly established its reliability as a protection against the acceptance of rails having pipes, laps or any interior mechanical defects. We think the nick and break test made on every ingot is a step forward in the testing of manufacture, and insures greater protection to the purchasers of steel rails than is given by any other existing specification; and, at the same time, it conserves the interests of the makers, and is executed with a minimum of expenditure of money.

PLATE 1

HEAT NO. 5497, INGOT NO. 1, SAMPLE NO. 7, PHOTOGRAPH NO. 1036.

Etching of a section 6 ft. 6 in. from top of "B" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 35.2 per cent.

Analysis.	Corner of head.	Junction of head and web.
Carbon by combustion	.64	.66
Per cent. of segregation	3.1	

PLATE 1

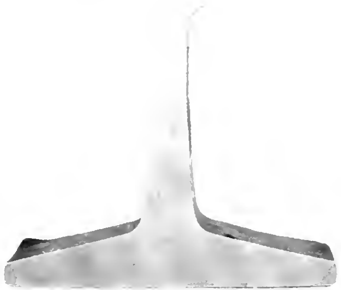
Heat No 5407, Ingot No 1, Sample No 1 Photograph No 1032

Etching of a section adjacent to the fracture obtained on the nick and break test which showed no sign of interior defect

Approximate distance from top of ingot, 12 per cent

Analysis	Corner of head	Junction of head and web	Ladle test
Carbon by combustion	.643	.683	.63
Phosphorus	.008	.009	.012
Manganese	.80	.83	.73
Silicon	.13	.15	.133
Sulphur	.045	.053	.046

Per cent. of segregation of carbon 6.2



Heat No 5407 Ingot No 1 Sample No 3, Photograph No 1033

Etching of a section 3 ft 6 in from top of "A" rail The fracture showed no sign of interior defect

Approximate distance from top of ingot 14 per cent

Heat No 5407 Ingot No 1 Sample No 5, Photograph No 1034

Etching of a section 7 ft from top of "A" rail The fracture showed no sign of interior defect

Approximate distance from top of ingot 16 per cent

Analysis	Corner of head	Junction of head and web
Carbon by combustion	.65	.72
Per cent of segregation	10.7	

Heat No 5407 Ingot No 1, Sample No 6 Photograph No 1035

Etching of a section from top of "B" rail The fracture showed no sign of interior defect

Approximate distance from top of ingot, 31.5 per cent

Heat No 5407, Ingot No 1, Sample No 7 Photograph No 1036

Etching of a section 6 ft 6 in from top of "B" rail The fracture showed no sign of interior defect

Approximate distance from top of ingot, 35.2 per cent.

Analysis	Corner of head.	Junction of head and web
Carbon by combustion	.64	.66
Per cent. of segregation	3.1	

PLATE 2

HEAT NO. 5497, INGOT NO. 15, SAMPLE NO. 3, PHOTOGRAPH NO. 1049.

Etching of a section from bottom of "A" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 30.6 per cent.

Analysis.	Corner of head.	Junction of head and web.
Carbon by combustion	.65	.70
Per cent. of segregation	7.7	

HEAT No. 5407, INGOT No. 15, SAMPLE No. 1-A, PHOTOGRAPH No. 1046.

Etching of a section adjacent to the fracture obtained on the nick and break test which showed no sign of interior defect.

Approximate distance from top of ingot, 1.2 per cent.

Analysis	Corner of head	Junction of head and web	Ladle test
Carbon by combustion	634	69	63
Phosphorus	009	010	012
Manganese	77	79	73
Silicon	15	14	133
Sulphur	042	045	046

Per cent. of segregation of carbon 8.8

HEAT No. 5407, INGOT No. 15, SAMPLE No. 1-B, PHOTOGRAPH No. 1047.

Etching of a section from top of "A" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 12.2 per cent.

HEAT No. 5407, INGOT No. 15, SAMPLE No. 2, PHOTOGRAPH No. 1048.

Etching of a section from middle of "A" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 21.4 per cent.

Analysis	Corner of head	Junction of head and web
Carbon by combustion	625	68
Per cent. of segregation	8.8	

HEAT No. 5407, INGOT No. 15, SAMPLE No. 3, PHOTOGRAPH No. 1049.

Etching of a section from bottom of "A" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 30.6 per cent.

Analysis	Corner of head	Junction of head and web.
Carbon by combustion	65	70
Per cent. of segregation	7.7	

PLATE 3

Heat No. 7451, Ingot No. 11, Sample No. 2, Photograph No. 1054.

Etching of a section 4 ft. from top of "A" rail. Showed segregated on fracture.

Approximate distance from top of ingot, 14.5 per cent.

Analysis.	Corner of head.	Junction of head and web.	Center of web.
Carbon by combustion..........	.65	.671	.757
Per cent. of segregation........	3.2		
Per cent. of segregation........	16.0 (maximum)		

HEAT NO. 7451, INGOT NO. 11, SAMPLE NO. 2, PHOTOGRAPH NO. 1055

Etching of a section adjacent to the fracture obtained on the nick and break test which showed no sign of interior defect.

Approximate distance from top of ingot, 12 per cent.

Analysis	Corner of head.	Junction of head and web.	Ladle test.
Carbon by combustion	.63	.64	.65
Phosphorus	.012	.012	.010
Manganese	.73	....	.75
Silicon	.12	....	.122
Sulphur	.023	....	.038

Per cent of segregation of carbon 1.6

HEAT NO. 7451, INGOT NO. 11, SAMPLE NO. 2, PHOTOGRAPH NO. 1054.

Etching of a section 4 ft. from top of "A" rail. Showed segregated on fracture.

Approximate distance from top of ingot, 14.5 per cent.

Analysis.	Corner of head.	Junction of head and web.	Center of web.
Carbon by combustion... . .	.65	.671	.757

Per cent. of segregation........ 3.2

Per cent. of segregation.... ...16.0 (maximum)

PLATE 4

HEAT NO. 4433, INGOT NO. 17, SAMPLE NO. 7, PHOTOGRAPH NO. 1041.

Etching of a section 6 ft. 6 in. from top of "B" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 35.2 per cent.

Analysis.	Corner of head.	Junction of head and web.
Carbon by combustion	.655	.755
Per cent. of segregation	15.3	

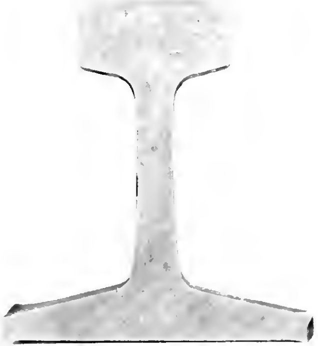
HEAT NO. 4433, INGOT NO. 17, SAMPLE NO. 1, PHOTOGRAPH NO. 1037

Etching of a section adjacent to the fracture obtained on the nick of break test which showed no sign of interior defect.

Approximate distance from top of ingot 12 per cent.

Analysis	Corner of head	Junction of head and web	Ladle test
Carbon by combustion	.657	.724	.60
Phosphorus	.007	.008	.017
Manganese	.61	.62	.67
Silicon	.02	.025	.134
Sulphur	.030	.041	.034

Per cent. of segregation of carbon 10.2



HEAT NO. 4433, INGOT NO. 17, SAMPLE NO. 3, PHOTOGRAPH NO. 1038

Etching of a section 3 ft. 6 in. from top of "A" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot 14 per cent.

HEAT NO. 4433, INGOT NO. 17, SAMPLE NO. [illegible], PHOTOGRAPH NO. [illegible]

Etching of a section 7 ft. from top of "A" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot 16 per cent.

Analysis	Corner of head	Junction of head and web
Carbon by combustion	.62	.807
Per cent. of segregation	30.1	

HEAT NO. 4433, INGOT NO. 17, SAMPLE NO. 6, PHOTOGRAPH NO. 1040

Etching of a section from top of "B" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot [illegible] per cent.

HEAT NO. 4433, INGOT NO. 17, SAMPLE NO. 7, PHOTOGRAPH NO. 1041

Etching of a section 6 ft. 6 in. from top of "B" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 35.2 per cent.

Analysis	Corner of head	Junction of head and web
Carbon by combustion	.655	.755
Per cent. of segregation	15.3	

PLATE 5

HEAT NO. 5497, INGOT NO. 2, SAMPLE NO. 3, PHOTOGRAPH NO. 1045.

Etching of a section from bottom of "A" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 30.6 per cent.

Analysis.	Corner of head.	Junction of head and web.
Carbon by combustion	.624	.69
Per cent. of segregation	10.5	

HEAT No. 5407, INGOT No. 2, SAMPLE No. 1-A, PHOTOGRAPH No. 1042

Etching of a section adjacent to the fracture obtained on the nick and break test which showed no sign of interior defect.

Approximate distance from top of ingot, 12 per cent.

Analysis	Corner of head	Junction of head and web	Ladle test
Carbon by combustion	65	675	63
Phosphorus	009		012
Manganese	80		73
Silicon	12		133
Sulphur	043		046

Per cent. of segregation of carbon 3.8

HEAT No. 5407, INGOT No. 2, SAMPLE No. 1-B, PHOTOGRAPH No. 1043

Etching of a section from top of "A" rail. The fracture showed no sign of interior defect.

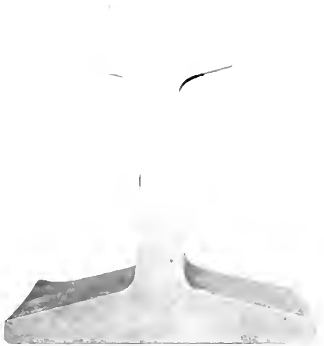
Approximate distance from top of ingot, 12.2 per cent.

HEAT No. 5407, INGOT No. 2, SAMPLE No. 2, PHOTOGRAPH No. 1044

Etching of a section from middle of "A" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 21.4 per cent.

Analysis	Corner of head	Junction of head and web
Carbon by combustion	65	655
Per cent. of segregation	8	



HEAT No. 5407, INGOT No. 2, SAMPLE No. 3, PHOTOGRAPH No. 1045

Etching of a section from bottom of "A" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 30.6 per cent.

Analysis	Corner of head	Junction of head and web.
Carbon by combustion	624	69
Per cent. of segregation	10.5	

PLATE 6

HEAT No. 7460, INGOT No. 4, SAMPLE No. 3, PHOTOGRAPH No. 1053.

Etching of a section from bottom of "A" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 30.6 per cent.

Analysis.	Corner of head.	Junction of head and web.
Carbon by combustion	.61	.65
Per cent. of segregation	6.5	

HEAT No. 7400, INGOT No. 4, SAMPLE No. 1-A, PHOTOGRAPH No. 1050

Etching of a section adjacent to the fracture obtained on the nick and break test which showed no sign of interior defect.

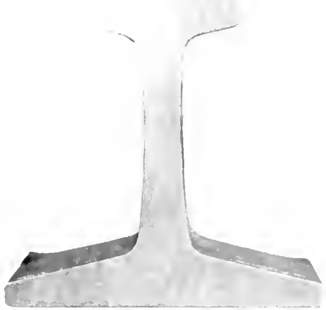
Approximate distance from top of ingot, 12 per cent.

Analysis	Corner of head	Junction of head and web	Ladle test
Carbon by combustion	.666	.733	.65
Phosphorus	.009		.014
Manganese	.70		.78
Silicon	.18		.130
Sulphur	.036		.038
Per cent. of segregation of carbon		10.0	

HEAT No. 7400, INGOT No. 4, SAMPLE No. 1-B, PHOTOGRAPH No. 1051

Etching of a section from top of "A" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 12.2 per cent.



HEAT No. 7400, INGOT No. 4, SAMPLE No. 2, PHOTOGRAPH No. 1052

Etching of a section from middle of "A" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 21.4 per cent.

Analysis	Corner of head	Junction of head and web
Carbon by combustion	.653	.673
Per cent. of segregation	3.0	

HEAT No. 7400, INGOT No. 4, SAMPLE No. 3, PHOTOGRAPH No. 1053

Etching of a section from bottom of "A" rail. The fracture showed no sign of interior defect.

Approximate distance from top of ingot, 30.6 per cent.

Analysis	Corner of head	Junction of head and web
Carbon by combustion	.61	.65
Per cent. of segregation	6.5	

REPORT OF COMMITTEE XVI—ON ECONOMICS OF RAILWAY LOCATION.

JOHN G. SULLIVAN, *Chairman;*	C. P. HOWARD, *Vice-Chairman;*
F. H. ALFRED,	FRED LAVIS,
WILLARD BEAHAN,	J. DEN. MACOMB, JR.,
R. N. BEGIEN,	S. S. ROBERTS,
MAURICE COBURN,	E. C. SCHMIDT,
D. F. CRAWFORD,	A. K. SHURTLEFF,
A. C. DENNIS,	L. L. TALLYN,
R. D. GARNER,	WALTER LORING WEBB,
A. S. GOING,	H. C. WILLIAMS,
F. W. GREEN,	M. A. ZOOK,
P. M. LABACH,	*Committee.*

To the Members of the American Railway Engineering Association:

Your Committee on Economics of Railway Location is not in shape to submit any conclusions or recommendations this year, and therefore reports progress.

Sub-Committee No. 4, under Prof. E. C. Schmidt as Chairman, did some work and sent out a circular, but is not in position at present to present information from which we can draw conclusions. Sub-Committee No. 5, under Chairman P. M. LaBach, made a study and submitted the result of freight locomotive tests on the Logansport Division of the Pennsylvania Lines made in 1912. This shows results for special conditions and are very instructive. It was thought advisable, however, not to publish this report at this time.

The Chairman of the Committee made a careful study of the statistics of coal consumption in freight service on the Western Lines of the Canadian Pacific Railway for the past eight years. These studies have convinced him that instead of attempting to base coal consumption directly on the amount of work done, that it is better to divide the coal into two factors, one varying directly with the amount of work done and the other varying with the engine miles run. As a result of these studies, the following formulæ have been adopted for Western Lines on the Canadian Pacific Railway:

> Single-Track Operation.—Fairly busy lines, 3.5 lbs. coal per calculated horsepower hour, plus 70 lbs. coal per engine miles run.
>
> Double-Track Operation.—3 lbs. coal per calculated horsepower hour, plus 60 lbs. coal per engine miles run.

The above figures are an average for the year, for conditions on the Canadian Pacific Railway Western Lines, using engines equipped with superheaters and having drawbar pull varying from 36,000 to 42,000 lbs. each. The calculated horsepower is the work done overcoming resistance, lifting loads from a lower to a higher elevation and overcoming curve resistance. Acceleration and work done running air pumps being indeterminate, was not taken into account in the calculated horsepower hours. The amount of coal per engine miles run covered the above work besides coal used in keeping steam up in locomotives, burned at sidetracks or wasted at roundhouses.

Respectfully submitted for the Committee by

John G. Sullivan, *Chairman.*

DISCUSSION

DISCUSSION ON SIGNALS AND INTERLOCKING.

(For Report, see pp. 65-75.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON SIGNALS AND INTERLOCKING.

C. C. Anthony.	C. E. Lindsay.
Chas. S. Churchill.	H. R. Safford.

The President:—The first Committee to present a report is the Committee on Signals and Interlocking. The Committee will now please come forward and take their places on the platform.

Mr. C. C. Anthony (Pennsylvania Railroad):—The report is found in Bulletin 181, at page 65. Of the subjects assigned to the Committee, No. 2 is, "Continue the study of economics of labor in signal maintenance." A final report is now submitted on that subject. As stated at the bottom of page 65, a progress report was submitted in 1914. The keynote of this report will be found in the conclusion near the top of page 67 and that is that cooperation rather than combination of forces is the best means for attaining efficiency and economical results. If there is any discussion on this report we shall be glad to hear it.

The President:—This Committee has made no definite recommendations, as I understand. The report is submitted as information. If there are any questions anyone has to ask in regard to the report, the Chairman of the Committee will be glad to answer them.

Mr. Anthony:—If there is no discussion, I move that this report on economics of labor in signal maintenance be received as information and appear in the Proceedings.

(The motion carried.)

Mr. Anthony:—Subject 3 is, "Study the problem of signaling single-track roads with reference to the effect of signaling and proper location of passing sidings on the capacity of the line." The report on this subject begins on page 67. As stated in the introductory paragraph, the Sub-Committee to which this subject was assigned was very fortunate in securing the cooperation of Mr. F. L. Dodgson, Consulting Engineer of the General Railway Signal Company, who subsequently became a member of this Association and was made a member of that Sub-Committee. Mr. Dodgson has given a good deal of study to this subject and kindly presented to the Committee through the Sub-Committee an analysis of the location of passing sidings on single-track. This analysis, which begins on page 67 and continues to page 73, may seem slightly elementary at the start, but the Committee feels that it is a very valuable contribution on the subject, as it develops definite formulas for determining the proper locations of passing sidings—I might say the ideal locations—since in many cases the proper locations are impracticable; and, on the other hand, for determining the capacity of the line in trains of one class with a given arrangement of passing sidings.

I might say further that Mr. Dodgson has continued this work and has prepared a second chapter on the same subject, which is now ready for submission to the Railway Signal Association by its committee on Signaling Practice and we expect it will come before this Association next March.

That second chapter takes into account the conditions brought about by the movement of trains at different speeds and by the movement of passenger trains on fixed schedules.

I move that the report on capacity of single track be accepted by the Association as a progress report.

(The motion carried.)

Mr. Anthony:—Under Subject 4, following the action taken last year, the Committee presents a list of the specifications, standard drawings, etc., adopted by the Railway Signal Association in 1916—they were adopted in 1916 by letter-ballot, after the convention of 1915. As the Association last year accepted that list for publication in the Manual for the information of the members, the proposal of the Committee is that this list be accepted in the same way as supplementary to the list already in the Manual, so as to bring the information up to date.

There is one typographical error that I should like to call attention to, about the middle of page 74, under the heading "Masts, Signal," fourth line, "Supports and Caps"; the drawing number should be 1022 instead of 1023.

I now move that this list of the Railway Signal Association specifications and standards be accepted as information and published in the Manual for the information of the members.

(The motion carried.)

Mr. Anthony:—That finishes our report so far as completed material goes. Near the bottom of page 74 we state that we are unable to submit anything on requisites for switch indicators, Subject No. 5. We are studying that subject and have prepared revised requisites and statements of the uses of switch indicators which will cover both single-track roads and roads of two or more tracks. That revised report is now ready for submission to the Railway Signal Association and we expect it will be brought here next March.

Mr. H. R. Safford (Grand Trunk):—Mr. President, is it in order to make a suggestion in connection with the committee work for the future?

The President:—I believe it is.

Mr. Safford:—A great deal of difficulty is being met by railroads, at least the railroad with which I am connected, in working out agreements for interlocking plants due to the fact that there is not very much uniformity in expressions in such contracts covering obligations and the rights of the various companies. It is true that, in some of the states we are drifting into the practice of having all crossings covered by an order of the Commission, as in Canada, but the efforts which are being made to-day by the railroads to put into proper form a contract covering crossings and their protection, which have been in use a good many years, without proper agreement, we are finding a good deal of trouble due to the different practices as to responsibilities and obligations. I have reason to believe that some progress can be made along this line by this Committee. If it is proper for it to take that step it would be necessary for the Committee to work in some manner with the law departments of the different railroads, but I have reason to feel, from our experience before regulating bodies, that these boards would appreciate and be glad to get suggestions from the railroads along the lines of standardizing agreements. There seem to be three classes of crossing condition: (1), the simple crossing of the junior line and the senior line; (2), such a crossing with the addition of functions for the exclusive benefit of the senior line, and (3), where both lines are equally interested. This has gotten to be a very important subject in Canada and Michigan, and I presume in other states. I would like to suggest that it be taken up by the Committee and studied.

Mr. C. S. Churchill (Norfolk & Western):—The Committee on Outline of Work has put that subject down for recommendation to the Board at its meeting on Thursday as one of the subjects to be taken up. They propose to give it to the Committee on General Uniform Contract Forms, with the recommendations that they take it up with the Signals and Interlocking Committee.

The President:—For the information of Mr. Safford and members of the Association I will say that this subject is already before the Association. We have a Special Committee on Uniform General Contract Forms and that Committee has made a progress report this year. They say they can only report progress, but that they are considering forms for interlocking and railway crossing contracts, so that the matter is being taken care of, and the Committee on Outline of Work also has it in mind.

Mr. C. E. Lindsay (New York Central):—I would like to call attention to the last recommendation of the Committee, on page 75. The situation presented is like the play of Hamlet with Hamlet left out. The interlocking of drawbridges concerns the bridgeman, the signalman and the trackman. I move that the Committee on Track be added to the joint consideration of that subject.

The President:—I think all that is necessary to do is to refer this to the Committee on Outline of Work, and the matter will be brought to the attention of the Board at its meeting Thursday. Are there any further suggestions in regard to these recommendations for next year's work, or has anyone any suggestions to make with reference to the work of this Committee? If not, the Committee will be excused with the thanks of the Association.

DISCUSSION ON SIGNS, FENCES AND CROSSINGS.

(For Report, see pp. 77-88.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON SIGNS, FENCES, AND CROSSINGS.

C. W. Baldridge.	C. E. Lindsay.
J. L. Campbell.	Hunter McDonald.
W. C. Cushing.	G. J. Ray.
W. H. Elliott.	L. L. Sparrow.
E. A. Frink.	W. F. Strouse.

The President:—The next report is that of the Committee on Signs, Fences and Crossings, and will be presented by the Chairman, Mr. W. F. Strouse.

Mr. W. F. Strouse (Baltimore & Ohio):—The outline of work assigned the Committee will be found on page 77 of Bulletin 181. The only portion of the Manual considered this year was that part bearing on track construction and flangeways at street crossings and in paved streets, which was referred back to the Committee last year for further investigation. The results of our investigations this year will be found on the first seven pages of the report. In view of the many different forms of track construction in use and the variety of flangeways found by the Committee in its investigations, it feels that the subject is still worthy of further consideration, particularly that portion pertaining to flangeways in crossings of steam railroads and electric roads at street crossings. There seems to be considerable difference of opinion as to the advisability, from an economic standpoint, of the use of standard street paving, particularly the use of the concrete base under the ties and between the ties. This style of construction is expensive to install at first, and in case of re-surfacing or other work on the tracks, in whole or in part, its removal is required. A style of plank crossing was designed by a committee of railroad and city officials of Kansas City, several years ago, which is of rather cheap construction and seems to be proving satisfactory where used. A modified plan of this crossing is submitted with this report (Plate B), which the Committee recommends for adoption.

On page 81 are a series of conclusions prepared by the Committee in regard to track construction to meet different conditions. Since the report was prepared and submitted I received a communication relative to the use of 60-foot rails in paved streets, by electric railway companies, with no provision made for expansion or contraction. The question is raised as to whether this style of construction would be satisfactory in steam construction in paved streets, the point being that the fewer the joints the simpler the maintenance matters should be. This matter was brought to my attention after the report was made and I simply mention it so that the matter can be discussed if thought desirable by the members.

On page 83 and following the Committee submits some additional information on the matter of railway signs. This question was gone into rather fully several years ago, particularly the matter of laws relating to the use of crossing signs, trespass signs, etc. This year we present some additional information on signs governing the actions of railroad employés, that is, the matter of whistle posts, ring signs, etc.

On pages 86 and 87 there is given some additional information on the subject of concrete posts. The Committee was unable this year to secure any new information on that subject. The Committee recommends that the subject of flangeways be given further consideration next year and this year submits for adoption and inclusion in the Manual the crossing shown on Plate B.

I move the adoption and inclusion in the Manual of the crossing plan shown on Plate B.

The President:—There is a motion that Plate B, accompanying the report of this Committee, be adopted and included in the Manual. Are there any remarks to be made on this motion?

Mr. C. E. Lindsay (New York Central):—I want to call attention to the use of the word "standard" cross-section on Plate B. Unfortunately, in the Manual, it has crept in at a good many places. I think we all recognize the objection to that word, and I would like to have you accept a substitute, say merely "street or highway crossings" and "types of planking for street crossings."

The President:—I think the Committee is unanimous in accepting that suggestion. They are simply submitting these now as types of construction and that can be covered in the same way as we cover other items. We do not say "Standard cross-section of roadbed," but Class A roadbed; Class B roadbed; so that this can be considered in the same way. Instead of using the word "standard" they can say "crossing for light traffic or construction for light traffic, Class A," "Class B construction for heavy traffic." Would that be satisfactory to you?

Mr. J. L. Campbell (El Paso & Southwestern):—I raise the question of the advisability of placing this single-step in the Manual. I have no objection to this crossing, believing it is a good one and, under certain conditions, acceptable. However, it is far from covering the subject. It cannot be universally used. There are many places where different kinds of crossings would be required. It is not sufficiently permanent for some places. I do not wish to enter into an extended discussion of the merits of crossings at this time, but I do raise the points above indicated.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—I wish to second Mr. Campbell's motion and call attention to one or two other matters. In the first place, I do not like the trail form of flangeway for the reason that it necessarily runs all the water that accumulates on the crossing into the joint. You cannot carry the flange rail past the joint and necessarily all the water runs to the joint. We have had lots of flangeways constructed in this manner, but we are not building them to a very great extent at the present time. We are using planks trimmed out to fit against the rail, and instead of using a double plank for heavy traffic, as shown below, we strip the ties and lay the plank on the strips. We do this in order to get away from the heaving of the top plank, which often occurs with double plank. The water accumulates under the upper plank and it is difficult to get them fastened down good enough to prevent heaving.

These are the two objections which I desire to make. I appreciate that any sort of continuous metal flangeway necessarily has to be cut at the joints and therefore has the same objection of running water to the joints. If you have a 60-ft. rail at the crossing that objection is eliminated, but there are many objections to the use of 60-ft. rails or any rails longer than the standard.

Therefore, I would like to see the plan referred back to the Committee for further consideration.

Mr. C. W. Baldridge (Atchison, Topeka & Santa Fe):—There is one item the Committee appears to have overlooked in their table of costs at the top of page 83 where they have recommended the use of a 9-in. girder rail. The use of a 9-in. girder rail in crossings necessitates the use of compromise joints; and the compromise joints for connecting the ordinary track rail with a girder rail under contracts made a number of months ago cost about $8.50 each or about $34 for each crossing. If you add that cost to the cost of that girder rail as given in the table it will materially increase the cost of that type of flangeway.

Another factor which should be followed up in estimating the costs is the credits of the different types of material whenever they must come out of the track. A standard track rail headed in for a flangeway can be frequently used the second time. In the case of the girder rail flangeway, when it is necessary to remove the track rail, the flangeway must go to the scrap pile along with the track rail.

Another factor is in the case of any excess length of girder rail, longer than the necessary width of crossing, the flangeway is a part of the rail and is provided at an extra 40-cent per foot expense, and must go into the cost of crossing and be chargeable to the effective width of crossing, and it seems to me a careful consideration of the costs that enter into the use of girder rail in a crossing will show a considerably larger cost per foot than this table indicates.

Another item which comes to my mind from the objection just offered about the rail headed in or any type of continuous flangeway leading the water to the joint is that that can probably be overcome, ordinarily, at least, by drilling a few additional holes through the web of the rail that is headed in, and in that way permitting the water to pass through it.

The President:—I fear you have mistaken the meaning of that table at the top of page 83. If I understand that table it is intended to refer to construction longitudinally in a street, not covering just a single street crossing, but a long stretch in a street. In such cases as that, you would have a compromise joint at each end of the long stretch, which would change the figures a trifle, but not to any great extent.

Mr. Baldridge:—As I understand the report, that subject was brought up last year as to whether it shall apply both longitudinally and in crossings, and as I understand this report it is intended to apply both ways.

The President:—The Committee says not.

Mr. Strouse:—Near the bottom of page 81 mention is made of several types of track construction in paved streets, in which the girder rail is recommended, and that table is prepared with that in mind.

Mr. Lindsay:—On page 78, about the eighteenth line down, the Committee says there is no essential difference in the principle involved, that is, as between a girder rail running longitudinally and at a crossing. The Committee also says on page 82, about one-third way from the bottom: "The form of flangeway which most nearly meets all requirements, and at a moderate cost, is that provided by the girder rail now extensively used in the construction of tracks in paved streets, and to which attention has already been called in this and previous reports," giving the impression that this type of structure is desirable under certain conditions of crossings. I cannot concede the truth of that statement because I think the girder rail at a crossing, unless it is different from the girder rails of which we now know would not be safe at high-speed points. There is also the desirability of the continuity of the structure at a point of that kind.

The President:—I rather fear you have misread their meaning. It may not be entirely plain, but it seems to be the thought in this report that this kind of construction is only to be laid in long stretches in a street, and not just across a street crossing, and the Chairman of the Committee now bears me out in placing that construction on their report.

Mr. Campbell:—The Committee says on page 81 that the flangeway should be made with a continuous iron or steel filler. We have found on the El Paso & Southwestern, where a relaying rail is used for the flangeway, that we are able to make a thoroughly satisfactory filling for the flangeway by the use of a bitulithic composition of sand, stone and asphalt, or of concrete. It costs less than iron filler. It can be moulded to any desired form and dimension. If the Committee intended to suggest only one form of filler, I would not agree with it.

The Committee also says on page 81 that when the flangeway guard rail is set upright, the side of the head of the rail adjacent to the flangeway should be beveled to an angle of about 45 degrees to prevent horses' feet from getting trapped. We have not found that necessary. There is no case in our experience of over eight years in which a horse's foot was caught in any of our crossings. We have one crossing where the track is on a curve and in order to preserve the rail and prevent flange wear, the base of the guard rail was planed so that the clearance in the flangeway was only 2¼ inches, with the result that the flanges of the wheels do not touch either track rail.

This is mentioned to show that the guard rail may be set close enough to the track rail to avoid trouble with the horses without planing the guard rail. A close setting of the latter also makes a smooth riding crossing. The joints are important and should be carefully considered. If they could be eliminated on crossings, one objection to permanent construction would be removed. In the course of time, the joints will go down and make rough riding track which, however, is not usually very objectionable on crossings where the speed is slow. In case of asphalt pavements, we place brick liners along the outside of the track rail and along the inside of the guard rail. We have not found it practicable to maintain asphalt unbroken in direct contact with the track rail.

The Committee appears to be wedded to a girder rail weighing 141 ℔s. and 9 inches high. It would be better to make the specification for girder rail more general. For wood block pavement and other forms requiring paving blocks only a few inches deep, a rail 9 inches high is unnecessary. Nearly all modern paving surfaces may be amply accommodated by a standard track rail of a height equal to or greater than a 75-℔. rail.

The President:—Not unless you get the consent of the people in the municipality.

Mr. E. A. Frink (Seaboard Air Line):—I would like to support Mr. Campbell's motion that one design of crossing is not enough. In a good many cases the city will call for something more permanent than a plank crossing. A plank crossing may be more desirable from the railroad's point of view, but the city will not accept it. We find we have to provide more permanent crossings than plank crossings.

I notice that the Committee submitted a design used by the Montreal Tramway Company, and while they do not say so, I imagine that they present that as a possible and desirable form of a permanent crossing. It seems to me there are several objections to it. One is the use of a concrete base on top of ballast. I believe that the elasticity in the ballast will tend to break up the base. It will also be objectionable to carry the concrete below the ties for various reasons.

I notice that same design of the Montreal Tramway Company calls for a sand filler, and the modern tendency seems to be to use a cement mortar filler, as being more permanent and as preserving the surface of your pavement better. Therefore, if you are going to use a concrete base, I think you should also use the cement mortar filler.

The President:—The question has been called for on this motion to refer these proposed types of crossings back to the Committee with instructions that they should report further on them next year with such alternate types of construction as they may deem advisable, after having heard the discussion which has taken place.

(The motion carried.)

Mr. Strouse:—The Committee presents on page 83 a discussion of the principles governing the use of railway signs, and on page 86 it has given some further information in regard to concrete fence posts.

This is all submitted as information. There are no recommendations made. With your consent, this will be submitted as a progress report and as information.

On page 88 the Committee makes recommendations for next year's work.

The President:—Have you any suggestions to make for the benefit of the Committee? We would like suggestions for the work of the Committee on Signs, Fences and Crossings.

Mr. Lindsay:—I suggest that the display of caution signals and of slow signs be given consideration by this Committee for repairs of track and structures.

The President:—The Committee on Outline of Work will take note of that suggestion by Mr. Lindsay.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I would like to suggest the consideration of audible signals at highway crossings.

Mr. W. C. Cushing (Pennsylvania Lines):—Apparently the subject of concrete fence posts is considered by the Committee as exhausted in this report. I would like to know if it is the fact that it so regards it. In reading it over, I have gathered that it considers it as finished.

Mr. Strouse:—No, we do not consider it as finished, but we could not find any information that we considered as new this year.

Mr. L. L. Sparrow (Atlantic Coast Line):—I do not know whether it properly comes before this Committee, but in connection with tracks in paved streets, I suggest that some Committee should take up the question of turnouts in paved streets where we are not permitted to use the usual method of operating switches; where switchstands are objectionable; and where the ordinary split switch cannot be used.

Mr. W. H. Elliott (New York Central):—In reference to the matter of audible signs at highway crossings, these are generally controlled by track circuits, and it is my suggestion that this Committee confer with a Sub-Committee of the Committee on Signals and Interlocking on the subject.

The President:—Are there any other suggestions for the work of this Committee? If not, the Committee will be excused with the thanks of the Association for its work during the past year.

DISCUSSION ON WATER SERVICE.

(For Report, see pp. 89-97.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON WATER SERVICE.

A. F. Dorley.	W. C. Cushing.
R. A. Baldwin.	Geo. W. Kittredge.
J. L. Campbell.	C. E. Lindsay.

The President:—We will now take up the report of the Committee on Water Service, Mr. A. F. Dorley, Chairman. We will ask Mr. Dorley to outline the report of the Committee.

Mr. A. F. Dorley (Missouri Pacific):—The report of the Committee on Water Service will be found in Bulletin 181. The subjects assigned to the Committee for study are given on page 89. The first subject is a "Report on Cost of Pumping Water by Various Methods." The report on this subject will be found to begin on page 89 and includes the insert opposite page 96. A list of questions was sent to a large number of railroads by the Sub-Committee, who had this subject in hand, and the result of the canvass will be found in the insert. The Committee had hoped it could make some specific or, at least, general deductions from this information with a view to ascertaining the merits of various methods of supplying water on railways, but the information lacked uniformity to such an extent that the plan was found to be impracticable.

The method used for supplying water at any particular locality is usually determined not so much by the efficiency or lack of efficiency of any particular type of pumping unit, but rather by the conditions that are met and which must be overcome. Water is usually supplied, not where it is plentiful or easily obtained, but where it is needed. Rather than make any definite deductions the Committee submits the information with the hope that it will be of interest and value to the members in comparing the cost of water at one station on a given road with the cost of water at another station on the same road; or the cost of water at a station on one road with the cost of water at a station on another road where the conditions are the same or very similar.

The President:—Gentlemen, you have heard the statement of Mr. Dorley, the Chairman of the Committee. This Committee does not make any recommendations at this time, as I understand the report. The two divisions of the report are submitted as information. They say their subject-matter is not in shape to be included in the Manual.

Are there any questions that any member of the Association would like to ask the Chairman or other members of this Committee in regard to this report that has been made? Have you any suggestions to make in regard to the work of this Committee for the coming year?

There is another section of the report on protection for water stations against freezing, and we will hear the statement of the Chairman of the Committee in regard to that matter.

Mr. Dorley:—In its study of this subject the Committee addressed a set of formulated questions to some thirty or more railroads to ascertain the methods used in protecting piping, pumps, tanks, etc., against freezing. From the information received in this way the Committee had in mind the designing of some typical plans for insulating the various parts of water stations against freezing and to recommend their adoption. We had in mind dividing the country into about three zones, the first zone to include the States in the South and along the Gulf, the second to include what might be called the Middle States and another the Canadian territory and the northern part of the United States, and to suggest typical plans for each zone. The scheme was discarded as impracticable for the reason that the details of water stations in use on the various roads differed so widely that it was out of the question to design a typical plan of insulation that would fit the varied standard plans.

The Committee finally decided to present to the Association the digest or resumé, given on page 91, of the information gathered from the various railroads to which inquiries were addressed and we hope that the members of the Association will find some information in this digest that will be of assistance in overcoming troubles arising from water stations freezing up.

The President:—You have heard the statement of the Chairman of the Committee. This report is submitted as information on the subject of protection of water stations from freezing, but there are no plans recommended and there are no definite recommendations, and this report will be received as information.

Mr. C. E. Lindsay (New York Central):—There is being given a great deal more attention nowadays to the care of boilers, and as the boiler is an essential part of the water station, I would ask if it would be proper for this Committee or the Committee on Rules and Organization to outline a set of examination questions as to the qualifications of the pump man—the man in charge of the operation of the water station, as a part of the recommended work for next year?

The President:—That suggestion will be referred to the Committee on Outline of Work for consideration and attention.

Mr. R. A. Baldwin (Canadian Northern):—I notice in going over the reports of the different railways that a number of the pumping engines are operated by gasoline. On account of the high price of gasoline, I would suggest that the Committee consider the use of an oil-burning attachment. We have made some experiments with it, and would like to have further information.

Mr. W. C. Cushing (Pennsylvania Lines):—In reading over the reports on pumping water and protection to water station against freezing, and noticing that they are not included in the recommendations for the committee work for next year, I infer that the Committee considers that the subject is finished. I would like the Committee to explain that point.

Mr. Dorley:—We consider the work on these subjects to be finished unless the Board of Direction instructs otherwise.

Mr. George W. Kittredge (New York Central):—I have nothing further to say in regard to these suggestions—I wanted to bring before the convention here a situation which developed on the New York Central in the case of a water station put into service last fall which was entirely novel to me, and which for a while considerably puzzled me.

We installed near Tivoli on the Hudson Division of the New York Central Railroad a water station with pans 2200 feet long. The owner of the land adjacent to this plant is a man who has been there, with his predecessors, for many generations, ever since there was a landowner on the Hudson River. A singular thing is that the man is very deaf—can hardly hear thunder.

We had hardly gotten the water pans nicely in operation for winter service, and begun the use of steam to heat the water, when we got a complaint from him that the noise developed at those water pans was something fearful. No one connected with the railroad had discovered it. We sent someone to his house. We found that after a train had taken water and the water had been lowered in the pans to a certain extent that there was some escape of the free steam, that at the location of this man's house, which was 100 or 150 feet higher elevation and probably half a mile away from it there was a very decided rumbling noise. The man admitted that it did not disturb him, but disturbed the rest of his family. It was a case that had never come to my attention before, and it took some little time to figure out a scheme which would so mask the escape of steam as to break up apparently the rhythm that resulted in a monotonous sound one-half a mile away.

This is simply an interesting incident in the operation or maintenance of water pans which I desire to bring to the attention of the convention, and to suggest that possibly the Committee might, in its wisdom, take some cognizance of it.

The President:—You have not told us what the scheme was which was devised to eliminate that annoyance.

Mr. Kittredge:—Do not make me confess my ignorance—I do not know what it was—suffice it to say that a satisfactory scheme was devised.

The President:—Are there any further suggestions? I would like to call your attention to a report that has been made by Mr. Campbell, Vice-Chairman of this Committee, on "Corrosion Tests on Iron and Steel." This is a special report that he made for this Committee and the thanks of the Association are due to Mr. Campbell for this very careful and interesting report prepared by him.

Mr. J. L. Campbell (El Paso & Southwestern):—This report is found in Bulletin 183, beginning on page 423. Therein you will find set out the data on which it is based. The analyses of the different irons and corrosive mediums are given to show what they were actually composed of regardless of what they might be called. The effort throughout these tests, extending over a period of two years, was to have them strictly comparative as to each sample tested, this being accomplished as indicated in the report. The representative of the American Rolling Mill Company, manufacturers of American ingot iron, requests me to say that his company did not recommend or guarantee the ingot iron pipe for the sewage service at El Paso, Texas. I so understood it, but it did not occur to me that it was necessary to make such a statement in the report, the quality of the product and the results of its service being independent of the company's guarantees. However, it is due to the American Rolling Mill Company to submit the statement of its representative at this time. In this connection, I may say that the representatives of the special irons and steels tested have raised a question as to the value of the tests. We are all in more or less trouble with the tests. Personally, I started out hoping to find the claims of the manufacturers of these special products sustained. The question has been raised as to whether or not these tests were of value as indicating what might be expected in actual service. The Water Service Committee does not wish to have it understood that this report shows results that will be secured in actual service. However, the effort was to approximate service conditions of iron and steel pipe laid in various kinds of soil with a light covering and I believe that such conditions have been approximated in these tests and that the latter are indicative. The outfall sewer at El Paso was a 24-inch pipe. The corrosion shown in the photographs took place on the upper third of the perimeter of the pipe. The corrosion worked from the inside to the outside, indicating that collection of sewer gas in the upper part of the pipe was the agency that brought about the destruction of the pipe. The latter lasted about two years. My recollection is that the gage of the metal was about 18. The pipe was well galvanized.

The President:—If there are no more suggestions in regard to the work of this Committee, the Committee will be excused, with the thanks of the Association for their work during the past year.

DISCUSSION ON IRON AND STEEL STRUCTURES.

(For Report, see pp. 99-140.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON IRON AND STEEL STRUCTURES.

J. L. Campbell.
A. J. Himes.
Geo. W. Kittredge.
A. F. Robinson.
F. E. Turneaure.

The President:—The next business will be the report of the Committee on Iron and Steel Structures. Mr. A. J. Himes, Chairman of the Committee, will present the report.

Mr. A. J. Himes (New York, Chicago & St. Louis):—On page 99 of Bulletin 181 is to be found the report of the Committee. The subjects assigned are listed on the first page, the first subject relating to the subject-matter in the Manual and directing the Committee to submit definite recommendations as to changes. No material progress has been made during the year in the revision of the Manual. A new edition of the Manual is now in the hands of the Association. The verbiage of the specifications has been improved and I trust will be found satisfactory to the Association. There was no intention to change the meaning materially. Further changes are contemplated, but they are so extensive that much time will be required.

The second subject is to continue the study of methods of protection of iron and steel structures against corrosion. This was assigned to a Sub-Committee, which reports progress on page 102 of the Bulletin. There has been so much activity in engineering work during the past year that no large amount of work has been done by this Sub-Committee, but it is worth while to call your attention to a very novel process for protecting steel structures mentioned in Appendix A. "The process involves an apparatus called a 'pistol,' which is a mechanism somewhat resembling a large pistol and which feeds the wire of the metal to be deposited into a blast flame of combined oxygen, reducing gas and compressed air, which results in the issuance from the nozzle of the pistol of a spray of fused metal." I will not read any more. Of course this new process has not been fully developed and we are merely observing and studying the process. This is submitted as a progress report.

The third subject is to continue the study of the relative economy of various types of movable bridges. This was assigned to a Sub-Committee and there is a very brief progress report on page 113 of the Bulletin. This report is so short that you may think very little work has been done, but if you will read it, you will find: "The Committee has tabulated the weights of twenty bridges." Those of you who are acquainted with movable bridges will agree that is no small task. Other information, useful to the members, will probably be submitted another year. This likewise is only a report of progress.

The fourth subject is to continue the study of secondary stresses and impact. This also has been in the hands of a Sub-Committee of which Professor Turneaure is Chairman, and he undoubtedly will have something of interest to say about this report. It is a progress report. No action is desired by the Association at the present time. I would say, however, that it is the fruit of the labors of this Committee for a number of years past in the investigation of impact and secondary stresses. We are now arriving at the point where the work is in process of crystallization and is likely to become useful.

Prof. F. E. Turneaure (University of Wisconsin):—The members of the Association are all doubtless familiar with the work which the Sub-Committee on impact has been doing for the past six or seven years. This Bulletin contains a brief resumé of that work, and in addition a study of the practical application of the results of the experiments to the subject of working stresses and design. The paper begins with a review of the report on impact made some years ago. It brings together also some additional data so as to include all data thought to be of value as applicable to American practice. It then presents a suggested formula for impact, which on page 119 is compared with the formula now in use. In the judgment of the Committee the present formula agrees with the experiments up to a span length of about 150 feet, but beyond there the experiments show a materially lower impact effect than is given by the present formula. The suggested new formula includes practically all of the most important results obtained by the experiments of the Committee and the others that are quoted. Following the discussion on impact is a review of the work the Committee did on the subject of secondary stresses and which was reported in Bulletin 163. The relation of the secondary stresses to the subject of working stresses is discussed in the third part of the report, entitled "Working stresses for tension members." This part is new material. It endeavors to develop in a logical way the relation of impact and secondary stresses to the other elements involved in the selection and application of a working stress. A study is made of the effect of various impact formulas and unit stresses in the resulting sectional areas of chord members and in the weights of structures. Diagrams are presented showing in a general way the results of this analysis.

If a fixed unit stress is used for both dead and live load, as is now the case in the American Railway Engineering Association specifications, it naturally follows that when a bridge becomes overloaded up to a point where the maximum stress is 24,000 or 25,000 ℔s. to the square inch, the overload capacity of the bridge depends a great deal upon the dead load as well as upon the live load. The result is that the overload capacity of different members of the same bridge is very different. With a 16,000-℔. unit stress for dead load there is a much larger margin for increase in live load, in the case of a large structure where the dead load is relatively large than in a small structure where the dead load is relatively small. An attempt has been made to show how this overload capacity of different span lengths varies according to the unit stress and the impact formula that may be used.

The Committee has presented some suggestions, showing what unit stresses might reasonably be used with the proposed impact formula, and how the different combinations affect the overload capacities of bridges of different span lengths.

The Committee does not make any definite recommendation, but the subject is presented in this manner with the hope of getting some written discussions from members of the Association so that within the next year or two the Committee may be able to recommend something which will be acceptable. It is to be hoped that members will contribute freely their discussion of this important subject so that the Committee may have the benefit of the opinions of all of those particularly interested in this problem.

Mr. Himes:—Subject No. 5, which was assigned to the Committee, is to continue the study of column tests. This subject is also in the hands of a Sub-Committee and it submits a progress report on page 106. There is very little to be said about the work of this Sub-Committee during the past year. These tests of columns are still in progress at the United States Bureau of Standards in Washington. The first series, completed something like a year ago, consisted of 18 columns and the tests now made are being completed on a series of 24 columns manufactured during the past year. It is not expected to make rapid progress with these tests. It has been the thought of the Committee that it would be more reasonable to go slowly and weigh and consider the results of the tests as they are made and to plan further tests in the light of the experience that was derived from the work that had been done. Thus far our work has been satisfactory to the Committee, and we feel that the work is well worth while and we hope to continue the work for quite a while to come.

No action is to be taken by the Association on this report, it being submitted merely as a matter of information.

Subject No. 6 is to continue the study of design, length and operation of turntables.

In 1912 the Committee was requested to take under consideration a specification for phosphor bronze for use in drawbridges and like structures, and since that time much consideration has been given to the subject. It has been assigned to the Sub-Committee on Turntables.

This year we submit a quite generous amount of information concerning phosphor bronze. It will be found in Appendix C, on page 104 of the Bulletin. This information includes papers by Mr. Tinker and Mr. Chase. While no recommendations are made by the Committee there are submitted for information on page 107 specifications for bronze bearing metals for turntables and movable railroad bridges. It is expected that in time the Committee will make a recommendation concerning these specifications, but we do not ask any action to-day. We believe that the information submitted will be found highly interesting and valuable to those engaged in the design of structures in which it is necessary to use bronze for bearing purposes.

The report is submitted as a progress report for the information of the Association.

Another subject which is not included in the list on page 99 was held over from previous years, and that is the requirements for the protection of traffic at movable bridges, referred to in the middle of page 101. A resumé of the subject has been published in Bulletin 178 and the Committee recommends for adoption the specifications printed on page 274 of that Bulletin.

This subject has been before the Association previously, and referred back to the Committee. In the present instance the Chairman of the Sub-Committee, Mr. Smith, has published in Bulletin 178 a very complete statement of the subject, and has included therein certain conclusions which embody in general the principles set forth in the former report of the Committee, but amended to meet the views of those who discussed the report. It is now our understanding that the Committee of the Railway Signal Association, having this subject in hand, and Committee X of our own Association, agree with Committee XV in recommending to the Association the adoption of this report.

The conclusions are found on page 274 of Bulletin 178, and it is for the Association to determine whether it should be voted on as a whole or taken up item by item.

The President:—Perhaps you had better read, item by item, the recommendations which are made, so as to have them adopted.

Mr. Himes:—I will say, before reading these recommendations, that there has been a little difference of opinion as to just how much we should include in this statement. There is no protest as to the propriety of the things that are included, but a question has been raised whether it is essential to recite all of these things. However, the Committee felt that by so doing the report would be very complete.

(Mr. Himes then read the recommendations on pages 274 and 275, of Bulletin 178, paragraph by paragraph.)

Mr. Himes:—Now, that covers, in a comprehensive manner, all of the things that are to be borne in mind in the operation and design of a drawbridge. We have carefully avoided the specification of minute details, leaving considerable leeway for the design of the various parts of the structure. I should say for the information of the members of the other committees referred to that this Committee has embodied in its report, on page 101 of Bulletin 181, three further recommendations of Committee II of the Railway Signal Association. It seems as though it would be wise to act now on the conclusions which have been read from Bulletin 178, and I will therefore move that they be adopted and incorporated in the Manual.

The President:—The motion is that the conclusions presented on pages 274 and 275 of Bulletin 178 be adopted by the Association and printed in the Manual.

Mr. Himes:—We have three further recommendations to present, about the center of page 101, Bulletin 181.

I will now move that these three items be added to the recommendations of the Committee, that they be adopted by the Association and printed in the Manual.

(The motion carried.)

Mr. Himes:—Reference was made to some papers presented by members of the Committee, one by Mr. Leffler, and that is a subject of special interest because it deals with a subject on which there is little or no information in print; it is original work dealing with the power required to operate turntables and movable bridges. Mr. Leffler has measured this power in a number of instances and has compiled a lot of useful information. His work is still in progress. The other paper referred to is that on which we have already taken action, dealing with movable bridges.

There is another subject I would like to bring to the attention of the Association as information. That has to do with turntables. Last year the Committee presented a recommendation as to the length of turntables. There was some discussion of the subject and a difference of opinion as to whether it would be wise for the Association to adopt a specific length as desirable for turntable construction. During the past year one of our members, Mr. Robinson, has had experience with turntables of unusual length and he has consented to tell us something about this work. I am sure it is well worth the time of the Association to get this latest information concerning long turntables.

The President:—We would be glad to hear from Mr. Robinson, of the Santa Fe.

Mr. A. F. Robinson (Santa Fe):—The Santa Fe installed and put into service, about the first of last November, three 100-ft. turntables, of the through pattern, with steel floor, floor beams and stringers and six-inch ties. The main features in the design are to make a drawbridge out of the table. The rails on the table project about 9 or 10 inches beyond the ends of the girders over onto the circle wall; the radial tracks come in and rest on heavy cast steel bases. The radial track bearing on the circle wall takes up about half of the thickness. The forward section is the support for the rail from the table. There is a set of wedges that slide in and out on the bottom flanges of the track rails on the table, to fill in the space between the rails and the top of the shoes. When the corner wheels under the ends of the table are hard on the circle track these wedges shove tight and make a positive support for the overhanging rail. The circle track or pit track is probably the key to the situation in that it is adjustable. Under the rail, on every tie, is a set of adjustable wedges. They are like a tie-plate and the wedges shove in from the opposite sides. The wedge starts with a feather edge at one end and runs up to half an inch or a little more at the other end. The holes for fastening with screw spikes are slotted. As a result, it is a very easy matter to adjust the circle rail as to height or as to position. In operation, if the circle rail under the main lead tracks pounds down slightly, as it has probably 75 per cent. of the traffic, it is only a few minutes' work to adjust these wedges and bring the circle rail up to the true level. A couple of weeks ago I spent an afternoon at Albuquerque and watched the performance of the table at that point. In about three hours there were something over 50 movements of the table, large and small. There isn't the slightest pound or jar when the engine runs on or off of the table and you scarcely notice when it runs off of the high end. The thing seems to balance down without any especial shock. I may note the motor end of the table is counter-weighted, so that when the table is empty that end is always down on the circle rail and the instructions to the men are that they turn the motor end to meet the oncoming load. After the load is turned if they want to go off the high end, a slight movement of the locomotive will put the high end down on the track. While watching the table at Albuquerque, what we call the "goat"—it is a heavy engine, three axles, with about 64.000 lbs. to the axle—came over the table and went into the house and took out one of our 3500 class engines, which is very long and has 59,000-lb. axles. This engine was without coal or water; was being repaired. The "goat" took the engine out onto the table. It was taken to ten or a dozen stalls and put into the house. I saw this operation repeated with two other engines, and the operator did not know who I was and therefore did not take any more pains in handling the table than as though I had not been there. It did not seem to be any more trouble to handle the two engines than it did to handle an ordinary road engine. After four months of service with these three tables our people seem to be so well pleased with them that they are asking for two more. I consider them, as to efficiency, very nearly one hundred per cent. The working is even better than I had hoped for. It is the result of several years' hard study, and I feel very much gratified at the results. I may say, however, that these tables are not foolproof. They must be *properly erected, properly adjusted*, and *kept in perfect shape*. They cannot be allowed to get out of condition in any way. I thank you for your attention. (Applause.)

Mr. George W. Kittredge (New York Central):—I would like to ask Mr. Robinson what metal they have for the discs or cones.

Mr. Robinson:—It is the Santa Fe standard, 500-ton center, which is very similar to the American Bridge Company's Type D. It has steel cones working between two special nickel steel discs. These discs or treads can be taken out and replaced with new discs and new cones without having to send the center back to the shop.

Mr. J. L. Campbell (El Paso & Southwestern):—I would like to ask Mr. Robinson if there is any tipping of this table when two locomotives coupled together are passing over it?

Mr. Robinson:—How do you mean—when you run on?

Mr. Campbell:—I understand you to say that the motor end is counter-weighted?

Mr. Robinson:—When the table is empty?

Mr. Campbell:—Yes.

Mr. Robinson:—When the engine runs on, it comes on over and as soon as the load gets over this side, the heavy end is loaded gradually. There is no pound at all.

Mr. Campbell:—Does the tipping take place before the second locomotive is entirely on the table?

Mr. Robinson:—Until you get the hind end of the single engine.

Mr. Campbell:—Two engines are moving over the table. Is their combined length longer than the table?

Mr. Robinson:—No, sir; not longer than the table.

Mr. Campbell:—Is any tipping of the table deferred until all the wheels of both engines are on the table?

Mr. Robinson:—Yes, sir; I might say the table was designed for the Mallet engines, which is really two engines in one.

The President:—I think Mr. Robinson is to be congratulated in having something that exceeds his expectations. Most of us get something that comes short of our expectations. The Committee recommends the continuation of the same subjects for further study next year, and the Committee on Outline of Work will please take notice of this recommendation. This is all that we have from this Committee and the Committee is excused, with the thanks of the Association for its work.

DISCUSSION OF REPORT ON DRAWBRIDGES.*

By Thos. S. Stevens, Signal Engineer, Santa Fe System.

I have received Bulletin 178, containing report on drawbridges, and have the following comments to make: I have checked the report with reference to interlocking and find it is in accordance with the report made to the 1914 convention and I believe in accordance with the joint report made by Committee 15 and Committee 10. It has always been found difficult to find a proper term for No. 1 under the title "to open drawbridge." The report starts out with the statement that the particular plant you are dealing with is a swing bridge having home and distant signals, derails, etc.; then under the general term to open drawbridge you start out with No. 1, display stop signals, when in reality the operation is to display stop and caution signals, and in the next place there are no stop signals in existence, but there are signals which, in a certain phase of operation, display the stop indication or stop aspect.

I realize of course that everyone will understand what is required with reference to this matter, but it is not technically correct, and I have been wondering whether the purpose of the report would not be covered so far as the drawbridge is concerned if the instructions of the order of operation began with No. 3, open derails. This is really the

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*Bulletin 178, August, 1915.

first thing which is done to really protect against the open drawbridge. When derails are used, the rest of the performance is the ordinary interlocking procedure, which is so well established that no instructions are necessary.

I think the same thing is true about the instructions as to the order of operation when it is desired to pass trains over a drawbridge in any way is to close derails. If, however, it is desired, as I expect the Committee will, to let the matter stand as it is on account of the joint discussion which has been given it, I call your attention to sentence 10 "display clear signal;" it should be "signals."

COMMENTS BY C. E. SMITH, CHAIRMAN OF SUB-COMMITTEE ON DRAWBRIDGES.

I was very much interested in the letter of Mr. Stevens of December 2, commenting on report of drawbridge devices in Bulletin 178, and take pleasure in sending it to Secretary Fritch for publication in connection with any other discussions he may receive.

I realize that the various words and phrases used in the subject matter possess a greater technical significance to experienced signal engineers than to bridge engineers or railroad engineers in general. However, even after allowing for the full technical significance of the terms, I fail to see how any misunderstanding could possibly arise from the rule "Display Stop Signal," when in reality the operation is to display stop and caution signals. In ordinary practice the caution signal would most certainly be displayed if the stop signal were displayed, but the important function is to display the stop signal.

It is possible that by a strict technical interpretation of terms, it might be true to state that there are no stop signals in existence, but clearly the words "stop signals" will be interpreted by engineers and others of ordinary intelligence to mean a signal which, in that certain phase of its operation, displays the stop indication or aspect. For general rule I would certainly prefer to use the words "Display Stop Signals" than any other wording I can imagine, to set forth the meaning.

The report does not state that derails must be interlocked with the signals, as that has been taken for granted in standard practice. The report does contain the recommendation, however, that the bridge operating mechanism, rail locks, etc., be interlocked with the signals, so that if the recommendation be carried out, there will be a train, including signals, derails, bridge locking and operating devices, and the order of procedure to be recited in the report might start almost anywhere, on the assumption that the preceding operation would have to be performed in the ordinary procedure.

I would consider it preferable to describe a complete operation from the time the operator disturbs the first lever affecting the signals to the time when he performs his last operation, placing the signal at "proceed."

I am very glad that Mr. Stevens has gone into this matter so fully as his letter indicates, and have regretted that more of the members did not take sufficient interest in the matter to send in a discussion.

DISCUSSION OF REPORT OF SUB-COMMITTEE ON IMPACT AND STRESSES.*

By Henry B. Seaman.

I have read with keen interest the report of the Sub-Committee on Impact, and have never read any report with greater satisfaction. The work of the Committee has been conducted on practical lines and its deductions seem justified by the work it has done. My own thought and study for the past ten years or more have been upon similar lines. Particularly would I endorse and emphasize the opinion "that very little aid can be had from theory, and that results of experiments must be relied upon." I have tried to follow every theory which has been offered for impact, but never found one which was satisfactory.

We are here offered for our consideration three formulas:

$$(1) \quad I = \frac{300}{L + 300}$$

$$(2) = 125 - \tfrac{1}{8}\sqrt{2000L^2} \quad \text{(quarter ellipse).}$$

$$(3) \quad I = \frac{300}{1 + \dfrac{L^2}{30000}}$$

(1) has been considered too heavy and has been abandoned. (3) has apparently been modified from

$$I = \frac{300}{1 + \dfrac{L^2}{20000}}$$

which was proposed† some four years ago. These formulas are empirical and depend for their acceptance upon their conformity with the tests already made, and with conditions which would probably occur beyond the scope of these tests.

I know of no theory which explains why a quarter ellipse (conic-section curve) should particularly apply to this subject, but a conic-section has helped us over many difficulties and seems to help us over this. It is unfortunate that Fig. 2 has not been extended to spans of 1000 ft., as the conic-section curve will be found to run to *o* at that point, which is a consideration to be desired in practice.

No tests are shown for spans of less than 25 ft., but it is recognized that unbalanced drivers, etc., have the greatest effect on short spans; on rails I believe the impact has been found to approach 250 per cent.

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*Bulletin 181, November, 1915.

†Trans. Am. Soc. C. E., Vol. LXXV, p. 356, plate X.

It would, therefore, seem advisable that a formula should give large values for very short spans, and the elliptical curve shows for these spans a rapid increase, as desired.

The accompanying table of impact values for the elliptical formula and the full diagram of the formula, with the tests, was published in 1912. It will be noticed that a number of the higher tests on longer spans come very close to the line of this formula, as follows:

Test on 60-ft. span shows 83 per cent. impact.
Test on 68-ft. span shows 78 per cent. impact.
Test on 70-ft. span shows 79 per cent. impact.
Test on 157-ft. span shows 58 per cent. impact.
Test on 204-ft. span shows 50 per cent. impact.
Test on 300-ft. span shows 32 per cent. impact.
Test on 300-ft. span shows 28 per cent. impact.

Some of these tests do not appear in Fig. 1. They are considerably above the line of the formula now suggested but are well covered by the elliptical curve.

It has been suggested that in very short spans the rail relieves the girder, but these very short spans may need the assistance of the rail in addition to the impact provided by the formula. Thus, if we have an impact blow of 250 per cent. on the rails, the formula provides for only one-half of this. If the depth of a girder is assumed at one-tenth of the span, a rail 6 inches deep will have the same rigidity as a girder of 5-ft. span, and the impact will be divided equally between the two, or may nearly reach 125 per cent. in each. This is all that the formula provides. For spans exceeding 5 ft. in length the depth of the girder will be increased, while the depth of the rail remains constant, and the rail will then be of little assistance to the girder. The elliptical curve, therefore, seems to meet the desired conditions, and it is not clear why it should not be used.

In the selection of an impact formula we must consider more than the mere convenience in designing new bridges. We must remember that we have many old bridges to maintain, and for this purpose must have the most authoritative data obtainable. If one formula gives values too high, or another gives them too low, we might, on the one hand, condemn good bridges or restrict useful traffic over them, or, on the other, we might continue unsafe bridges in service and jeopardize the traffic.

In regard to methods of proportioning that noted as 4-b, Fig. 8, seems to compare favorably with methods already in vogue, but I think the suggestion that new bridges be designed for an "overload" is an excellent one, thoroughly scientific and justified by former practice and experience. Just as in general estimates we add "10 per cent. for engineering contingencies," in bridge work we may add 25 per cent. for "contingent increase," i. e., increase of live load, contingent upon a corresponding increase of allowable strain. In former years we have designed bridges with a "factor of safety" on the material, providing thereby also for a factor of uncertainty in the loading. As we now approach more closely to the known qualities of the material, may we not wisely provide a small factor in the loading to cover the uncertainties of the future? If we add 25 per cent. overload and at the same time add 25 per cent. to the allowable strain used (i. e., increase 16,000 lbs. to 20,000 lbs. for both the dead and live load strains) we will obtain a structure of practically the same weight and cost, and at the same time will produce a bridge better proportioned for future service. It will have stronger counter members, and it is in these members that our old bridges are found deficient.

PERCENTAGE OF INCREASE TO LIVE-LOAD STRAINS TO PRODUCE STATIC EQUIVALENT, ACCORDING TO THE FORMULA:

$$S = 125 - \frac{1}{8} \sqrt{2000\,L - L^2}$$

Where,

S = Increase, in percentage;

L = Length, in feet, of applied loading which produces maximum strain in the member.

Applied loads shall be increased according to their various lengths by the above formula to produce the Static Equivalent.

L.	*S.*	*L.*	*S.*	*L.*	*S.*	*L*	*S.*
1	119.41	25	97.22	150	59.15	390	25.95
2	117.10	26	96.68	160	57.18	400	25.00
3	115.32	27	96.15	170	55.28	410	24.07
4	113.83	28	95.63	180	53.45	420	23.17
5	112.52	29	95.12	190	51.70	430	22.29
6	111.33	30	94.61	200	50.00	440	21.44
7	110.23	35	92.22	210	48.36	450	20.60
8	109.22	40	90.00	220	46.78	460	19.79
9	108.27	45	87.91	230	45.24	470	19.00
10	107.37	50	85.97	240	43.76	480	18.23
11	106.51	55	84.12	250	42.32	490	17.48
12	105.69	60	82.35	260	40.92	500	16.75
13	104.91	65	80.67	270	39.57	510	16.03
14	104.16	70	79.06	280	38.25	520	15.34
15	103.43	75	77.51	290	36.97	540	14.01
16	102.73	80	76.01	300	35.73	560	12.75
17	102.05	85	74.57	310	34.52	580	11.56
18	101.39	90	73.17	320	33.35	600	10.44
19	100.75	95	71.82	330	32.20	650	7.91
20	100.13	100	70.51	340	31.09	700	5.76
21	99.52	110	68.00	350	30.01	750	3.97
22	98.92	120	65.63	360	28.95	800	2.53
23	98.34	130	63.37	370	27.93	850	1.41
24	97.78	140	61.21	380	26.92	900	0.63

Where L = 1000 ft. or more, S = 0.

DISCUSSION ON WOODEN BRIDGES AND TRESTLES.

(For Report, see pp. 185-212.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON WOODEN BRIDGES AND TRESTLES.

E. A. FRINK.

The President:—The next report which we will take up is that of the Committee on Wooden Bridges and Trestles, and Mr. E. A. Frink, Chairman of the Committee, will present the report.

Mr. E. A. Frink (Seaboard Air Line):—The general subjects assigned to the Committee for the past year's work were: (1) Continue study of design of docks and wharves; (2) report on relative merits of the ballast deck wooden trestles as compared with reinforced concrete trestles; and (3) continue study of the use of lag screws in trestle construction. Of course, in addition to that we had the consideration of recommended changes in the Manual. The Committee has considered the question of changes in the Manual, and in view of the many changes passed at the last convention we decided that no changes were advisable at this convention.

In regard to the first subject, to study the design of docks and wharves, we find we are only in a position to present a progress report. The matter has been given a good deal of study, and you will find printed in the Bulletin, page 187 and following, a good many of the points that had to be considered in this question, followed by a number of designs of various types of docks and wharves. I would say that we are confining our study of this subject to the construction of docks and wharves up to the level of the floor and not above that, for the reason that the substructures can be of certain general types regardless, to a certain extent, of the superstructure. Therefore, we thought best to get the substructure up to the top of the floor out of the way before going further, and leave the question of further consideration of this matter to the direction of the Board of Direction.

With reference to the second subject, to report on the relative merits of ballast deck wooden trestles as compared with reinforced concrete trestles, the Sub-Committee in charge of that subject has found there is very little information extant that would aid them in presenting information on that point. One of the great questions we have not information on is the cost of concrete trestles. We were successful in getting the cost of ballast deck wooden trestles to a large extent, but the cost of concrete trestles was very varying in amount; they varied so much that we thought there must be something left out of consideration in some of the costs we have. Of course, the cost of a concrete trestle is a large factor in the comparative merits of the two types of construction, and for that reason we wanted to give it further consideration before making a report.

As to the third subject, to continue the study of the use of lag screws in trestle construction, you may remember that at the last convention the Committee made a recommendation that due to the fact that comparatively few roads have experimented with the use of lag screws, and that therefore there was not sufficient information upon which to base a conclusion, that the Committee make an attempt to have other roads try that method of construction.

The Committee, therefore, sent out a circular letter to various roads, with the result that not less than 33 roads that had not previously used that method of construction expressed a willingness to experiment with it. A further circular letter was sent out and of the 33 roads four roads are actually making a trial now, and 14 others expect to make the experiment within a short time. The general experience of those that have used lag screws is good. With very few exceptions they report in its favor, and our investigation so far is promising, but at the same time we feel there has not been sufficient use made of the lag screw in that manner to warrant presenting a definite conclusion to the Association for adoption. We think that it will be probably necessary to carry the experiment further, for perhaps several years, before we can finally formulate a conclusion.

Your Committee therefore presents a progress report on that subject also.

Our recommendations for next year's work are: (1) Continue study of design of docks and wharves; (2) continue report on relative merits of ballast deck wooden trestles as compared with reinforced concrete trestles; (3) continue study of the use of lag screws in trestle construction; and (4) investigate and report on merits of galvanized iron fastenings for timber trestles as compared with plain iron and steel fastenings, especially in relation to their use on creosoted structures.

You will note that we have added a new subject with regard to the question of galvanized iron fastenings in ordinary timber structure. It has occurred to us that the use of plain iron fastenings in creosoted timber structures might possibly be objectionable. It is questionable what the effect of the creosote would be on the metal, for one thing, and whether the life of the metal fastenings will be as long as the life of the timber, and therefore we thought that would be a fruitful subject for investigation.

The President:—Gentlemen, you have heard the statement of the Chairman of the Committee on Wooden Bridges and Trestles. Their work this year has been submitted as information. They have no recommendations to make except the recommendations which pertain to next year's work, and these recommendations are referred to the Committee on Outline of Work, which will take notice of these recommendations.

Are there any questions which you wish to ask of the members of the Committee while they are on the platform? If there are no questions to be asked and no further discussion, this Committee will be excused, with the thanks of the Association for its work.

DISCUSSION ON MASONRY.

(For Report, see pp. 213-232.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON MASONRY.

A. S. Baldwin.
S. P. Brown.
A. W. Carpenter.
W. A. Christian.
T. L. Condron.
W. H. Courtenay.
W. C. Cushing.
Dr. P. H. Dudley.
W. R. Edwards.
S. B. Fisher.
E. A. Frink.
J. B. Jenkins.
B. R. Leffler.
Hunter McDonald.
G. J. Ray.
C. H. Stein.
A. N. Talbot.
E. B. Temple.
F. L. Thompson.
R. M. Wilson.

The President:—The next business will be the report of the Committee on Masonry. The members of this Committee will please come forward and take their places on the platform. In the absence of Mr. Schall, the Chairman of the Committee, the report will be presented by Mr. F. L. Thompson, Vice-Chairman of the Committee.

Mr. F. L. Thompson (Illinois Central):—The following subjects were assigned to the Masonry Committee this year: (1) Make critical examination of the subject-matter in the Manual and submit recommendations for changes; (2) report on cost and method of constructing concrete piles; (3) report on appearance, wearing qualities and cost of surface finish of concrete; (4) report on design of foundations for piers, abutments, retaining walls and arches in various soils and depths of water (not including pneumatic foundations).

There was also some work in connection with the Joint Committee on Standard Specifications for Cement, and Joint Committee on Concrete and Reinforced Concrete.

In regard to the revision of the Manual, the Sub-Committee in charge of that work had a report, but after written discussion between the members of the Committee the report was forwarded to the Secretary, inasmuch as the Manual was ready to go to press.

The Sub-Committee have made a further study of the data collected last year on the cost and method of constructing concrete piles, and presents a progress report, together with some general specifications for concrete piling.

The Sub-Committee on the appearance, wearing qualities and cost of surface finish of concrete present a final report of the subject, which is found on pages 220 to 224.

I move that the conclusions on page 224 be adopted by the convention.

Mr. Chas. S. Churchill (Norfolk & Western):—I would like to know what is in the minds of the Committee with reference to the second paragraph in those conclusions reading, "Coating with a wash of cement is not recommended." Some coatings are being largely used. Why is it necessary to speak detrimentally? I have had brick work preserved a great many years by washes and certainly the same waterproofing effect may be secured in the case of concrete. When I speak of brick work, I mean brick work which was erected in 1850 or 1855. My point is that I do not think it is necessary to have this conclusion in, unless the Committee has some reason for inserting it.

Mr. Thompson:—The Committee, when it inserted that conclusion, was not considering brick buildings; it was more in the nature of a coating for concrete work.

The President:—The statement is very clear that these conclusions refer to the surface finish of concrete and would not apply to brick work.

Mr. Churchill:—I am arguing from analogy; if it is a good thing in one piece of masonry, it is probably a good thing in another, in some cases.

The President:—Possibly the Committee can answer from experience as to why it is not good on concrete work. If they will give that information, we will be glad to receive it.

Mr. T. L. Condron (Consulting Engineer):—If you will turn to page 221, paragraph 2, you will see that that matter was considered and the Committee states: "The film of mortar thus put on usually develops checks and hair cracks and later scales and flakes off." That, as I remember the expression at the meeting of the Committee, was almost the general experience of the Committee with reference to cement wash on the exterior of concrete facings.

It would seem to me that as a member of the Committee, the specifications which precede these conclusions might properly have been recommended to the Association for printing in the Manual. Frequently requests for information come to us with reference to methods of carrying on these processes of finishing surfaces of concrete. The conclusions give us a little information, but the specifications which have been prepared after considerable study by the Sub-Committee which had the matter in hand, and by the entire Committee in its several meetings, contain a great deal of valuable information relating to this subject.

The President:—Can we have some more experience stated in regard to this question that has been raised by Mr. Churchill, because I think that is the meat of the whole thing as to whether the coating with a wash of cement produces the result that is referred to on page 221, that is, develops checks and hair cracks and later scales and flakes off. Is there anyone who can give any experience on that point?

Mr. S. B. Fisher (Missouri, Kansas & Texas):—My experience bears out the recommendation of the Committee. I coated scores of bridges when we started with a wash of cement concrete in 1890, and the general effect has been to scale off, and in later years we quit doing it. This is in the mild climate of the Southwest. I think the effects would be worse in a colder climate. This coating of cement has not, in my experience, usually adhered to the original work. Sometimes it adhered pretty well when it was moist, but after it dried out the adherence was very slight and the appearance of the abutments generally has not been good since that time. They look worse than if this coating of cement had not been put on.

Mr. S. P. Brown (Mt. Royal Tunnel & Terminal):—My experience bears out the views of the Committee. The only satisfactory results I have ever had with a wash was when it was rubbed in, which is practically the floating method which the Committee recommends. I have had a great deal of trouble with the wash flaking off on concrete.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—My views are in full accord with those expressed by the Committee. My experience has been that where cement is put on a surface of finished concrete, after the forms are taken off, it invariably checks. It does not always come off, but shows a sort of alligator appearance, if you please. That describes it about as well as one can. This trouble is eliminated where the surface is rubbed as is mentioned in the next paragraph on page 221, under the heading, "Rubbing." I think the Committee's recommendation is absolutely right.

Mr. E. A. Frink (Seaboard Air Line):—I would like to say that my experience has been right in line with the recommendations of the Committee. I have found in my work that the surface washing of cement applied as a coating is very apt to come off; in fact, it almost always does come off, sooner or later. I have in mind an arch built in Atlanta, called the Druid Hill Arch, on which a great deal of labor was expended. I think that they had an expert Italian plasterer put the coating on the concrete, that has been on three or four years now, and it has cracked and come off badly. There is in the rubbed finish, though, that the Committee speaks of, a practice of applying neat cement as a rub, and that cannot properly be called a wash. It is just the effect of rubbing the cement into the pores of the concrete and it assists in making the rubbed surface. That, I think, as distinct from washing, is good practice.

I would ask the Committee why, in their recommendations on page 224, they have omitted reference to the brush face treatment, which they refer to on pages 222 and 223. The experience I have had with ornamental concrete work leads me to believe that the brush finish is one of the most satisfactory finishes you can have, if the aggregate, as the Committee says in their report, is selected with a view to color and size, and then the mortar is brushed out carefully before it gets too hard, and the resulting face is washed with acid and then with water. In this way you can get a pleasing surface which does not show cracks as badly as a rubbed surface does. I have used it on several structures and found it very satisfactory.

Mr. S. P. Brown:—If the Committee is going to continue the study of this subject, I think it would be well for them to take up the subject of plastering, as I remember seeing it done, with apparent success, in the subways in Paris when they were being built. I have not seen that work since and do not know how it lasted, but it is to be assumed that the engineers knew what they were doing and were able to make a satisfactorily permanent job. The form work was very rough, there sometimes being a difference of over an inch in thickness between the individual pieces of lagging. These irregularities were covered with cement plaster, which was applied by throwing it against the concrete with their hands.

The waterproofing was also done in this plaster coating, which was sometimes a couple of inches in thickness. Where a wet spot appeared in the roof or sides of the tunnel, a herring-bone was tacked to the forms, made up of grass rope, usually braided, about one inch in diameter. The herring-bone led down from the wet spot to the base of the tunnel wall. After the forms were removed the grass rope was pulled out, leaving chases in the surface of the concrete. When the plaster was applied, pure gum rubber tubes were laid in the chases and the plaster troweled down over them. The plaster was put on in comparatively small batches and allowed to set sufficiently to permit the rubber tubes to be pulled out before the next batch of plaster was put on. Thus, the herring-bone chases, just inside the plaster finish, were formed into open ducts to carry the water down to the base of the side walls, where it escaped into the sub-grade drains. Practically no waterproofing was attempted outside the tunnel walls. The result was pleasing and apparently entirely successful.

Personally I have not had very much luck in making plaster stick to tunnel walls, and I believe authentic information would be valuable.

Mr. Churchill:—We are talking on two different lines, at least, I am talking on a different line from the Committee. What I refer to is the so-called Government waterproof wash which we have used for many years with success.

Mr. Thompson:—We refer to a plain wash of cement.

The President:—What is the difference?

Mr. Churchill:—I cannot give you off hand the constituents, but we have used this waterproof coating for probably twenty years.

W. H. Courtenay (Louisville & Nashville):—Soap and alum wash?

Mr. Churchill:—Alum is one element. The formula is as follows: Mix one 1) pound of concentrated lye and five (5) pounds of alum with two (2) gallons of water, care being taken that every particle is dissolved. This mixture constitutes the stock. To one (1) pint of stock add ten (10) pounds of Portland cement, thinning out the mixture with water until it can be applied easily and well on the walls of the concrete masonry with a whitewash brush and fill all the pores of the masonry.

This wash should lather freely under the whitewash brush. It should not be applied when walls are too hot or in frosty weather, and in case the wall is dry, the surface should be wet with water before applying this wash. The earlier the above operations are performed the better will be the result.

The President:—Is there anyone else who desires to discuss this question? My own experience is directly in line with that of the Committee and I am wholly in accord with this conclusion they have arrived at in regard to wash cement. It has not proved a success where we have used it on our work, and some of it, I am free to confess, we are very much ashamed of; it does not look well, and has the alligator markings Mr. Ray mentions.

Mr. Condron:—Would an amendment to the Chairman's motion be in order, that the specifications be published in the Manual?

The President:—A question has arisen as to whether we wish to approve the specifications on pages 221 to 224. Do you wish to have these approved by the Association, Mr. Thompson, and have them included in the Manual along with the conclusions?

Mr. Thompson:—Yes, we would be glad to have that done. We thought it might be asking too much, in the first place, but as long as it seems to be desired, we would be glad to have them included.

The President:—These specifications are before you.

Mr. A. W. Carpenter (New York Central):—I move that they be read.

(Motion seconded and carried.)

The President:—The Vice-Chairman will please read, starting on page 221, and he will pause after each paragraph for just a moment, and if there is no discussion we will pass on to the next paragraph.

Mr. J. L. Campbell (El Paso & Southwestern):—I have no objection to this paragraph of the specification, but wish to make this suggestion—it is not well to interpret these specifications as suggesting a latitude in the construction of concrete forms with an indifference to resulting rough work. I recognize the necessity at times of some treatment of concrete surfaces. The better plan is to endeavor to secure as nearly a perfect concrete surface in the construction of the work as possible, and I believe that if we would put a little more money into the form surfaces, a portion of which would be liquidated by the cost of treating the concrete surface, we would find it practicable to produce a surface which would require no treatment. I understand this specification to be a provision for a surface treatment when necessary.

The President:—That is set forth—these are specifications for rubbing with carborundum or cement bricks. If your surface is so good that you do not wish to have it rubbed, it is not necessary to apply these specifications.

(The Vice-Chairman read the section, "Specifications for rubbing with wooden floats.")

Mr. George W. Kittredge (New York Central):—It looks to me as if the word "washed" in the second paragraph under "specifications for rubbing with wooden floats" was used in a different sense than the word washed has been used heretofore. It says there that the surface shall be thoroughly washed. Heretofore it has said that the work shall not be washed. I think they refer to different things. Is the term "washed" sufficiently taken care of to apply to the two different senses in which it is used? That needs attention by the Committee.

The President:—We can refer that matter to the Committee without taking time to discuss it.

Mr. Kittredge:—That is entirely satisfactory.

Mr. Frink:—I think the proportion of one part of cement to two parts of coarse sand and two parts of granolithic grit is good, but if you are going to use a coarse aggregate, say, pebbles from ¼ to ⅜ inch in size, you would have to have a larger proportion of aggregate, otherwise it would not make a continuous surface on the concrete. Some of the best effects on the brushed concrete is obtained where you use pebbles or crushed stone of similar size, or crushed marble or red sand, which will produce a color effect. If you make a finish with an aggregate of ⅜ inch in size, you must be extremely careful to get the exactly proper proportion of aggregate throughout the mortar. You must not have too much mortar. If you do you will have streaks. You must have enough mortar to flush all the spaces full.

I think there should be a provision in all these specifications for surface finish that the brand of cement shall not be changed in the work. If you start the work with one brand of cement and finish it with another you get a different color. I think you have all probably had that experience.

I make a motion that the paragraph be changed to vary the proportion where you use an aggregate, say, ¼ or ⅜ inch in size, to about 1, 2, 4, with the proviso that the engineer in charge must constantly test it to see that he is getting just enough aggregate to fill the surface and just enough mortar to fill the holes. It is a nice operation and one that requires constant control. I do not think that we can specify the exact proportion because it will vary according to the character of the aggregate, but I am sure it will be a greater proportion of aggregate than 1, 2, 3.

The President:—I think that is what the Committee intended to do, but it is not quite clear from the wording that they have accomplished it. I think it will be satisfactory to leave it to the Committee to revise this section so that these parts are not fixed absolutely just as they are here, but will vary according to the materials that will be used. That is your point?

Mr. Frink:—Yes, that is my point.

Mr. Thompson:—That is one reason that was left blank.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—I would like to call attention to one point which I think should be taken into consideration, if these specifications are to be published in the Manual. In finishing the surface of the concrete by any tooling method, it is very essential to have the face so treated in a continuous run of concrete. Otherwise there is sure to be very disfiguring marks where the day's run starts. For instance, if you construct a retaining wall from the bottom to the top during the day or in a continuous run, the surface can be tooled in any manner you like, without having construction lines show on the surface. It is a noted fact that it is practically impossible to complete one day's work and start the next without showing a line on the finished face. This line is brought out very prominently when you tool the face of the concrete. There is apt to be a little sludge on top of a day's run. Even when this sludge is all taken off at the start of the next day's work the two days' work are apt to be a little different in color. When the surface is too large to complete in a day, then the design of the decorations should be such as to cover up the construction cracks. Originally, we permitted foremen and contractors to build retaining walls about as they desired. Now we require that all retaining walls, regardless of height, shall be constructed from the bottom to the top by one continuous operation. If the wall is in a wet place where there is water behind the retaining wall you are certain to get seepage through the horizontal construction joints. In most wall work it is not a difficult matter to so design the work that the daily construction joint does not appear. I would like to suggest to the Committee the addition of a clause in paragraph 5 something like this: Where practicable the face shall be a continuous run, and where it is impracticable to place the concrete in a continuous run the design of the surface decorations shall be such as to hide the joints.

Mr. Thompson:—Part of Mr. Ray's remarks are taken care of in paragraph 5, page 222, and on the next page, 224, there is an indication of what might be done along the line of Mr. Ray's remarks.

The President:—Do you make a motion to that effect, to have that added?

Mr. Ray:—I would like to make a motion that that be added.

The President:—The substance of that is where tool work is to be done, the day's run be made in such a manner and the design on the surface be carried out in such a way as to obliterate the lines between the different days' work.

Mr. W. R. Edwards (Interstate Commerce Commission):—I rise to a point of information. Should not paragraph 5 on page 222 follow paragraph 4 on page 223? Isn't there a misprint in the Bulletin on that point? It seems to me that paragraph 5 belongs to specifications for washed and scrubbed surfaces and not to specifications for rubbing with wooden floats. The sense is better followed if it is inserted immediately after paragraph 4, page 223.

The President:—Mr. Thompson thought paragraph 6 covered the point Mr. Ray was trying to make. Do you think it does, Mr. Ray?

Mr. Ray:—I do not take it that way.

Mr. Thompson:—The point that Mr. Ray is making applies to all of these surfaces. The working joints should be taken care of in any system of decoration or in any concrete work where there is no decoration. In retaining-wall work, or construction work of any kind, it should be done in such a way that those defects will not appear.

The President:—As I understand it, the last two paragraphs read by Mr. Thompson are information. I refer to what he says in regard to the wearing surface of concrete floors. These matters are not recommendations, but information, and these two paragraphs should not be put in the Manual. We will now vote on these specifications as a whole.

Mr. Campbell:—Before we take this vote I would like to ask the Committee if it is willing to substitute in these specifications the word "should" for the word "shall" wherever "shall" occurs? We are proposing now to put a set of specifications into the Manual of Recommended Practice. These specifications are not really mandatory, but they are recommendations. I believe it is well to substitute for the word "shall" the word "should," and then in these specifications generally we will probably find some specific reason for it. I want to refer you to (4) on page 222, under specifications for rubbing with wooden floats. There it says, "All work shall be finished free from discolorations, streaks, or other imperfections that injure the appearance or life of the work. Sometimes we will succeed in doing that and at other times we will not. It is frequently impossible to do it. I think it would be better to say all work should be finished free from discolorations.

Mr. Churchill:—This question raised by Mr. Campbell has been passed on by this Association time and time again. I suppose the Committee will change that without any vote being necessary. We avoid the word "shall," in other words, in the specifications.

Mr. Thompson:—There are some cases here where the word "shall" might be changed to the word "should," but I do not think it should be changed in all places.

Mr. J. B. Jenkins (Baltimore & Ohio):—I think the word "shall" is the proper word to use in the specifications. It is not necessary in the adoption of the specifications to say that these specifications "shall" be used, but when the specifications are used by any railroad in a contract, the word "shall" is the word that should be used. If the word "should" is left in the specifications and they are copied by a railroad company, they will be without force.

Mr. A. W. Carpenter (New York Central):—I understood you to rule that the last two paragraphs should be omitted. I would like to call your attention to the first of the last two paragraphs, which refer to concrete floor. The heading of section 7 is, "Sidewalk and floor finishes," and I think the only reference to floor finishes is in the second paragraph. It looks as though the substance of what is said there ought to stay in.

The President:—I think possibly you are correct. I think that that ought to have a number. However, part of it is information and not specifications, and there ought to be a distinction made. These are specifications that we are adopting, not information. I think that we could leave that to the Committee to call that No. 8 and make some changes. With your permission we will make that suggestion to the Committee.

Mr. B. R. Leffler (New York Central):—In the middle of paragraph 7, page 224, it says, "The top surface shall be well troweled, and where necessary prevent slipping," and so forth. It seems to me that we ought to specify that slipping shall be prevented and not put a provision in there that it may be prevented, because I think it has been recognized by city authorities that all pavements must be roughened. In Cleveland they require owners to actually bushhammer the sidewalks in front of their property, if they accidentally receive a glassy, hard finish.

I make a motion to that effect, that "the top surface shall be well troweled and finished with a rough surface," for the first clause.

The President:—Please read the paragraph as you would like to have it, so that we will get it clearly. I am not sure whether I understand how you want it to read.

Mr. Leffler:—It have not formulated it very clearly. I think it might be this way: "The top surface shall be finished to a rough surface with a bristle or coarse broom, or roughened with a tool." The wording should be improved.

The President:—It is a question whether that is advisable. There are places where you want a smooth surface inside.

Mr. Leffler:—That is the point that I had in mind. Is it the proper thing, in view of the tendency to require rough surface, to specify any floor or require it to be of hard, glassy finish?

Mr. Condron:—I think ordinarily a hard, smooth surface is desirable for warehouse purposes, and a smooth, glassy floor is more easily kept clean.

Mr. W. A. Christian (Interstate Commerce Commission):—I am of the opinion the paragraph would be satisfactorily explained by omitting the words "where necessary," the wording to be "top surface should be well troweled to prevent slipping and where necessary finished with a wooden float," etc.

Mr. Leffler:—I think that will fix it. The Chair has already called attention to the fact that clauses on page 224 are not included in the specification, but are simply information. That same remark seems to apply to the clauses on page 223, treatment with acid and treatment with sand blast, and in this connection there are scattered throughout this specification little sentences which have the same characteristics. In No. 5 this statement occurs: "This treatment carried to the extent of cutting slightly into the aggregate produces attractive surfaces and bushhammering is considered by many to give the best possible appearance at a reasonable cost." I want to suggest that if this is to be called a specification that the Committee should edit it a little bit, and convey information in one part and specifications in another.

Mr. E. B. Temple (Pennsylvania Railroad):—I do not think that these recommendations are in the sequence they should be. I would suggest that this matter be referred back to the Committee, and let them go over it carefully next year, or that it be referred to the Board of Direction.

Therefore, I move that this matter be referred back to the Committee.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—Speaking to that motion, I do not think it is a matter that ought to be referred back to the Committee and kept out of the Manual. I think it simply needs editing. The basic principles have been set down and they are well understood. It is simply a question of separating argument from the specifications. The Committee can do that very well without having the fundamental questions referred back to them again.

Mr. Ray:—Speaking in support of Mr. Temple's motion, I want to say that in reading these specifications before coming to the convention I did not go over them with the idea that they were to be submitted for adoption in the Manual, and I doubt if anybody did. I agree with the conclusions at the bottom of page 224, and I am willing to vote for those conclusions, but I do not believe the specifications, in the form presented, should go into the Manual. I believe they should be carefully gone over, and I think there is a lot of additional information that ought to be put in the specifications.

Mr. S. P. Brown:—Are these specifications intended to be used as they stand or merely as guides to engineers who are preparing specifications? Is that a point to be considered? If they are merely a guide to engineers who are preparing specifications these little sidelights that we have from time to time would give assistance.

The President:—We are trying to put them in such shape that people can use them.

Mr. C. H. Stein (Central Railroad of New Jersey):—I would like to say that notwithstanding the conclusions of the Committee were adopted, it seems to me they are so much a part of the specifications that their insertion in the Manual would be incomplete if the specifications did not accompany them. I am of the opinion that we ought to reconsider the adoption of the conclusions and refer the entire matter back to the Committee so that it can re-prepare the specifications, the subject-matter of which is good; they, however, need some rearrangement. The specifications and conclusions are inseparable and the data should be referred back to the Committee for report to the convention in 1917.

The President:—Mr. Ray took the correct view of the specifications, that is, that they were not to come up for adoption to-day. They were submitted for information.

Mr. Thompson tells me he did not expect they were to be adopted to-day for inclusion in the Manual, but it looked as though we were perfectly willing to swallow them and he was willing to unload them on us. He has not succeeded. You will vote now on the motion made by Mr.

Temple and duly seconded, to refer this whole subject back to the Committee.

(The motion carried.)

Mr. Stein:—I understand the conclusions have been referred back to the Committee.

The President:—Yes, unless you wish to make another motion.

Mr. Stein:—I thought the conclusions, having been adopted, could not be referred back without reconsideration.

The President:—We did adopt them. Possibly it would be best to make a motion to reconsider them.

Mr. Stein:—I move a reconsideration of the conclusions already adopted.

(The motion carried.)

The President:—Now, possibly we would better have a motion to refer these conclusions back to the Committee.

Mr. Temple:—I think the conclusions are good, but I think it would be better to refer the other matter to the Committee also. I think we all agree to that, and we have got the benefit of the conclusions, now, and we can carry them away with us, but it would be better to have the conclusions referred back also.

Mr. Thompson:—The Sub-Committee on Foundations, Abutments, Retaining Walls and Arches made a progress report, and they are working on some forms. This work will go on during the next year. On pages 214 and 215 there is given some information in regard to Joint Committee on specifications for cement. The Sub-Committee have heard of some criticism in regard to the statement made on page 215 and they would like to change the word "resented" in line 6 to "objected to," and the word "forced" in line 9 to "urged." The Sub-Committee would like to have the three questions on page 216 voted on by the Association, as the Sub-Committee is divided in the matter and cannot agree on it. There is to be a joint meeting on March 28, and they would like to have instructions of the Association as to what position the Association wants to take in this matter. The items referred to are as follows: (1) Are steel reinforcing bars rolled from steel rails recommended for general use in reinforced concrete construction; (2) are steel reinforcing bars rolled from steel rails recommended for general use in reinforced concrete construction, provided such bars are used only when the bars do not require to be bent; (3) are steel reinforcing bars rolled from steel rails recommended for general use in reinforced concrete construction under the same conditions as steel reinforcement bars rolled from billets under the requirements of the specifications for high carbon steel of the American Society for Testing Materials?

The President:—The Committee are asking the Association now for instructions, and ask you to give your preference or your vote in regard to No. 1. What is your wish? Can the Committee give us any information on the subject as to why the question is raised?

Mr. Thompson:—The Committee is hopelessly divided.

Mr. Condron:—Regarding the use of "re-rolled steel" for reinforcement of concrete, the following facts are worthy of consideration: First, all steel bars may be said to be "re-rolled," that is, steel blooms are first cast and then these blooms are rolled into billets. These billets are afterwards heated to a rolling temperature and rolled into bars of specified size. Or billets may be rolled into other shapes. Sometimes blooms are rolled into rails instead of into billets. These rails are shipped after due inspection and are laid in railroad tracks. There the rails remain until the heads become worn or traffic demands a heavier rail. Then the rails are taken up and either relaid in secondary tracks or they are sold. The so-called re-rolling mills buy such rails and cut them into shorter lengths to place in heating furnaces. Therefore these 10 ft. or 15 ft. rails are really steel billets to all intents and purposes. If the steel rails have been overstrained in service it is reasonable to suppose that the reheating must remove such overstrain. After the rails are heated it is customary to make two longitudinal cuts so as to separate the head and the flange from the web. The heads are rolled into the larger section bars and the flanges and webs into smaller sections of bars or angles, etc.

Of course other material than rails finds its way to a re-rolling mill, and therefore it is customary for some engineers to limit their use of re-rolled steel bars to bars re-rolled from railroad rails. This limitation, under proper inspection, is desirable, for railroad rails are a fairly uniform product, at least they are usually made of what is known as "rail carbon steel," and such steel will have an elastic limit of 50,000 lbs. or more per square inch. It is possible to make a reasonable number of tests on finished bars and so keep a check on the material furnished.

It has always seemed to the speaker that of all classes of engineers railroad engineers would be the last to condemn or decline to use reinforcing bars re-rolled from rails, because if the steel used in the rails is not good enough to be used as a direct tension member in reinforcing concrete it certainly should never be used in tracks where it is constantly subjected to the severest kinds of stresses in rapid reversal from tension to compression, to say nothing of transverse shear.

In a concrete structure the bar is subjected only to tension, and only so much tension as can be developed in the bar through the bond or adhesion of the concrete to the surface of the bar. Some say they would be willing to use re-rolled bars except where bent bars are required. This is because they are afraid bending will break the bar. Is it not wiser to say that in case of any doubt about the material it would be used only for bent bars, and in case a bar broke in bending it would be rejected? It is true that some types of deformed bars, so deformed to increase the bond with concrete, frequently break in bending. This is particularly true in case these bars are rolled of high carbon steel because in rolling the knobs or ribs on their surfaces unequal stresses are set up in the bar, particularly if the bar is finished too cold. Little or no trouble is experienced in bending plain round bars of high carbon steel, and it is possible to avoid the weakness referred to in the case of deformed bars.

It therefore seems to the speaker that this Association should not go on record as opposed to bars re-rolled from rails, but rather that it should prepare a reasonable specification and recommend for use, to govern the acceptance of such bars and leave its membership free to individually decide when and where and how he will use a material which has much more in its favor than can be said against it.

In the extreme West a market is created for wornout rails by the fact that mills have been equipped to re-roll these rails into bars for reinforcing concrete. This material is made readily available to the advantage of the railroads who sell as well as to all users, whether railroads or others. Many thousands of tons of such bars have been used by railroads radiating from Chicago, and so far as the speaker is aware no ill has resulted.

Regarding bending of bars, some attention should be given to the bending apparatus used, as that is very important, and also as to whether the ribs or bumps on the bars increase their liability to break in bending. Deformed bars are desirable, as they increase the bond strength, but the deformations may explain breakages in bending also.

The President:—Has anyone any experience that would lead to an adverse vote as to using bars rolled from rails?

Mr. Courtenay:—It is a pretty well-established fact that those who have used old rails know that they are very brittle at times, and there is a greater lack of uniformity in rails than there is in ordinary medium or low carbon open-hearth steel. These reinforcing bars are subject to pretty rough handling by inexperienced men, in the South generally negroes. They are frequently abused, and I think it is running a rather undue risk to use reinforcing bars generally rolled from old rails, on account of the uncertainty of the material.

Mr. A. S. Baldwin (Illinois Central):—I would be inclined to agree with Mr. Courtenay on that. We know that there is a marked difference between the new rail and the rail that has been in use. Take a rail that has been used on the outside of a curve and no trackman would dare turn it around and reverse the curvature and use it. There must have been a change of structure in that rail to have brought about that condition; and we know that the top surface of the rail, where it has been heavily rolled, is different from the interior surface, and it seems to me that there would be a risk in using bars that were rolled from old rail. I would certainly wish to have them very thoroughly tested before it was done.

I would like to ask Mr. Condron, how can he know that the structure of the steel is the same after it has been re-heated that it was before? Our experience with re-rolled rails has been that they furnish a higher percentage of breakage than new rails. A great many of us believe that transverse fissures develop after the rail has been in use. How could you know that there were not transverse fissures in some of the rail that was re-rolled? It seems to me that there is certainly an element of uncertainty in the use of old rails for this purpose, and I believe we should put it to such tests as have been stated.

Mr. Campbell:—I am of the opinion that any rail that has carried traffic until it should be removed from the track is probably composed of good material and is a reliable article. I am of the opinion that Mr. Condron has fairly stated the matter of re-rolling. I do not have sufficient specific knowledge about the matter and I question whether this Association as a body has looked into this question and is sufficiently familiar with it to give a final answer upon it this afternoon. This is a question which should be settled by special qualification and as the result of a special investigation by men specially qualified. I believe it is up to this Committee to determine this question and come before the Association with a recommendation rather than to ask us to decide this important question without sufficient knowledge.

Dr. P. H. Dudley (New York Central):—I saw to-day rails which have been severely strained in the gagging which have developed into checks in the subsequent service in the track. These checks were not welded in the re-rolling of the metal. Should there be cracks or fissures in the rails, they would roll out in the bars, but the surfaces of the cracks or fissures would not be welded.

The President:—It seems as if the suggestion made by Mr. Campbell is a very wise one. We are hardly justified this afternoon, with the information that we have, in voting on the questions that have been submitted to us. It looks as if it would be advisable to refer this back to the Committee and see if they cannot come here a year from now with a definite recommendation on which we can vote.

Mr. W. C. Cushing (Pennsylvania Lines):—I quote from page 215: "The general opinion of a number of members of the Joint Committee is that the Committee has outlived its usefulness and an early closing of its affairs is looked for." It would appear that we should have some explanation of that statement in order to know whether our commission is being duly executed or not, or whether there is any further necessity for the commission.

Mr. Thompson:—This is a Joint Committee, composed of members of the American Society of Civil Engineers, the American Society for Testing Materials, the American Concrete Institute and Cement Manufacturers' Association. Certain members of this Association meet with the gentlemen representing other associations. There is to be a meeting in New York March 28, to vote on this proposition, which is supposed to be a final vote in regard to the adoption of this matter. For that reason the Joint Committee representing this Association wanted some instructions, or at least to find out how the members feel in the matter.

Mr. McDonald:—I would like to ask Dr. Dudley to explain to us what will be the effect of rolling out the transverse fissure. I have seen high-tension bars break when dropped off of a wagon. We all know that different rails in different heats have different degrees of brittleness. Whether breakages are due to transverse fissures or not is not always determined. I believe it would be well to have some gentleman enlighten us on the question of transverse fissures, because we know there are transverse fissures concealed in rails after they have been long in service.

The President:—Dr. Dudley, will you please answer the question?

Dr. P. H. Dudley:—The separation of the surfaces of metal is not closed in re-rolling. Material for re-rolling should be carefully selected to secure sound bars.

Mr. Carpenter:—I do not know that I am much in favor of the re-rolled bar, but so far as the old rails are concerned I would like to call attention to the fact that we have built hundreds of small bridges with old rails as the supporting material; they seem to be satisfactory.

Mr. Leffler:—An important point in the use of high carbon bars is this: There is a tendency to use high unit stresses in designing and using high carbon bars, and it seems to me that, in connection with the defects which we know occur in high carbon, we should eliminate such material from reinforced structures, particularly where the bars must be bent. Possibly, where the bars are straight, we can slip through without having serious accidents.

The President:—It would be unwise for us this afternoon to vote on this question. I think we will have to allow our Committee to go to this meeting which is called for March 28, and exercise its best judgment with the information it has before it. The Committee is probably better qualified to vote on this subject and act on it than the majority of members here. That action will be brought here a year from now, if you agree with me, and then we will have the information before us and we can either agree to what they agree to or we can disagree and change their recommendations. If there are no objections to this line of procedure we will leave the matter in the hands of the Committee to be so acted on.

Mr. R. M. Wilson (University of Australia):—There is one point I would like to hear an opinion on. In speaking to leading contractors of this city yesterday, they said in cold weather the steel became brittle. I have been wondering what the effect of bending reinforcing bars is in cold weather, and whether there is any possibility of cracks from those bends.

Mr. Kittredge:—Before deciding on that, it might be illuminating to some of us to know who, of this Committee, is to act with the Joint Committee, and, possibly, how those members stand. I can well see there might be a decided advantage in having certain members represent us, Mr. Condron for one; we might be perfectly willing to leave it to him.

Mr. Condron:—Mr. Condron is not a member of that Committee.

Mr. Kittredge:—Mr. Cushing raised the point as to why there was a recommendation that that Committee had outlived its usefulness. It seems to me that it might be very useful now.

The President:—I think possibly that was written by the Chairman of the Committee, was it not?

Mr. Thompson:—Yes, sir.

The President:—Unfortunately, Mr. Schall, the Chairman, is not here to-day. He has been attending the joint meetings with the other societies, and I think he has the feeling that we are not getting anywhere in the Joint Committee work, and it is his belief that we ought to do what we think is right regardless of what other people want to do.

Prof. A. N. Talbot (University of Illinois):—As a member of the Joint Committee on Concrete and Reinforced Concrete, I think it may be well to say that the Joint Committee as a whole is of the opinion that it is best to make a final report and withdraw, and that when anything arises in the future for such a committee the matter can be taken up anew, a new membership formed and fresh results obtained. So, for some time, the Committee has been working toward that end. This matter of reinforcing is one of the questions still up for discussion. I understood, however, that at a meeting in New York in January—and I was not able to attend the full session—an agreement was reached by which no change was to be made in the specifications. The former specifications provided for the inclusion of reinforcing bars made of soft steel; did not include anything for the high carbon steel.

The President:—Is there any objection on the part of the Association to permitting this matter to take the course suggested by the Chairman? If there is no objection, we will understand that that is agreed to. The Committee makes recommendations on page 216 with reference to next year's work, and this is referred to the Committee on Outline of Work. There is nothing further for this Committee to report and the Committee is excused, with the thanks of the Association.

DISCUSSION OF PAPER ON "NICK AND BREAK TEST IN THE INSPECTION OF STEEL RAILS."

(See Part 2, pp. 751-776.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION OF NICK AND BREAK TESTS.

A. S. BALDWIN.
W. C. CUSHING.
J. M. R. FAIRBAIRN.
C. W. GENNET, JR.
J. H. GIBBONEY.
ROBT. W. HUNT.
C. A. MORSE.
BRADLEY STOUGHTON.
JOHN G. SULLIVAN.
M. H. WICKHORST.

The President:—We are greatly honored this evening in having with us Capt. Robt. W. Hunt. Capt. Hunt has had much experience in the rolling of rails at the Algoma steel mills for the Illinois Central Railroad, and he has prepared a paper on the subject of "The Nick and Break Test in the Inspection of Steel Rails." He has done us the honor of coming all the way from Florida to be here to-night at this meeting, and I am sure we appreciate Captain Hunt's interest in our welfare in making this trip at this time of the year when he would very much prefer to stay down in Florida and play golf, so you see the interest he has in coming here to talk to us on this most interesting subject. He is so well known to all of you that it is needless to make any long introductory speech, and I have a great deal of pleasure in presenting to you to-night Capt. Robt. W. Hunt, who will talk to us on this nick and break test in the inspection of steel rails.

Capt. Robert W. Hunt:—Mr. President and Gentlemen: The President certainly was right in assuming that it gives me pleasure to be with you to-night. One of the penalties that I have paid for spending my winters in Florida during the past years has been the fact that so doing has kept me from having the benefit and pleasure of attending your annual conventions. I remember distinctly the early days of your organization. I had the pleasure for a number of years of being with you at these sessions, which were always interesting and instructive, and I know that your organization is playing a tremendous part in promoting the better operation of the railroads of the United States.

My pleasure in being with you to-night is marred greatly by a physical disability that I have. Unfortunately, something happened to me on the way up here. I think it was because of my eating some St. John's River shad. I got a little dose of ptomaine poisoning, and it has affected me in a peculiar way, in my eyesight, so that it is impossible for me to read. I am glad to say that my ailment is improving, but I will have to delegate to my co-laborer in the preparation of this paper, Mr. Gennet, the duty of reading it to you.

We have spent a great deal of thought and a great deal of time in preparing this paper, I know, and we have approached the subject in an honest spirit. While we hoped to prove something, we did not try to prove it—we entered upon the investigation with open minds, we allowed the results to speak for themselves, and I think you will be convinced of that spirit of ours by the paper itself, because we give you all sides of the subject. We have suppressed nothing. Personally, I think the results obtained are most gratifying, and when you come to understand and appreciate the details, I believe you will unite with me in holding that the inspectors did extremely good work.

Some of you know that a number of years have passed during which I personally have tried my best to have this nick and break test given a practical demonstration, but for a long time my efforts were unsuccessful. We were met by the United States rail makers with objections, they assuming that it would add greatly to the cost of manufacture, in that it would retard their production; at all events none of them were willing, I think I am right in saying, to even set a price at which they would be willing to undertake a contract. They certainly were very positive they would not do it without a premium being paid.

It happened, owing to the extremely hard times in Canada, that the Algoma Steel Company was short of work. They approached the Canadian Pacific Railway to give them an order for 10,000 tons of rails so that they might keep their mills going and give their people some work. I happened to be in Montreal at the time when the management had the subject under consideration, and in conferring over it we concluded that it was a most excellent opportunity to try to get the nick and break test subjected to a practical demonstration. The result was that the Algoma Steel Company was told that they could have an order for 10,000 tons of rails, provided they would make them under specifications embodying the nick and break test. After some negotiation they agreed to do it.

The manufacturing results which they obtained were so satisfactory that when they came down into the States to try to sell rails to our American roads they voluntarily offered to take an order from the Illinois Central Railroad Company for some 35,000 tons of rails, subject to that test, without any extra compensation. It is the results obtained in the making of these 35,000 tons of rails that we are going to present to you. Mr. Gennet has had the labor incident to the preparation of the specimens which we are going to submit to you. He has given a great amount of time and labor to it and worked conscientiously. We put the whole resources of Robert W. Hunt & Co.'s testing laboratories at his command. As I have already said, we want to give you the exact truth. You will see both the weaknesses and the strength, the accomplishments and the failures, and I will say, considering that it was a new departure, I think our inspectors did wonderfully well.

Now, it goes without saying that everybody and anybody cannot do it, and I think that is just what we want in all kinds of inspection. We want the kind of inspection that anybody *cannot do.* You want an intelligent and trained and reliable individual to supervise the product under your specifications, let them be what they may. Our work will speak for itself, and without further detaining you I will ask Mr. Gennet to present the paper.

(Mr. C. W. Gennet, Jr., then read the paper, and commented on the lantern slides.)

The President:—The purpose of having this paper to-night was to have it discussed by anyone desiring to do so. Mr. Sullivan, have you anything to say in regard to this paper?

Mr. John G. Sullivan (Canadian Pacific):—I think this Association owes considerable to Capt. Hunt and Mr. Gennet for this paper and the care with which it has been gotten up. I can add but little to what has already been said. It has been my personal opinion that the testing of every ingot was the logical way of making tests. Some eight years ago the Dominion Steel and Iron Company were making objections to some of our specifications, and they claimed that they would rather test every ingot. We gave them that permission. We wrote in our specifications a clause giving them permission to test every ingot, but when we came to get them to enforce their own suggestions they wanted two dollars per ton extra. I got from our Engineer in Montreal to-day, who is in charge of rail specifications for our road, some interesting figures in this connection. It only confirms what the Captain said in his paper. Of the first week's work, 139 heats, there were 286 rails rejected. Not a single rejection was made in that amount of heats on account of a drop test failure, and the chances are that in that particular case, had they been working under our old specifications, there would have been very little, if any rejections. It might have been possible that on the few rails that were nicked and broken later, it would have led to rejection. Of those 286 rejected rails, 267 were A rails, 13 were B rails and only 6 were C rails. I am advised by the inspectors, of the entire 10,000 tons, that there were, of 322 heats, approximately 26,000 rails, there would have been 2 heats rejected; in the second week's rolling, under old specifications, there were rejected on account of the nick and break tests 263, and they reported to us had they inspected those rails on the American Railway Engineering Association specifications, they would have rejected 911. So it appears to the advantage of the mills to have the nick and break test adopted, and not to the advantage of the railroad company only.

Mr. J. M. R. Fairbairn (Canadian Pacific):—I do not know that I can add anything to what Mr. Sullivan has said in regard to the inspection of the 10,000 tons that we rolled last year. We have found very good satisfaction from what we have put in the track, but they are not all in the track yet. Our general feeling about the nick and break test, when Capt. Hunt suggested it to us, was that the heat as a whole was checked for chemistry by the drop test, and if the chemistry was right the drop test would stand; on the other hand, that each individual ingot had a physical characteristic of its own and that the nick and break test would determine whether the physical condition of the ingot was proper or not. That was practically the basis on which we felt that the nick and break test was the proper thing to go to and on which we adopted it.

Mr. A. S. Baldwin (Illinois Central):—I will say a word in connection with these tests. So much was said about the result from the standpoint of segregation that I think there is a possibility that the results from piping may be overlooked. In the Illinois Central tests of the rails produced from Algoma there were 930 rails which disclosed pipes and were rejected, that would have been accepted under the American Railway Engineering Association specifications. From the beginning of these purchases, in all of the tests, accurate records were kept to show exactly what would have been the result under the American Railway Engineering Association specifications as compared with the nick and break test on every ingot so as to be able to make comparisons at the end of the work. There were 930 rails that would have been accepted and gone into the track that were rejected. It was almost inevitable that sooner or later some of these rails would have given down under traffic. We all remember the various stages that we went through in the effort for years to find out what was a safe amount of discard in the ingot, and we know how for years it was specified in percentage, and many of us in our specifications were desirous of making this very high. At the same time we knew that a great deal of good metal was being discarded, but we did not know where it was safe to stop, because we did not know where the segregation and the piping discontinued. It seems to me, that under the nick and break test on every ingot we have developed a method for safe, progressive discard on the ingot, and I believe that is the true value of it. In other words, that it takes out of the ingots what metal is not good, and at the same time gives the manufacturer credit for metal that is good.

The most interesting feature of this test is, what will be disclosed in the future. We have had those rails in the track ten months, and we cannot feel in so short a time as that that we have sufficient data to say absolutely what will be the result. At the same time we have at this time gotten some results that I think are quite significant.

In 1913, we produced from a mill which I will designate as No. 1, 5,000 A rails. At the end of ten months there had been 14 failures in those A rails, or 28 per ten thousand A rails. From the same mill, in 1914, we produced 10,000 A rails. At the end of 10 months there had been five failures of those rails, or five per 10,000. From another mill, which I will designate as No. 2, in 1913 we purchased 4,900 A rails, among others. At the end of 10 months there had been 37 head failures among those rails, or 58.8 per ten thousand. From No. 2 mill, in 1914, we purchased 8,000 A rails. At the end of 10 months there had been 12 failures, or at the rate of 15 per 10,000. To-day, at the close of 10 months, of the 14,500 A rails purchased from Algoma we have not had a single failure. I think that fact is significant.

Mr. J. H. Gibboney (Norfolk & Western):—Representing one of the members of the Sub-Committee on Rail Mill Practice of the Rail

Committee, we had the pleasure of visiting all of the rail mills in this country, and the rail mill of the Algoma Steel Company at Sault Ste. Marie, Canada, during the past year. When at Algoma we had an opportunity to witness the "nick and break" test in its application to the Illinois Central Railroad rolling, and we were greatly impressed with the rapidity of movement of the test pieces and the apparent encouraging possibilities of judging homogeneity of metal by visual inspection of the fractured ends of the pieces. The speed of testing was apparently ample to preclude any possibilities of delays in the normal movement of the output, and the fractures gave differences indicative of segregation, especially as to the metal in the web, where the appearance of a thin white line of metal was described as an evidence of segregation.

We took occasion in our visits at other mills to discuss the merits of this test, and we were somewhat unfavorably impressed with the uniform skepticism of practically all of the mill experts as to the possibilities of developing fracture inspection to a point where correct and consistent findings as to segregation would be obtained. All seemed to be agreed that the only feature of merit in the test was to be found in its elimination of pipes.

In order to satisfy our desire for first-hand information as to our ability to judge segregation by fracture, we arranged to follow rollings at several mills making deliveries to us, nicking and breaking all of the A rail test crops, passing judgment at the time on the fractures, and in many cases making records by means of full-size photographs. The fractures were then classified into three groups, namely: Uniform, Low Segregation, and High Segregation, and the sections then drilled for chemical analysis at the O. and M. positions as outlined in the P. R. R. specifications regarding segregation requirements. On comparing our chemical results as to segregation with our fracture classification, we were greatly surprised to find that in the majority of cases our judgment was grossly incorrect; in fact, there was hardly a semblance of consistency presented in our whole work, in spite of the fact that in one particular rolling we had a large number of sections showing segregation far in excess of 12 per cent.

We are prepared to attach such importance to this test as may result from a more thorough elimination of pipes from service rails, however, in its present state of development we do not believe that its usefulness can be extended to correctly judging homogeneity in the rail section.

Mr. M. H. Wickhorst (Engineer of Tests, Rail Committee):—Capt. Hunt and Mr. Gennet have given us some valuable results and deserve the thanks of the Association for them. First it may be said that a large proportion of rail failures have been traceable to excessive segregation and the other conditions attending it, and the effort has been to effectively eliminate segregated rails.

As to the ordinary drop test, its purpose, fundamentally, may be said to be to detect bad segregation. When the rail is tested with the base down the segregated portion generally does not extend far into the base, and then a rail with considerable segregation may stand the drop test. If the head is placed downward the segregation is more effectively detected in the drop test, and largely for that reason most specifications now require, at least optionally, that the head of the rail be placed downward and the head put in tension.

The Pennsylvania Railroad, in order to eliminate segregated rails, have used the method of analysis which Captain Hunt has described in his paper. That is a comparatively cumbersome method of detecting segregation, and as an actual operating proposition only one ingot of a heat would be put through such a test.

For that reason, this nick and break test of every ingot and examination of the fracture would seem very desirable, in that the units subjected to test can be made smaller. When there is considerable segregation it can generally be told in the fracture, and particularly if it is concentrated into a mass instead of being distributed pretty well over the section, but the trouble with that test has seemed to be that we have not yet gotten a numerical value of the amount of segregation as judged by the appearance. Any bad segregation can generally be told. Now, whether the method is finally to be a success or not is hard to tell. At this stage I am a little bit afraid that we will have difficulty in getting a concensus of opinion from different inspectors. It might work very well if we had, perhaps, one inspector and he has nobody to contradict his judgment, but it is doubtful just how it would work if we try to get a number of inspectors to pass on the same specimen; even though the segregation can be plainly seen there would be difficulty in judging how extensive the segregation is and whether it would warrant the rejection of the sample. However, we have reached the point where there is need for making the ingot the unit of inspection rather than the whole heat, and this is a commendable effort in that direction.

The President:—Prof. Bradley Stoughton was invited to be present to-night, but for some reason could not come and he has sent a written discussion. It is so short that I will read it.

"There are two general methods of safeguarding materials for construction which are commonly accepted to-day. The first method is to inspect or test certain specimens chosen more or less at random and then to accept or reject a large amount of material on the basis of the result so obtained. In the case of rejection, the amount of material so discarded will represent the size of the factor of safety; in the case of acceptance, the larger the amount accepted on the basis of the one test, the smaller is the factor of safety. In either event this method depends chiefly on a more or less scientific process of 'taking chances.'

"The second method of safeguarding is to choose for test certain representative or indicative specimens and to accept or reject only as much material as is actually represented by the test made.

"The nick and break test described by the authors of this paper is an attempt to follow the second method of safeguarding, and to avoid, as far as possible 'taking chances,' which may result either in causing some good material to be rejected or some poor material to be accepted, as the case may be. We heartily endorse the statement of the authors, that the attempt is a step forward in the testing of manufacture, and that the advantage of regarding each ingot as a unit which must be tested by itself is sound. We also endorse the authors' statement that many unsound and unhomogeneous rails escape the present test and would be rejected by the nick and break test.

"This new test aims to correct the weakest point now remaining in the inspection of steel, namely, the defects arising during and subsequent to the casting of the liquid steel in molds. It is possible to safeguard the manufacture of steel up to the point of teeming it into molds, but it must be admitted that steel which is excellent up to this point may be ruined by conditions arising subsequently and these conditions can, in general, only be determined by a test of each individual ingot. The fact that one ingot, or three ingots, out of an open-hearth heat containing, say, 20 ingots altogether, was good or was bad is only a 'hit-or-miss' method of determining the quality of the 17 or 19 other ingots of the same heat.

"The defects which may arise during, or subsequent to, the ingot stage of steel manufacture are:

1. Pipe; which may appear in the rails later in the form of seams, laminations, cavities, etc;
2. Segregation;
3. Coarse crystallization, due to heat treatment;
4. Occluded particles of slag, etc.;
5. Combined oxygen;
6. Combined nitrogen.

"Of these defects, the most serious ones from the standpoint of the user of railroad rails are the first three, and the nick and break test aims to discover the existence of such defects by an examination of the fracture. This point in itself introduces an additional safeguard, because the judging of fractures can be properly done by skilled men only, and the necessity for the employment of men of this class is in itself, indirectly as well as directly, a benefit to the quality of the material. We are all ready to agree that an experienced man can determine accurately many different characteristics of steel by an examination of the fracture, such as, for example, the carbon contents and, therefore, the segregation of carbon; the previous heat treatment; seams; cracks, cavities, etc. We agree with the authors that experience with this test will increase the accuracy of the results, especially in the matter of segregation.

"In applying the nick and break test, the top end of the top rail of each ingot is chosen for the test, in the belief that, if this proves to be reasonably free from defects, all of the rails made from this ingot will be at least equally good.

"If, however, this top end should be defective, then the first rail from the top of the ingot is rejected and the top end of the next rail is tested, and so on down lower and lower in the ingot. This principle seems to be in general sound, but as a further safeguard all unbroken drop test pieces are nicked, broken and examined.

"The authors have presented evidence on the 13th and 14th pages of their paper to show that freedom from these specific defects in the top of the ingot indicates freedom throughout the whole ingot. The results are favorable as far as they go, but it seems to us that the number of cases tested are too few to enable a positive assertion to be made at present, even in the matter of seams, laminations, etc.

"As regards the matter of segregation, the authors have compared the results of the fracture test with segregation as determined by the Pennsylvania specifications, and have shown that of the 25 specimens shown in Table 2, three of the fracture tests disagree with the Pennsylvania test, and 22 agree with it. Of the 26 specimens in Table 3, 16 of the fractures agree with the Pennsylvania test and 10 disagree. Of the 12 specimens in Table 4, 7 agree and 5 disagree. While this does not indicate that the nick and break test is entirely reliable, we believe that the Pennsylvania test itself is unreliable, because it depends upon analyses made at only two points in the cross-section of the rail, and it might well be that these points would not be truly indicative. Indeed, we should be more inclined to trust to the judgment of the skilled and competent inspector of fractures than to analyses made arbitrarily at only two points.

"The observations of the authors upon segregation tests longitudinally of the ingot and of the cross-section thereof are borne out by many other authorities. In this connection we call attention especially to pages 131 to 152 and 551 to 556 of a book by Henry M. Howe, which is just off the press, entitled 'The Metallography of Steel and Cast Iron.'

"It is to be hoped that the publication of this splendid research by Messrs. Hunt and Gennet will rivet attention to the importance of defects in steel ingots and lead to the general adoption of this test, or some other test, aiming to prevent the acceptance of materials containing these defects."

The President:—I would mention one matter that neither Capt. Hunt nor Mr. Stoughton referred to in their discussion. They overlooked one thing, at least, that the Pennsylvania people had in mind when they adopted this new specification. We all know that every time we have an investigation from Washington of a failed rail where there has been an accident that we have been criticised in regard to our methods of inspection. The statement is made that we are buying our rails in accordance with a test made on a test ingot which does not represent the material that we get; in other words, when we make an investigation of a rail that has failed we find that the chemistry of that particular rail is usually very different from the chemistry of the test ingot which represented the rail. So we are criticised. We are told that it is not a good reliable way of buying material, that we ought to actually take the chemistry of the finished rail. That is one of the things that the Pennsylvania people aim to do, to get the chemistry of the finished rail, rather than the test ingot. We do not care anything about the test ingot. The mill can make that test for its own use, but we are after the chemistry of the rail, and we want that to be what the specification says it ought to be.

Mr. C. A. Morse (Rock Island):—The Rock Island purchased 3,000 tons of Algoma steel mill rails and had the rails tested under the same specification as the Illinois Central. The tests were made by our own inspectors. The other tests had been made by the Robert W. Hunt Company. Our results correspond very closely to those which Mr. Baldwin has related, as having shown up in the Illinois Central test, and we are very much pleased with the results.

Mr. W. C. Cushing (Pennsylvania Lines):—Capt. Hunt has called attention, at least in his paper, to the defects in the specifications of the American Railway Engineering Association. The Rail Committee of that Association has recognized for a long time, and in fact from the beginning of the rail study, that it has not reached perfection in its rail specifications by a long way. It has had to fight every step of the way for each improvement that has been introduced into the specification, and it does not consider that the fight has at all been ended yet. It expects to keep up the struggle and to continue to introduce improvements in the specification each year, as it becomes evident they are required. Each individual company is carrying on the study as well as the Committee of this Association, and each company introduces what it considers to be improvements in its specifications from time to time, and indeed it is those improvements by each company which bring about the improvement in the specifications of this Association.

Ever since I first heard of the test now spoken of to-night by Capt. Hunt I have been unwilling to accept it, for the reason that I did not think it was sufficiently accurate in its definition of the defect for rail inspection. I believe our specifications should as much as possible be on scientific lines, and the instructions to the inspector should be clear and specific. A set of specifications are nothing more than a series of instructions to the inspector for his guidance, and should make it unnecessary for him to go to headquarters for special advice each time he runs up against a difficulty. Performing the inspection under the nick and break test requires, as Capt. Hunt has said, a great amount of skill, like the determination of the degree of heat in a melt requires a great amount of skill on the part of the man in charge of the operation. I have always wished to have the results of this test tied in with the results of actual chemical inspection, such as is being carried on by the Pennsylvania Railroad at the present time, and Capt. Hunt has furnished in this paper to-night the first comparison with that inspection.

The nick and break test itself is all right for the purpose of disclosing interior defects, but I do not think the method of visual inspection of segregation is sufficiently definite and accurate for our purposes. Nevertheless, we do feel that it is necessary to continue our endeavor to improve these specifications, and therefore this idea is a stimulant to bring about the continuation of this work and to follow up the test as outlined, so that it can be brought to a scientific basis, in order that we may not be dependent upon one man's skill for the inspection of all of our rails. The number of inspectors required for the rails of all the railroad companies in the country is a very great number, and to have them trained up to this degree of skill to enable them to determine the amount of segregation accurately would be rather a difficult task.

We do not regard the Pennsylvania specification as the ultimate improvement to be brought about, but it is one step in advance, and it has the great advantage, as Mr. Trimble pointed out, of being an examination of the rail, and not of the test ingot. Speaking for the Pennsylvania Lines West of Pittsburgh, the result of that inspection has been that it brings about a discard at the present time of from 30 to 40 per cent., being about 23 to 32 per cent. from the top and about 7 or 8 per cent. from the bottom. The ordinary specification only gives a discard of about 10 to 15 per cent. The mills rolling for the Pennsylvania Lines West of Pittsburgh no longer submit the A rails for inspection.

Therefore the result of the chemical inspection is to bring about a progressive discard, which we believe is necessary, and it brings it about in a logical and scientific way; it is not and should not be brought about by a specified uniform discard for every mill. We have found as a result of the inspection at a number of mills that the same discard is not required at the different mills, and the justice of our long-established hostility to a fixed discard of 25 per cent. has been amply verified by the results obtained by the Pennsylvania specifications. Some mills have passed the inspection with only a discard of between 15 to 30 per cent., and, as I have stated, other mills require 40 per cent.

We do believe, since the specification has been put in use, that improvements in the manufacture of the ingot and of the rail have been brought about. We find less variation in the later inspection tests compared with the earlier ones, and there is a genuine effort on the part of the manufacturers, we are convinced, to make as good an ingot and as good a rail as possible.

Now, I do not think that this is the real problem in the rail question. I think the real object to be striven for in the rail problem to-day is the improvement in the manufacture of the ingot. We have proved that with the chemical inspection of the rail itself a large discard is necessary to obtain sound material from the ingot as now made. It is unnecessary to inspect every ingot in the heat to establish that fact. We have established it from merely the selection of the first, middle and last ingots, and it makes little difference at present whether there is a difference between each ingot or not, the main problem is to make a better ingot, and that will bring about a greater uniformity in quality between different ingots of the same heat, and will bring about improvements in various other ways as well, which can be brought about in no other way.

A large discard takes off the bad material from the top. It makes no change in the lower part of the ingot. We know from the study of our rail failures that we have failures in the lower part of the ingot as well as the top, and it has been extremely difficult to ascertain the cause of the failures of the lower rails. There is evidently an improvement necessary in the material in the lower part of the ingot as well as the top, and no reasonable amount of discard will improve that condition. For that reason, I say that the problem before our Association is to bring about, by every manner of means, an improvement in the manufacture of the ingot. There has been enough done in that line already, not only in foreign countries, but in this country as well, to show that it is advantageous, and that it can be done, and that it is a good thing to do it. It brings about a saving in the material, and that should mean a saving to the railway companies by not having to pay for so much discard. It brings about the improvement that Captain Hunt is endeavoring to bring about by the "nick and break test," but the "nick and break test" does not go far enough, and it should be our place, in my opinion, to emphasize the necessity for the improvement of the whole ingot so as to have our material of better quality all the way down.

Capt. Hunt:—I have but a word to say. My friend, Mr. Cushing, and others have emphasized the necessity of skill on the part of the inspector, and I believe I emphasized that myself, that it should not be lost sight of, that you do want a skilful man to properly enforce and apply these specifications, but that there is going to be a scarcity in the inspector market even if all the railroads of the country adopted the nick and break test, I do not believe. Robert W. Hunt & Company, I will say with all due modesty, is willing to undertake to supply the inspectors. Let me illustrate—can you conceive, gentlemen, of a task where more skill and judgment of heat and manipulation of materials is required than in the tempering of tools? I have never heard that the production of axes, or hatchets, or chisels, or saws, has been limited through the difficulty of finding workmen competent to properly temper them.

Mr. Cushing:—We have a good deal of trouble to get good track tools.

Capt. Hunt:—I think many track tools are made out of rail butts.

DISCUSSION OF PAPER ON "SYSTEM OF STANDARDIZING MAINTENANCE OF WAY WORK."

(See Part 2, pp. 247-263.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON SYSTEM OF STANDARDIZING MAINTENANCE OF WAY WORK.

Hadley Baldwin.
W. H. Courtenay.
A. C. Irwin.
A. J. Himes.
C. E. Lindsay.
W. D. Pence.
H. R. Safford.
Earl Stimson.

The President:—We will now take up the next subject, "A System for Standardizing Maintenance of Way Work," by Mr. Earl Stimson. He is to give us the benefit of the work that has been accomplished on the Baltimore & Ohio Railroad in the line of systematizing maintenance of way work. I am glad to introduce Mr. Stimson.

(Mr. Stimson presented the paper and commented on the lantern slides.)

The President:—Any questions anyone would like to ask Mr. Stimson?

Mr. W. H. Courtenay (Louisville & Nashville):—Will you kindly state what your organization is, and what is the authority of the supervisor?

Mr. Stimson:—Our organization is that of a division organization. The Division Superintendent is in charge of all departments on his division. He has a Division Engineer, who has the direct charge of the maintenance of way. This Division Engineer corresponds to the General Roadmaster on a number of the Western and Southern roads. The Division Engineer has under him Supervisors, who correspond to the Roadmasters. These Supervisors are in charge of sub-divisions of the road varying in length from about 25 miles on dense-traffic lines to as much as 100 miles on light-traffic branch lines.

Where this system is in effect the average length of the Supervisors' sub-divisions is about 45 miles, and each Supervisor has an Assistant, who looks after the details of the standard trackwork system.

Mr. Courtenay:—Do the men themselves share in the bonus?

Mr. Stimson:—The gang is considered as the unit. The foreman and each man in the gang receives a bonus based on the per cent. efficiency of the entire gang.

Mr. Courtenay:—Can you say what the maximum bonus earned has been?

Mr. Stimson:—One foreman, operating a pneumatic tamping machine, earned one month a bonus of $12, and his men a bonus of about

$6 each. In this instance the foreman's pay was $75 per month and that of the men about $40.

The President:—Would that pneumatic tamper show as great economy after you paid a large bonus as it would where the bonus was not so large?

Mr. Stimson:—You mean what was the quality of the work?

The President:—Which was the most economically maintained, the one with the tamper or the one that did not have a tamper?

Mr. Stimson:—Regardless of the bonus?

The President:—You say the man with the tamper got a bonus and that another man got a bonus because he did his work economically. So far as the Baltimore & Ohio was concerned, which was the more economical method?

Mr. Stimson:—There are overhead charges and the charge for operation against the machine, which make the cost for hand-tamping a little less than that with the machine.

Prof. W. D. Pence (Interstate Commerce Commission):—To what extent is the efficiency of the plan affected by the transient character of the labor?

Mr. Stimson:—It is quite seriously affected. The transients do not stay long enough to understand the advantages of the system.

The President:—You do not pay much bonus, then?

Mr. Stimson:—There is a considerable saving in favor of the company, even counting the cost of the installation of the system and the maintenance of these extra men on the Supervisor's sub-division.

Mr. H. R. Safford (Grand Trunk):—What does this represent in the way of additional expense, say, per one hundred miles? What I mean is, your organization expense, stationery, additional clerks and all of that.

Mr. Stimson:—The maintenance of this system is costing us about two dollars per month per mile of road where it is in effect.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—What provision do you make for the character of the traffic?

Mr. Stimson:—That is worked up for each division and sub-division. Over each section of a sub-division there is practically the same traffic.

Mr. Courtenay:—If it is a proper question, do you maintain your track under an appropriation made by the management for the season, or does that vary from month to month?

Mr. Stimson:—As a matter of fact this varies somewhat from month to month, being dependent upon the revenue. However, the season's work is covered by a definite program, which is adhered to as closely as conditions will permit.

Mr. Courtenay:—Is there a money allowance for the maintenance?

Mr. Stimson:—No maintenance allotment is made for the entire year. However, we do, prior to the beginning of the year, make up an estimate based on the recommended renewal program, which is adhered to as closely as the allotments given out, usually monthly, will permit.

Mr. Courtenay:—Suppose you exceed it by about 25 or 30 per cent. Do you ever do that?

Mr. Stimson:—No, we are always working under our estimate.

Mr. C. E. Lindsay (New York Central):—I was examining a section foreman about 25 years ago on a book of rules. I wanted to bring out the danger to him of his work when the train came along. I asked him: "When a train comes along what do you do?" "I get off the track." "What do you do then?" "Well, I look at it go by." "When the rear of the train comes along, what do you look for?" He said, "The Supervisor." I feel that Mr. Stimson has taken a very advanced step in eliminating, to a greater or less extent, some of the unknown quantities in the analysis of the cost of maintenance of track. We all try to subdivide the work into approximately equal portions and place a section foreman over each portion and then assign to him a force of men or an amount of money that is sufficient to enable him to do the work, and then we depend upon the Supervisor to bring the results. We try to stimulate his interest in various ways.

Mr. A. C. Irwin (Chicago, Milwaukee & St. Paul):—I believe we will recognize the system of track maintenance that we have just heard so well described as being an application of so-called efficiency engineering, as written about by Messrs. Taylor, Emerson, and others. The subject, some years ago, in its general features was discussed in the different engineering periodicals, and was criticised as well as applauded. The principal objection to such a system was thought to be the personal element. This objection applies here to a certain extent. The method of determining the bonus depends primarily upon the judgment of a man who is directly interested in receiving the bonus. If his degree of honesty is so high that he can properly criticise his own work he may not get the bonus. The fellow on the next section whose degree of honesty is not quite so high, who is very much set on getting the bonus, would judge his work at a higher standard. The mere fact of one gang obtaining a bonus and another one not obtaining the bonus has a tendency to arouse jealousy. The difficulty begins with a personal element.

Mr. Stimson:—There is a certain amount of faith that we must have in the system, as well as in the honesty of mankind. We cannot work successfully on the supposition that every man is dishonest. There are safeguards which prevent just what the speaker mentions. These are the periodical checks on the ground, made by the Assistant Supervisor, of the actual work done by the gang against the foreman's report of work done as made in his daily report.

Mr. Irwin:—I do not wish to pick out at this time each specific case in which this system is liable to fall down. I would not hazard a statement in the face of the fact that the system is in actual application, that it would always fall down. Perhaps this one is successful. If so, it must certainly be due to a very high order of intelligence, both of the men who put it into effect and of the men who are working under it—

clear down to the most insignificant laborer. It is not worth while now to take up at length the psychological attitude of the individual toward his own financial gain. We have to face certain facts in everything that we do, and it is undeniable that every man is influenced by his own self-interest. It is nothing against a man because he is ambitious. That is all very well, "but honesty, like charity, usually begins, and often ends, at home."

Mr. A. J. Himes (New York, Chicago & St. Louis):—It is of very great importance that employés should have faith in their employers. That would aid greatly in getting the men to do their work successfully and to the satisfaction of all concerned. I cannot refrain from mentioning a certain incident to illustrate a sentence in Mr. Irwin's remarks. It is a case in which two men were engaged in building concrete structures some years ago where the mixing was done by hand. The structures were about the same. They were built a good many miles apart, but under the same direction. Explicit instructions had been issued as to how the mixing should be done, how the sand and cement should be mixed and wetted, and the stone applied and turned over two or three times—the instructions were given in very great detail.

One of these men was accustomed to rigid discipline. He grew up that way. He was a reliable man. You could tell him what to do, and go away on your vacation, and be certain he would do exactly as told. The other man was of different development—he did not think in the same way. They were both good men, accounted excellent men. In the course of time the comment was made at headquarters that one man was a very much better man to do work than the other. There was no uncertainty about it. It was definitely established that he was very much the better man. I listened to that with a great deal of interest and wonderment, because I had seen both men work.

I had watched their work very closely, and it occurred to me that the man who had the lower rating was by far the better man. Not knowing what the basis for the judgment was I continued to wonder for several years how that had happened. After a while, in a casual manner. I discovered that the difference was this—the man who had secured the lower rating had, throughout all the periods of his work, been doing exactly as he had been instructed to do. The other man thought it was not necessary to do the work as he was told to do it, he thought some other way would be better, and so he did the work in the way that he thought was better, and the people at headquarters did not appear to know the difference. I think that illustrates Mr. Irwin's point exactly.

The President:—On behalf of the Association the Chair desires to thank Mr. Stimson for the very valuable paper that he has furnished us on the subject of Track Work and the very valuable information he has given to us.

DISCUSSION ON TIES.

(For Report, see pp. 233-270.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON TIES.

C. W. Baldridge.	C. E. Lindsay.
J. L. Campbell.	Hunter McDonald.
W. H. Courtenay.	John G. Sullivan.
L. A. Downs.	

The President:—The first order of business to be taken up this morning is the report of the Committee on Ties, which will be presented by Mr. L. A. Downs, Chairman of the Committee.

Mr. L. A. Downs (Illinois Central):—The first subject assigned to this Committee, and it is one that we have had for the last two or three years, is the effect of tie-plates and track spikes on life of cross-ties. The data that we have collected on this subject shows anything but a uniform practice, and neither the railroads nor this Committee are in the position to recommend anything definite in connection with the effect of track fastenings on the durability of ties, but the Committee furnishes you with information of what is considered the tendency of the railroads now and what we consider good practice as far as the matter has gone, and on pages 234 to 239, inclusive, you will find this information.

On pages 236 and 237 you will find some tabulated information on the spikes in use on various railroads and in the folded table between these two pages you will find reference to the tie plates in use on the various railroads. We collected this information in order to give you the benefit of the data which we have received, which is preliminary to the handling of this subject. The Committee feels that this subject is one of the most live subjects now before the maintenance engineers in this country, and we do not want to be too hasty in drawing conclusions on this subject; therefore, the Committee presents this subject as information to the Association with the understanding that we will follow it up and make reports until the matter is drawn to a final conclusion, and I move therefore that this part of the report be accepted as information.

(The motion carried.)

Mr. Downs:—The next subject assigned to the Committee was specifications for cross- and switch-ties. The Committee in going over this matter found but few changes to make in the specifications already in the Manual, and they are not of much value because the general specifications are the same, with a few minor changes. However, we have never had any specifications for switch-ties, and beginning at the bottom of page 245 will be found specifications for switch-ties. Now, in order to get the matter before the convention, I move that that part up to the bottom of page 245, where we start with specifications for switch-ties, be accepted.

The President:—You have heard the motion. I will make this suggestion, that the Chairman of the Committee call attention to the changes that are proposed in these specifications for cross-ties and we will then wait a few moments to hear whether there is any discussion with reference to these proposed changes. The changes are indicated by italics on the opposite side of the page containing the present form of specifications.

Mr. Downs:—As preliminary to that, I will call attention to the fact on pages 240 and 241 is a general explanation as to the reason why most of these changes have been made.

Mr. W. H. Courtenay (Louisville & Nashville):—I would ask the Committee why heart yellow pine is eliminated.

Mr. Downs:—It does not need to be treated. Good heart yellow pine does not need to be treated.

Mr. Courtenay:—It will last a great deal longer if it is treated.

Mr. Downs:—In the previous specifications, before we made the change as adopted in this specification, it was decided that the heart yellow pine did not need to be treated. The Committee sees no reason to change from that. My own personal opinion is it does not have to be treated to last longer.

Mr. Courtenay:—My experience is if it is treated it lasts about three times as long.

The President:—Will you not give us the benefit of your experience along that line, Mr. Courtenay? Some people have had experience with good heart yellow pine treated, and got about the same life out of it as with other material not quite so expensive.

Mr. Courtenay:—I will do that with pleasure. I believe I have stated to this Association before that there is now very dense close longleafed yellow pine in the structures of the Louisville & Nashville Railroad, which was treated with creosote with the Bethel or full-cell process in 1876, '77, '78, and most of that was in bridge structures. There were a great many bridge ties. They are now gone. There were no ordinary cross-ties. The company at that time did not feel justified in going to the expense of treating ties. The creosote oil does not penetrate through dense heart yellow pine more than a quarter of an inch. Notwithstanding that, old structures, exposed to the weather in a climate where untreated yellow pine perishes very fast, have lasted to this time. A great many ties were put on the long trestle structures between Mobile and New Orleans and they were damaged by fire or destroyed by storm. With the early ties which were treated the main trouble with them was that they split season cracks, and these splits were covered with pitch, mixed with lime, to protect the interior wood from decay. The engine fireboxes were lower at that time, and many fires were experienced because the pitch became ignited. However, the bridge ties on these bridge structures when they did not perish by fire or storm lasted for eighteen years. An ordinary, untreated tie, even a heart pine tie, in that country usually lasts about six years.

The President:—I will say a word with reference to what Mr. Courtenay has said. He has made the statement that the creosote oil does not permeate this kind more than one quarter of an inch. I believe that is the vital thing in connection with the whole matter. We cannot afford to take that tie out of the track after the tie-plate or rail has gone into it to the extent of a quarter of an inch. What is the use of treating it if that is all the protection you are going to get?

Mr. Courtenay:—I am not able to explain it satisfactorily, but abundant experience has demonstrated that if the outer wood of longleafed heart yellow pine is treated, in the course of time little or no creosote oil can be detected in the timber, but it is still preserved. I have taken old stringers which have been in the trestles many years and sawed them in two and cut chips of the outer wood and chewed them up to see if I could get the taste of the creosote oil. Very little remained. Some of the old stringers were scarred by the bridgemen's tools, and scarred beneath the original penetration, which was about one-quarter inch in dense heart yellow pine, and still the timber was preserved.

Mr. J. L. Campbell (El Paso & Southwestern):—The chairman of the Committee made the statement that yellow pine does not need treatment. I think a better way to put it would be that yellow pine is hard to treat and the treatment incomplete. I believe it does need treatment, and, if we can find a practicable way, that we should treat it. I am of the opinion that a penetration of even one-quarter inch will prolong the life of the tie. Ties fail materially by rotting on the bottom. In dirt track, where the surface of the tie is not broken by ballast, a penetration of one-quarter inch of creosote will prolong the life of a tie.

Mr. Downs:—We are discussing something which was passed on by this Association several years ago. We are only putting in a few words what is already covered in the Manual in a more extended way. This matter has already been passed upon. You will notice at the beginning of this second paragraph this language is used: "The following woods shall preferably not be used for tie timber without a preservative treatment approved by the purchaser." Under that wording railroads may treat these timbers if they so desire. We are only substituting a shorter sentence in the place of multiple words.

The next point is "Douglas Fir." We explain that on page 240. We have substituted "Douglas Fir" for "Red Fir." There may be objection to that on the part of some of the members living in certain localities, and it is explained on page 240 that Douglas Fir is substituted for Red Fir, as it is a more proper term. There is apt to be a misunderstanding as to what is meant, and for that reason we have substituted "Douglas Fir." Below that is given a list of what this wood is called in the different states.

Mr. C. E. Lindsay (New York Central):—The first half of paragraph 3, it seems to me, can be improved. I offer the following: "Cross-ties shall be cut from straight, sound live trees, which are felled in the season when the sap is down." It is not the tie that is cut when the sap is down but the tree"—they shall be hewed or sawed to the specified dimensions and out of wind, with straight and parallel faces and with the ends cut at right angles to the axis of the tie." I move a substitution of that for the Committee's recommendation.

The President:—The Committee will accept that proposed change. Is there any other discussion of this proposed paragraph?

The next is minimum dimensions. Any discussion on these dimensions? Not hearing any objections, we will accept this and pass on to the next.

Mr. Downs:—Allowable variations in dimensions (reading paragraph 5, page 245.)

Mr. C. W. Baldridge (Santa Fe):—It seems to me the width of twelve inches is too great to allow for a tie for various reasons, particularly that extra wide ties placed among narrower ties does not make as good riding track as is secured by the use of more uniform ties.

Another factor which has some bearing on the desirable width of ties was discovered in making investigations of the depths to which tie plates have cut into ties. It was found that a tie plate, if placed in the center of a tie, will, when it has cut into the tie a little bit, form a basin which holds water to a certain extent, and there is no means for the water to get out except by evaporation. Therefore, the tie plate should be wide enough to reach both edges of the tie or should be so placed that it will reach one edge of the tie so that it will cut away the edge as it sinks into the tie, thus releasing any water that collects.

It is a difficult matter in a very wide tie to provide for any such drainage.

It seems to me that in placing a tie plate on any tie, it should be so placed that an edge of the plate reaches an edge of the tie, to provide drainage of the basin formed in the tie. The plates should be staggered, that is, placed to reach opposite edges of the tie, to avoid any tendency to tip or roll the tie.

I think the width proposed is too great.

Mr. Downs:—I will say in explanation of that, that this is general and must not exceed 12 inches. If you feel that it ought to be 8, that is your privilege, even with these specifications.

Mr. Baldridge:—I do not consider that it is necessary to limit to 8 inches, but I do think that 10 inches will be abundantly wide as a limit.

The President:—Do you make a motion to limit it to 10?

Mr. Baldridge:—I make a motion that the maximum limit be placed at 10 inches instead of 12.

Mr. Downs:—I would like to say that the average width of the spaces must not exceed 10 inches. That is what you want, is it not?

Mr. Baldridge:—That does not entirely answer the question, because it permits one face to be 12 inches.

Mr. Downs:—Does not exceed 12.

The President:—If there are no objections, we will accept the specification in the form proposed by the Committee.

Mr. Downs:—Piling untreated ties. There is the word "preferable" and the words "at least," which make no difference in the sense.

The President:—If you are satisfied with these proposed changes we will accept them.

Mr. Downs:—"All ties piled on the company's property shall be at the owner's risk until inspected and accepted."

Piling treated ties. "Treated ties shall be cross piled closely on well-drained ground to prevent checking."

Mr. Lindsay:—Our experience with treated ties is that they must be piled with the ties close together in each layer, and I believe that is what the Committee wishes to convey. You don't want to convey the idea that the piles themselves must be close together. Will you add to that specification, "and piles shall be far enough apart to reduce fire risk"?

Mr. Downs:—There is no objection to that. All we desire to convey is how the ties shall be piled as to each tie.

Mr. Lindsay:—The idea may be conveyed that the piles themselves may be close together, which is objectionable.

The President:—Do you make a motion to have that added?

Mr. Lindsay:—Add that "piles shall be far enough apart to reduce fire risk."

(The motion carried.)

Mr. Downs:—We have finished the specifications for cross-ties and we start now with the specifications for switch-ties. The Committee was mindful of filling up the Manual with too many specifications and the specifications for switch-ties fit in with cross-tie specifications to a certain extent. (Reading bottom paragraph, p. 245.)

Mr. Downs:—Minimum dimensions (reading par. 2, p. 246).

The President:—Any discussion on paragraph 2? If there is none, we will accept the work of the Committee.

Mr. Downs:—Allowable variations in dimensions.

Mr. Baldridge:—This allowable variation brings up again the 12-inch width of space permissible in ties. The switch-ties under the frog are fixed in position by the frog-plates. It is therefore impossible to spread the ties to other than fixed positions and with 12-inch face dimensions it is almost impossible to tamp the switch-tie under the frog. It seems to me that for switch-ties the 12-inch width allowable is too great.

Mr. Downs:—The Committee did not intend to place the interpretation on that paragraph that you place on it.

The President:—As I understand Mr. Downs, and he confirms it, the variations he refers to are as follows: "Variations from the specified dimensions for cross-ties will be permitted of one-half inch over in thickness; 2 inches over in width and 2 inches over in length."

Mr. Downs:—Yes, sir.

Mr. Baldridge:—I move that the maximum dimension permissible on switch-ties be limited to 10 inches.

The President:—I do not hear any second. We will therefore take it for granted that you wish to approve the recommendation of the Committee as it stands in the report.

Mr. Downs:—Piling. Each set of switch-ties shall be piled separately and must be complete as ordered. The length or number of each tie must be plainly marked on each end.

The President:—Not hearing any criticism or objections we will consider that approved.

Mr. Downs:—The balance of that page gives information we collected that we thought would be of value to you. The next is the use of metal, composite and concrete ties. As we have stated each year, this is the building up of the history of these ties and is furnished you as information. You will find the information on the pages beyond this.

The President:—This report of the Committee on the use of metal, composite and concrete ties will be received as information. Has the convention any recommendations to make for next year's work in connection with the work of the Committee on Ties?

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—There is one question I want to direct the Committee's attention to. Of course, they have no right to anticipate action of this convention on any report that has not been presented, but the report on the grading of lumber, if adopted by this Association will wipe out all nomenclature, such as "longleaf yellow pine," etc., and in case it is adopted I think the Committee should revise their report to conform.

The President:—That will be the understanding. That would naturally carry along with it the revision of this specification to correspond with the other. Have you any suggestions to make for the benefit of the Committee on Outline of Work?

Mr. John G. Sullivan (Canadian Pacific):—It may be possible that in the Manual already there are instructions as to the piling of creosoted ties and protection against fire. We issued instructions that they be piled a specific distance apart, the idea being that the cost of cutting the grass and digging up the ground was greater than the cost of carrying them to the point at which they would be put in the track. That may have been covered in previous reports, but it appears to be a point that might be considered.

The President:—We understand that point has been covered.

Mr. Sullivan:—Mr. Lindsay spoke about the ties being piled close, but he did not say anything about protection. If they were 50 feet apart that might reduce the risk. If you had a single-track road, piling them

50 feet apart, that might reduce the risk, but if you dig up 10 feet of sod all around, might that not protect them from fire?

Mr. McDonald:—In piling treated timber, we not only pile it so that no air can get through or under it, but cover it with earth. I don't know whether that is covered in the Manual or not.

The President:—I think that practice is pretty well understood. People using treated ties now are pretty well informed as to how to take care of them. The Committee is excused, with the thanks of the Association for their work.

DISCUSSION ON CONSERVATION OF NATURAL RESOURCES.

(For Report, see pp. 271-278.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON CONSERVATION OF NATURAL RESOURCES.

L. A. Downs.	S. N. Williams.
C. E. Lindsay.	R. C. Young.

Mr. R. C. Young (Lake Superior & Ishpeming):—The report of this Committee is in the nature of information only and touches the subjects which seem to be of the most interest to the railways, namely, reforestation and the subject of the preservation of the timber supply; also the question of the development of water power with the idea of the conservation of the fuel and coal supply. Prof. Williams has been largely instrumental in the preparation of this report, and I will ask him if he has any comments to make.

Prof. S. N. Williams:—The instructions given the Committee were, first, continue the study of tree planting and general reforestation; second, study the resources of iron ore, coal, fuel, oil and timber; also report on water power for railway operation. In accordance with the general instructions, that two subjects were the maximum for action of the convention, it was thought best not to enter far into the study of resources of iron, coal, fuel, oil and timber. If the Association remembers the report of last year, you may be pleased to know that the Illinois Central Railroad has shown the possibility of practical work in the direction of forestation, and may, if interested, refer to that report, as it shows what has been done successfully by railway companies. As shown here, reforestation in general involves such a length of time and amount of money that railway companies will not care to devote themselves to it at present. It is a matter for either state or government management. For that reason it was thought best to present to you a report which has taken France several years to prepare on reforestation, and it has been done very successfully, particularly financially. About two years ago, in investigating subjects for our consideration, I decided to investigate the subject of electric power from water power for railway operation. I found that in Norway the government was taking control of the rivers and putting them in condition, or at least preparing to do so for the use of the river power to operate their steam railways. For that and other reasons, the subject has been formally placed before the Association.

We found last year that while there were many examples of profitable management of water power in the interest of city railways and electric lighting, there seemed to be a large opportunity for railway companies and the enormous development of water power, for general commercial purposes makes it advisable to call attention of the Association to its value for steam railway purposes. In our investigation we did not find steam railways using water power successfully, though we found quite a number of railways using steam to produce electric power. I am informed that the great power at Keokuk is possibly not being used as fully as it might be, and think there is a probability of using the Niagara power more profitably than at present, although that is a question under discussion between the two governments interested. I only refer to it because we are very practical and wish to use, as shown in this report, all the power that can successfully be used. None should be wasted, and we find two steam railways successfully using water power for running their trains. Hence the Committee invites your attention to them: the Butte, Anaconda & Pacific and the Milwaukee & St. Paul. As I came this morning I was pleased to find that "the psychological moment" had been improved by one of the great companies mentioned in this report, so if you don't have a copy of our report to carry away with you, simply get a copy of the Chicago Tribune and you will find the leading points referred to by our Committee in report on the Chicago, Milwaukee & St. Paul Railway. I may be excused for referring to these two railways so directly, because they have made a notable success in lines of operation considered by our Committee. The report is not as full as it might be on the subjects assigned. The Committee really had about three times as much information on them as the Secretary thought best to publish. Hence we cut down to a reasonable amount. and we hope every member will read the entire report. It is hardly necessary for me to remind you that the great war in Europe indicates a necessity for world-wide conservation of natural resources. We are temporarily at a standstill in this matter, as noticed in the report, in reference to the work of commissions, because we don't know just where we are at present. Until we know how much of the natural resources of the world have been consumed by the governments in Europe, and, possibly a little later by our own government in Mexico, we don't know how to advise the people best in conservation of natural resources. I think, however, that the work of railway officials in general is such that it is hardly necessary to emphasize the necessity of economy; only we would like to have the matter of economy of natural resources and of every other kind of resources impressed fully upon the people at large. So, without reporting fully on these three subjects, we invite your attention to the report now before you as information, and think that they might profitably be continued for study the coming year. The special lines of value to railway companies are indicated in the report, and possibly the Board of Direction may consider that we can best investigate subject No. 2 again. I thank you for your kind attention.

The President:—Is there any discussion of the report of the Committee on Conservation of Natural Resources?

Mr. L. A. Downs (Illinois Central):—Prof. Williams mentioned last year's report in his talk, and has also mentioned in this report the splendid showing made by tree planting on the Illinois Central. I intended speaking of this last year as to how different this Committee acts from other committees of this Association. Last year, in their report, there were ten or twelve railroads that reported on tree planting. All of them were dismal failures, with the exception of one on the Illinois Central, and that showed that it was a success. This one is located seven miles out from New Orleans. No mention was made in the Illinois Central report of one in Southern Illinois in the vicinity of Duquoin, that was a dismal failure. I was not familiar with any of these reports last year, except the one on the Illinois Central. This was planted in 1901. I was then Roadmaster there and had charge of this planting. I was the original tree planter on the Illinois Central. I had occasion to look at this plantation last Sunday. I don't agree with the report that was made last year, and from my observation it was a failure, although it is shown in this report that it was a good thing. It was surprising to me that in the report of last year all the railroads which have planted trees have had dismal failures, and even if the Illinois Central had had the alleged success shown in this report, the Committee would not have thrown it out. I don't believe there is anything to be gained by tree planting.

Prof. Williams:—The Committee was informed in a general way about the plantation in Southern Illinois, but we refer you to our previous report, which shows decided success on one plantation of the Illinois Central and gives the information furnished by other railways that had tried forestation, notably the success of the Pennsylvania Company, and admit that the report of most of the other railways was not encouraging. I think the Committee made no recommendation that railway companies should take this up, but considered that the success at Harahan was worthy of report since there had been on exhibition here previously ties obtained from that plantation. Last year we did not recommend the railway companies to generally practice forestation nor do we now urge this, because it takes so long a time, requires much money and, from a practical standpoint, does not pay.

Mr. C. E. Lindsay (New York Central):—Is it in order to make a motion?

The President:—Yes, it is, Mr. Lindsay.

Mr. Lindsay:—One matter about natural resources has not been mentioned by the Committee. The conservation of natural resources is a constant source of conversation, and should include the conservation of human life. Would it not be proper for this Committee to give us a broad resumé of this subject?

The President:—That is referred to the Committee on Outline of Work. Is there any further discussion? If not, we will accept this report of the Committee as information and excuse the Committee with the thanks of the Association. This is a very interesting report that this Committee has furnished us, and I am sure that you will receive benefit from it if you will read it, as has been suggested by Prof. Williams. The Committee is excused, with the thanks of the Association.

DISCUSSION ON YARDS AND TERMINALS.

(For Report, see pp. 279-298.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON YARDS AND TERMINALS.

C. W. Baldridge.
Geo. W. Kittredge.
C. E. Lindsay.
Hunter McDonald.
R. A. Rutledge.
John G. Sullivan.
E. B. Temple.

The President:—The report of the Committee on Yards and Terminals will be presented by Mr. E. B. Temple, Chairman of the Committee.

Mr. E. B. Temple (Pennsylvania Railroad):—The Board of Direction assigned four subjects to the Committee, outside of the revision of the Manual. The first subject was to make a report on the handling of freight in double-deck freight houses and cost of operation. We have not treated on this subject this year, because we have taken up two other matters which occupied all the space that should be given to our Committee. The Committee would suggest, however, and have requested of the Board of Direction, that this same question be referred to it next year. It is a subject which permits of ample discussion and much can be written on it. It is a very live subject with some of the railroads now. We are also suggesting that storage warehouses be studied in connection with the less-than-carload freight matter. Last year we gave instances of mechanical handling of freight in a number of freight houses in this country and abroad, and that feature was pretty thoroughly covered.

The next was to continue the study of typical situation plans of passenger stations and approaches and methods of operating same. For the last four or five years this subject has been reported on and a number of instances have been cited and articles printed. We did not pursue this matter this year for the reason which I stated before. Two of the diagrams which have been described in our previous reports have been tried out, one at the Kansas City Terminal and one at the Broad Street Station, Philadelphia, and the results were fully up to the recommendations, as shown by these diagrams and studies which were made by the railroad companies and this Committee.

The next subject assigned to us was to continue the study of classification yards. Last year this Committee made an effort, and it succeeded, in getting the cost figures on the operation of several classification yards; in fact, one hump yard and two flat yards. This year we have received and tabulated information on two hump yards and one flat yard. The information, I think, is valuable and instructive, and while we are not prepared to make any recommendations as yet, we find that this is a field that is promising, and I believe that good recommendations can be made when the subject is pursued a little further.

The Committee, in first taking this matter up, was undecided as to whether the cost should be per car passing through the yard or by counting each car twice. Some roads prefer to count the cars but once, but we decided to count the cars twice, once when they enter the receiving yard and once when they leave the classification or departure yard. I will give the figures to you just roughly—the cost per car in the hump yards, counting the car twice, in one of the yards, was 23.76 cents, in another yard 18.5 cents and in another yard 12.9 cents. In the case of flat yards, the cost per car, counting the car twice, was 21.3 cents in one case, in another case 15 cents, and in a third case it was 63 cents. This latter case we think should not be considered because there were certain conditions in the yard which ran the cost up.

It was found that the grades in the receiving yard had much to do with the cost as well as the type of motive power used in pushing the trains through the receiving yard over the hump. In addition to these costs, there are the costs of moving the cars from the classification yard to transfer sheds or shops. The figures are not included here, but they run about the same as the cost given for pushing the cars over the hump.

I believe that good conclusions can be drawn when this matter is followed a little further, and it is the expectation of the Committee that more yards will be studied this year and we will take up the study of some of the smaller yards. These yards referred to are pretty large yards, both in the East and in the West.

The last subject assigned to the Committee was to continue the study, and if possible make a report on track scales. This is a matter which has been before the convention for two or three years, possibly more, and there has been an endeavor made on our part to prepare a track scale specification that, perhaps, we could adopt next year, and there is printed in the Proceedings a report which we prepared after many consulations with the Committee of the American Railway Association, which association was about to revise its standard on this subject.

In January, unexpectedly, the Bureau of Standards of the Department of Commerce at Washington issued a tentative track scale specification, and they have sent this pretty broadcast throughout the country, asking for criticisms. They wrote to Mr. Trimble, as President of our Association, and sent him a copy of these specifications and also wrote to me. The second paragraph of Mr. Stratton's letter, who is the Director of that Bureau, is as follows: "We would be pleased to have the benefit of suggestions and criticisms resulting from any consideration you or the Society may give to the matter. In particular, we would appreciate a careful consideration of the second part of this circular, entitled 'Capacity Rating.' This is a technical treatment of the subject upon which it is difficult for us to get competent criticisms."

I would state that it is quite technical, and I know that our Committee cannot handle it without the assistance of other engineers of the railroad companies or some other committee of this Association. The

Bureau has been spending a couple of years in the preparation of this report and has gone into it in great detail. We are not prepared to criticize or accept this proposition, but it would appear from glancing over it, that it might be better if it could be condensed, or at least a synopsis given of it, so that the ordinary man could read it and understand it, without going into the technical end of it too much. If we undertake the consideration of this, it will be, I think, on those lines.

We have no recommendations to make this year, and nothing to ask the Association to insert in the Manual, except one definition of "Holding Yard," which really should have been placed in the Manual last year and it was only because of an oversight it was not. We were asked a year or two ago to give a definition of a holding yard which we do as follows:

"HOLDING YARD.—A convenient relief yard for holding cars or trains for immediate use."

I would move that this be inserted in the Manual as the definition for a holding yard.

Mr. C. W. Baldridge (Santa Fe):—It seems to me the terms "holding yard" and "for immediate use" are headed in opposite directions. I think the wording of this definition should be, "A convenient relief yard for holding trains or parts of trains between makeup and leaving time of trains." In my opinion that expresses the definition of holding yard better than "for immediate use."

The President:—Do you offer that as a new definition to take the place of the one recommended by the Committee?

Mr. Baldridge:—Only to the extent of modifying the latter part of that definition in the manner indicated.

(The motion of the Chairman carried.)

The President:—The definition offered by the Committee is accepted and will be added to the Manual.

Mr. George W. Kittredge (New York Central):—I would like to ask if in their discussion of cost of operating hump yards as compared with flat yards whether the Committee has secured any information as to just where the dividing line should come, that is, just where a hump yard should be resorted to, and where a flat yard should be resorted to. There is undoubtedly a very interesting point here, and where there is a very large number of cars to be handled, no doubt a hump yard is more expeditious and possibly less expensive, but I think that with a minimum number of cars it is quite possible that a flat yard is the better.

Mr. Temple:—We have not developed that yet, although last year a number of roads were asked that question and our last year's report gave some information on the subject. I might state as an instance of that, of a closely connected poling yard and hump yard, at Harrisburg, where the eastbound yard is operated by the poling method and the westbound yard by the hump method. The cost in the poling yard is 18.5 per car, and in the westbound gravity yard it is practically 18 cents. It appears from that instance that there is practically no difference in unit costs in a big yard of that kind.

Mr. C. E. Lindsay (New York Central):—Under "Yard A" on page 282, items 8 and 9, it speaks of the eastbound as a poling yard, I assume that is the Harrisburg yard.

Mr. Temple:—Yes.

Mr. Lindsay:—On page 283 you figure the average cost per hour, based on six miles per hour. Just why did the Committee use six miles per hour in that calculation? Is that the report you received from the railroad?

Mr. Temple:—That is a report from the Pennsylvania Railroad, and that is the way that the Pennsylvania makes up its cost.

Mr. Lindsay:—It is arbitrary?

Mr. Temple:—It is an arbitrary charge. A good many of these locomotive charges are arbitrary charges.

Mr. Lindsay:—On page 285, item (2), which I assume refers to Yard A, the writer speaks of having the classification tracks long enough to hold 150 cars—do they depart from the classification tracks?

Mr. Temple:—Yes, they do, and the same is true of the big yard across the river, the Enola yard, although some of our yards have departure tracks.

Mr. John G. Sullivan (Canadian Pacific):—I do not notice that they give any statement of interest on the amount of capital invested.

Mr. Temple:—These figures do not include any interest charges on the capital. They do include all other expenses which should go into the cost of handling the cars over the hump and in the yard.

Mr. R. A. Rutledge (Santa Fe):—Does that include the difference in the cost of repairs to equipment? I know that is the first thing I meet when I talk hump yard. The mechanical department claims it will greatly increase the cost of repairs to equipment. Does this item of cost include anything on that?

Mr. Temple:—The cost damage to cars? You mean by equipment the cars?

Mr. Rutledge:—Yes.

Mr. Temple:—That is given in each instance and you can see the difference. The damage to cars in these big yards is not very great. If you will read the report you will notice in each case the damage during the month has been given and the cost of repairs.

Mr. Lindsay:—Our experience is, with the hump yard, that our damage to equipment is less than it was with the tail switching method. We have further reduced it by the introduction of the poling car to push cars in to clear where they are stalled on the ladders and that method is being used very successfully.

The President:—There are certain matters in this report which are referred to the Committee on Outline of Work, including the recommendations and suggestions for next year's work. The Committee is excused, with the thanks of the Association.

DISCUSSION ON UNIFORM GENERAL CONTRACT FORMS.

(For Report, see pp. 219-307.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON UNIFORM GENERAL CONTRACT FORMS.

C. Frank Allen.
C. W. Baldridge.
J. L. Campbell.
W. H. Courtenay.
Thos. Earle.
E. A. Frink.
L. C. Fritch.
E. H. Lee.
C. E. Lindsay.
R. A. Rutledge.
C. A. Wilson.

The President:—The report of the Special Committee on Uniform General Contract Forms will be presented by Mr. E. H. Lee, Chairman of the Committee.

Mr. E. H. Lee (Chicago & Western Indiana):—The work assigned to this Committee is outlined in the report itself. You will note in addition to the changes in the Manual which we were requested to consider that two other subjects were given to the Committee, namely, the preparation of a report on siding agreements and a report on forms for interlocking and railway crossings, conferring with Committee on Signals and Interlocking.

Under rule 8-b of the General Rules of the Board of Direction it is indicated that only one subject is expected to be reported upon fully, and that subject in this report is the one on industry track agreements or siding agreements. In connection with that report I wish to call the attention of the Association briefly to the conditions. After mature consideration, your Committee concluded that the best method of procedure would be to submit the conclusions of the Committee in concrete form. Therefore, we submit the agreement in the form in which it is shown in the report. For the reasons stated in the report this subject is one of particular difficulty. Your Committee fully realizes that this suggested uniform industry track agreement can be expected to meet the requirements of relatively few railroads, in every respect, or as a whole. We do feel, however, that it is of importance that the various articles submitted in this agreement form shall be brought to the attention of members of the Association, when they are required to consider this subject.

Your Committee wishes to call the attention of the members of the Association to the fact that it will be entirely agreeable to the Committee if the action of the Association takes some other form than the definite approval of the agreement as submitted. It will be entirely agreeable to the Committee, for instance, if the report is accepted as information, without being considered in detail by the convention.

Prof. C. Frank Allen (Massachusetts Institute of Technology):—First calling attention to the bottom of page 299, a clerical correction is necessary at the end of the second line. The words "in other respects" should be underscored. The other changes in that paragraph are the word "shall" as underscored to provide that the bond shall be "written" and "in form and substance and with surety thereon" satisfactory and acceptable to the company "to insure the" faithful performance by the contractor," etc.

The suggestion is that the new reading makes it feasible to demand of the contractor that his bond shall be in the form of the bond that has already been adopted by this Association. The previous reading did not quite secure that. Then on page 300 are added the words "for the full amount or such smaller sum as may at any time be specified by the Chief Engineer," so that the sentence shall read "This bond shall remain in force and effect for the full amount or such smaller sum as may at any time be specified by the Chief Engineer."

The President:—I think we will act on each of these paragraphs as we come to them. Is there any change to be made by the convention in paragraph 1 as submitted by the Committee? If not, we will consider that as acceptable and pass to paragraph 9.

Mr. J. L. Campbell (El Paso & Southwestern):—I believe that the last part of paragraph 1 should be changed to read as follows: "This bond shall remain in force and effect for the time specified in the contract." I make a motion that it be so changed.

Prof. Allen:—It is probably true sometimes that the bond should remain in effect after the contract is substantially completed. It was thought better that the bond should not become outlawed at the time the contract is completed.

Mr. E. A. Frink (Seaboard Air Line):—The effect of Mr. Campbell's motion, in many cases, would be that the bond would not be in continuous effect during the progress of the work, because it is common experience that the contract is not finished on time. I think that limitation should not be put on it. I do not think it is right.

Mr. C. W. Baldridge (Santa Fe):—I think Mr. Campbell's motion would be right. I do not remember the reading exactly, but it should provide that the bond remain in full force and effect, as originally provided in the contract, until such time as the work is terminated. It is no uncommon experience to have a bond or contract voided entirely if a point of that kind is overlooked.

Mr. Campbell:—If the contract is properly drawn—and whether or not it is will be determined by the attorneys of the company—the bond provision will be fully covered by the contract which will state the kind, amount and duration of the bond and the conditions under which it shall terminate.

I do not believe that the management of a railroad company would, as a rule, consent to leave this matter entirely within the discretion of the Chief Engineer. The proposed revision says, "This bond shall remain in force and effect for the full amount or such a smaller sum as may at any time be specified by the Chief Engineer." On a technical construction of that, I believe the Chief Engineer would have power to annul the bond at any time after its execution. I believe the contract should cover the bond feature completely and if it does, it will make clear how long and under what conditions the bond will run. I do not believe that the proposed revision is fair to the contractor, inasmuch as it leaves too much uncertainty as to how long and in what amount he would have to maintain the bond.

Mr. Frink:—I am quite in sympathy with the spirit of Mr. Campbell's remarks. I do not think this provision as it stands is a good one. In the first place, I do not think it would be any benefit to the contractor, because when he gets that bond he pays for the whole time the bond is supposed to run, and if the bond is reduced or annulled, he does not get any rebate. I think it is a bad precedent to allow an annulment or reduction of the bond to be made at the option of the Chief Engineer. My objection was simply to the change in the wording that the bond should terminate at the time the bond is specified to expire by limitation.

I think we can clarify the situation by a motion to amend Mr. Campbell's motion, in this form: "This bond shall remain in full force and effect until the entire work contemplated by the contract is completed."

Mr. Campbell:—I accept that amendment.

Mr. W. H. Courtenay (Louisville & Nashville):—I think the amendment would be extremely disastrous. There are a large number of obligations which contractors incur which may become liens enforceable after the final estimate is paid. For that reason the effect of the bond or its action should not terminate at the completion of the work. It is my own practice to make such bonds run twelve months after the payment of the final estimate. By much experience we have found we are protected by that in many ways. A gentleman remarked in my hearing that "it will cost the contractor no more. The payment is made for the bond as long as it runs." That does not conform to my experience. Contractors are continually asking that bonds be cancelled when the work is completed in order to avoid additional payments. That has occurred, not once, but many times, so that I do not think that the protection given to the railroad company by the bond should terminate as soon as the work is completed, or as soon as the final estimate is paid.

Mr. C. A. Wilson (Consulting Engineer):—This means changing the reading. It is the feeling of the Committee that the subject-matter here presented is the result of careful consideration by the Committee, and the Committee would prefer to have such motions voted down, and then a motion for further consideration passed so that we can consider it further. The Committee does not feel that these gentlemen with the brief attention which they may have given to the matter can give the correct wording to which this wording should be changed. We have a standing form in effect now, and we ought not by motion, in a hasty way, change the form which is in the Manual. These are simply changes which the Committee would like to have discussed, but we do not like to see a motion such as that made by Mr. Campbell adopted.

Mr. R. A. Rutledge (Santa Fe):—There is a matter I want to call attention to along this line which is facing me at the present time. We had a contractor who unwittingly allowed an explosion which injured a boy 14 years old, and the case was settled in such a way that that boy when he is 21 years of age has the right to bring suit against the company or the contractor for that damage. I never release a bond until I know that every possible chance of a claim against the contractor has been satisfied, and I will not consider that the bond in this particular case to which I refer is released until that boy is 25 years of age. I do not think we can ever contend that a bond is released until every possible claim against the contractor is satisfied and we cannot fix the date for that release.

Prof. Allen:—In answer to Mr. Campbell's proposed change in reading, I will say that the change offered by the Committee is a change which does not affect the substance. The contract as adopted by this Association now reads: "This bond shall remain in force and effect in such amount not greater than that specified, as shall be determined by the Chief Engineer." As far as the substance is concerned, the recommendation of the Committee makes no material change; it says "for the full amount or such smaller sum as may at any time be specified by the Chief Engineer;" the present reading puts the burden on the Chief Engineer to specify the amount, and perhaps leaves the bond useless if he fails to specify anything. The proposed change simply perfects the reading, and there is no material change in substance.

(The amendment offered by Mr. Frink and accepted by Mr. Campbell's was lost.)

(The question was then put to vote and the amended paragraph was adopted.)

The President:—There is an additional sentence in paragraph 9. Is there any discussion on that paragraph? If not, we will consider it as approved and will pass to paragraph 12.

(Prof. Allen then read paragraph 12, and in connection with the latter part of the paragraph said:)

Prof. Allen:—The Chairman of the Sub-Committee, in looking through some contract forms that were not railroad forms, found this provision, which seemed to be a good one. It is proposed that this addition shall be made, because if this was not in the paragraph, it might cause some friction, if the Chief Engineer should ask to have portions of the work taken out.

Mr. Thos. Earle (Pennsylvania Steel Company):—I think that the following clause should be omitted, "even to the extent of taking out portions of the finished work; in case the work is found satisfactory, the cost of taking out and replacement shall be paid by the Company."

It does not seem to me that this is properly the function of inspection. An inspector is put on the work to see that it is done properly, and if there is any question of taking out portions of the finished work, this should be ordered by the Chief Engineer. The company is amply protected by the contract without this clause. Without it, if the work is not satisfactory to the Chief Engineer, he can order any portion of it to be taken out, and if it is not in accordance with the contract he can reject it, and if it is in accordance with the contract he would have to pay the extra cost of removing the work and replacing it.

I move that the clause be eliminated.

The President:—If there is no further discussion we will consider this paragraph as approved and we will pass to the next paragraph.

Prof. Allen:—In our correspondence objection to this clause was presented. The members of the Committee found that it left out one feature, that the contractor was interested in the insurance, that he had an insurable interest in the case of many structures, and that he ought to have some protection, so that the new reading, after a considerable investigation, was decided upon.

Fire insurance policies protecting more than one person or interest are sometimes a little intricate in form, and it was thought best to place on the contractor the burden of securing a form sufficient to protect him; this form, however, to be submitted to the Chief Engineer for his approval; he could submit it to the attorney for the company, if necessary, so that the interests of the company should be protected; any money paid to the company to be distributed by the Chief Engineer to the contractor and the company as their interests should appear.

That is the purpose of this new reading, and it seems a better provision than the former one, which did not find favor with some of our correspondents.

(Prof. Allen then read paragraph 22 and said:)

This is in harmony with the suggestion that came from one of the members in correspondence, that "upon, to or near the property of the company" seemed to be a better protection to the company than the former reading of this paragraph.

The President:—Any objection to this addition as proposed in paragraph 22? If not, we will consider that as approved.

Prof. Allen:—In the present reading of 33-b, it says, "The company not being at fault." This follows provision 33-a. (Prof. Allen quoted 33-a) and then this clause says, "if the company is not at fault." One of the Chief Engineers in correspondence with the Committee suggested it would be unfortunate if it was necessary in any case to prove the company was not at fault." It seems very desirable to make the opening words of 33-b read "In such case," following 33-a. It looks as if there was a little hole in the old provision.

The President:—Is there any discussion of this proposed addition to paragraph 33-b? Not hearing any objection, we will consider it as approved.

Prof. Allen:—There is something in connection with 33-b which should be mentioned. One of the correspondents called attention to the fact that in a certain case where work has been taken away from the contractor who was doing the work by the ordinary process of team haul, the company having taken over the work, for its convenience used the train haul method of procedure and the contractor claimed an allowance for such haul at the contract price of so many cents per foot. Proceeding in that way cost to the company turned out to be very large. I do not know how many thousands or hundreds of thousands of dollars it amounted to in one case, but it was suggested to this Committee that some provision should be made covering this point.

The Sub-Committee, therefore, suggests the following clause to be added 33-b, "In case of train haul of material, unless otherwise provided in this contract, the price for haul shall be computed at .... cents per cubic yard per mile."

This new paragraph to be added to 33-b is also to be added to 33-c.

This seems hardly appropriate to the general conditions of the uniform contract form. At the same time, the Committee having received this information from one of its correspondents, thought the matter was of sufficient importance so that it should not be passed over without calling the attention of the Association to the point. It seems to me, personally, that this applies more properly to the specifications for roadway than to the general conditions of the uniform contract form, and some of the other members of the Committee are quite of that opinion also.

It is quite likely that the fact that this appears in the Bulletin may be sufficient to call the attention of the members to the difficulty and danger of omitting some sort of a provision until such time as the Committee on Roadway, if they see fit to do so, shall incorporate some provision covering it in their specifications.

Mr. C. E. Lindsay (New York Central):—I think it is a very proper addition to be introduced here. I know of a case where the contractor had a contract for overhaul on the time basis. The material got scarce and the railroad company had an informal arrangement with the contractor and furnished the equipment on its railroad and hauled the material some thirteen miles. The contractor claimed overhaul on the material so hauled and won the case.

Prof. Allen:—To bring this matter before the convention, I move that this pragraph be included in the specifications for roadway.

The President:—It has been moved that instead of adding this clause to the general agreement that it be added to specifications for the formation of the roadway, subject to the approval of the Committee on Roadway.

Mr. S. P. Brown (Mount Royal Tunnel & Terminal):—I move that it be referred to the Committee on Roadway.

The President:—This is practically a reference to that Committee because it would not be inserted without their approval. The Committee accepts your suggestion.

(Prof. Allen's motion was put to vote and carried.)

Mr. Campbell:—I wish to make a motion before I get through and I will be brief. I believe this proposed change in the uniform contract is undesirable in the large discretionary powers that it confers upon the Chief Engineer in setting up conditions affecting the contract after the latter is signed. I believe it is a form that will not be generally acceptable either to the railroad company or the contractor. It places an unnecessary responsibility on the Chief Engineer and multiplies opportunities for mistakes of judgment which within my observation cost the railroad companies much money. The suggestion that the matter be referred back to the Committee is excellent because it requires more careful study than can ordinarily be given on the floor of this convention. I move that this whole question of the powers conferred by the contract upon the Chief Engineer be referred back to the Committee for further consideration.

The President:—The motion not being seconded, we will therefore proceed to the next order of business, and that is the form of agreement that has been submitted for an industry track. We understand this is submitted for the purpose of discussion. It is not recommended for adoption, but is read for criticisms and suggestions. The Committee deemed it proper to put its recommendations in concrete form.

Mr. Lee:—In order to call the attention of the members to this particular subject, I will read the agreement as printed.

Your Committee feels that the practice of the various railroads is bound to differ widely. The Committee feels that it cannot hope to provide a form, which will be more than suggestive; and therefore we offer a resolution that the reading of the form, as submitted, be omitted and that any members of the Association who have suggestions or criticisms reduce these to writing and submit them to the Committee for further consideration.

The President:—The Committee has submitted this to you as a matter of information. The Committee wishes your criticisms and would like to have them submitted in writing. Between now and the time of the next convention they will review these criticisms, and in view of any such criticisms will revise this form of agreement and bring it before you at the next convention. Are you satisfied to pursue that course, or do you wish to discuss it now?

Mr. L. C. Fritch (Canadian Northern):—I would like to suggest that in the future work of this Committee they formulate a standard lease agreement for industrial sidings. I understand there has been no such form of agreement prepared.

The President:—Mr. Fritch's suggestion will be referred to the Committee on Outline of Work for its information. The Committee is excused with the thanks of the Association.

DISCUSSION ON STRESSES IN RAILROAD TRACK.

(For Report, see pp. 309, 310.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON STRESSES IN RAILROAD TRACK.

A. N. Talbot.

The President:—The next business will be the report of the Special Committee on Stresses in Railroad Track. The Chair deems the work being done by this Committee as one of the most interesting items of work being done by this Association. I think the results of this Committee are going to inure in the future very much to the benefit of this Association, and have something to do with placing it in a higher position with reference to the railway world. Prof. Talbot, the Chairman of the Committee, has been intensely interested in this work, and he has with him a corps of assistants who are also largely interested in the subject, and they have all performed their full share of the work, and I am quite sure that the final results are going to be exceedingly valuable. Prof. Talbot will present a summary of the work of the Committee.

Prof. A. N. Talbot (University of Illinois):—The Committee is making a progress report. It will be found in Bulletin 182, page 309.

The work of the Committee, during the last year, aside from the development of methods and instruments was naturally devoted rather largely to stresses in the rail. It may be stated here that it was found, as has been pointed out by Dr. Dudley, that the wheel spacing of the locomotive drivers has a large effect upon the stress developed in the rail, the greater the wheel spacing the greater the stress developed for the same weight on driver. In fact, in the case of the two types of locomotives with which we have been experimenting, the amount of the stress developed is almost proportional to the wheel spacing. As would naturally be expected, the effect of the trailer is very much more per pound of load upon it than for the drivers which are spaced more closely. This, it seems, is a rather important matter, and it is quite possible that it will lead to more care being taken in the way the loads are distributed along the length of the locomotive.

It has been found, too, that the heavier weight of rail develops a higher bending moment in the rail per pound of load applied than the lighter weights of rail; in other words, the 125-lb. rail, which has a section modulus (moment of inertia over distance to remotest fiber) about twice the section modulus of an 85-lb. rail, instead of giving 50 per cent. as much stress under a given wheel load, gives something like 70 per cent. as much stress.

I think many have had in mind that the rail should be considered as a girder running from one tie to the next tie, and that all we have to do is to use the ordinary formula for a load half way between these two supports, with perhaps some reduction on account of the negative moment which would come at the tie. If you will stop to think, however, the loads are really the tie pressures upward, pressures against the rail, the wheels are the reactions, and the stiffer the rail the further and the greater are the tie reactions away from the wheel. The stiffer rail then puts the loads further away from the support, producing a higher bending moment.

It has been found, even on straight track, that the stresses on the outside of the base of the rail are higher than on the inside of the base of the rail, the results being for an average of runs rather than for anything which can be attributed to the counterweight, or to an unusual condition in the way the engine happens to strike the rail. It has not yet been determined what the cause of this excess is. That, of course, is one of the problems before the Committee.

On the matter of distribution of pressures along the length of the tie, less has been found. It is seemingly a troublesome problem. We have been able, I think, to get fairly well the division of the load among the ties, the tie reactions, sufficiently closely to tell how much load goes upon the ballast from a single tie, though probably not closely enough to be useful in calculating the stresses in the rail for a new wheel spacing and for a different arrangement of loads.

As to the matter of distribution of pressure down through the ballast and roadbed, measurements have been made of the depression of the roadbed below the ballast, across the roadbed and longitudinally. A start has been made to determine something about the way the load is distributed. The matter of the distribution through the ballast is an exceedingly difficult one. We have placed a number of instruments at the bottom of the ballast and in the ballast in an effort to obtain an indication of what the pressure is at various places. The pressure capsule, which is calibrated, determines the amount of that pressure per square inch at a given point, and we think considerable information has been found, but so much is dependent upon the laws governing the distribution of pressure down through the ballast below the tie that we have felt it best to make some laboratory tests on sand and broken stone ballast to learn something of the way in which the load is distributed below and along the ties. After this work is done we plan to make further measurements under the track, making use of the data of the laboratory tests for planning this work, and also for giving information to aid in interpreting the results found in the track.

I am giving these items at random, because I think you may be interested in some of the results. I said that we should not think of the rail as being merely a girder, from tie to tie; in fact, it has been found that the bending moment developed in the rail over a tie when the wheel is directly over this tie, in good track, is, say, about 75 or 80 per cent. of what it is at a point half way between ties when the wheel is directly above that point. There is, of course, a negative bending moment at points between wheels. This amounts to something like 30 per cent., say, of the value of the positive moment which occurs directly under the wheel.

Some tests have been made to determine the effect of poorly spaced ties, and of ties in bad condition, and, as would be expected, the stress in the rail is increased, though not to the amount that would be expected under the idea of a girder from tie to tie. In fact, if you will stop to think, if the action of a beam resting on adjacent tie supports were to govern the stress in the rail and one tie were to be poorly tamped or were left out for any reason, the increase in the stress in the rail would be away beyond what the rail could be expected to resist.

It is hoped in the coming season to go on with this work and also to make a start on finding the pressure of the wheels against the rail on curves and the stresses on curves, as well as to do some work on the effect of the locomotive counterbalance and other matters of that kind. If any of the members of the Association are especially interested, we have samples of the instruments here, and also photographs of the work which we shall be glad to show to you.

My attention is called to the fact that nothing has been said about the effect of speed. The effect of speed is somewhat variable and sometimes is different for different drivers, and it may differ considerably in different locomotives of the same class, the locomotives not being exactly in the same condition, but in general the additional stress in the rail may be said to be, say, three-quarters of one per cent. for each mile per hour increase in speed over five miles per hour. These values may be exceeded in individual runs. One of the matters we have before us is to determine the probable maximum for an individual run. The average value just stated means about 45 per cent. additional stress at 65 miles an hour over what it would be at 5 miles an hour for the Atlantic type of locomotive.

The President:—I might say that it is through the courtesy and liberality of the American Society of Civil Engineers and the United States Steel Corporation that we are able to make this investigation and report these results to you. They have furnished the funds which make it possible for us to carry on this investigation.

The Committee is excused, with the thanks of the Association, for their work during the past year.

DISCUSSION ON RULES AND ORGANIZATION.

(For Report, see pp. 423-445.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON RULES AND ORGANIZATION.

A. S. Baldwin.
G. D. Brooke.
S. P. Brown.
W. M. Camp.
J. L. Campbell.
J. B. Carothers.
A. W. Carpenter.
W. A. Christian.
Chas. S. Churchill.
W. H. Courtenay.
W. C. Cushing.
W. H. Elliott.
W. H. Finley.
R. H. Ford.
A. J. Himes.
A. C. Irwin.
J. B. Jenkins.
Geo. W. Kittredge.
E. G. Lane.
C. M. Larson.
C. E. Lindsay.
Hunter McDonald.
C. A. Morse.
G. A. Mountain.
H. R. Safford.
C. E. Smith.
C. H. Stein.
John G. Sullivan.

The President:—The next order of business is the report of Committee XII, on Rules and Organization. The principal subject of this report is Clearances. The Chairman, Mr. G. D. Brooke, will present the report.

Mr. G. D. Brooke (Baltimore & Ohio Southwestern):—The report of this Committee will be found in Bulletin 184. The report is, to a certain extent, in two parts. The first is taken up principally with a few revisions of the Manual. I think that they had best be considered first. If there is no objection, I will read these revisions, and if there be no objections from the floor, they be considered accepted.

The first change is in Rule 17, applying to Signal Supervisors. It is recommended that this rule be omitted. (Reading same.) The idea is that this work is a part of the duties of the track forces rather than of the signal maintainers. In the Supplement to the Manual of 1912, change Rule 22 as follows. The present rule reads: "In making temporary connections in main tracks an old rail shall be cut and fastened to the new rail, using compromise joints where necessary." The proposed rule reads: "In making temporary connections in main tracks a new rail shall be cut and fastened to the old rail, using compromise joints where necessary," the idea being to prevent damage to the new rail at the several places where the laying was stopped, in case there is an uneven joint between old and new rail. By using a short new rail, the end of the short piece will be damaged and the new rail left in the track will be in good shape.

The President:—If there is no objection this change will be accepted by the Association.

Mr. Brooke:—In Supplement to Manual of 1912, under Frogs and Switches, substitute the word "turnouts" in Rule 34 for the word "switches," and in Rule 33 for the words "switches and frogs." The Rule will then take this form: "32. Turnouts must be placed in accordance with the standard plans and as located by the engineer." "33. Turnouts must be kept well-lined and in good order. Particular care must be taken to maintain good surface through turnouts." "34. Turnouts must be inspected frequently to see that they are in working order and that all nuts, bolts and other fastenings are in place and properly tightened. Broken or damaged parts must be renewed promptly." The idea being that it is not simply the frog and switch that need inspection but the entire turnout.

The President:—If there is no objection, the changes will be considered approved by the Association.

Mr. Brooke:—The next is, omit the last sentence of Rule 39 under "Guard Rails," which follows: "The tops of the guard rails must be level with the tops of the main rails and must be securely held in place." The wording of that is somewhat ambiguous, as the real meaning of the sentence as written is that the tops of the guard rails must be held in place, so the Committee offers the rule in this form: "Frogs must be protected by guard rails, constructed and placed in accordance with the standard plans."

Mr. C. E. Lindsay (New York Central):—I object to the word "standard."

Mr. Brooke:—The words "standard plans" have been used in these rules as printed in the Manual, so I do not see any objection to using them in this place.

To the General Notice of the Rules Governing Construction Department Employés, Supplement to Manual of 1914, add the following rule, which has been adopted for the maintenance of way employés: "The use of intoxicants by employés while on duty is prohibited. Their use, or the frequenting of places where they are sold, is sufficient cause for dismissal." That is the American Railway Association rule. It was through an omission left out of the notice heretofore.

Under "Organization," in the same Supplement, after "Resident Engineer," add "(or title)." That is simply for uniformity. That concludes the report. The subject of Clearances of Maintenance of Way Structures will be taken up later. Progress only is reported under the other subjects assigned to the Committee.

The President:—We will now proceed with the report of the Committee on the matter of Clearances.

Mr. Brooke:—This matter of clearances of various structures was assigned to this Committee in December, 1914. The Committee held several meetings and it became apparent in April, 1915, that it would be necessary to have a report by October. The Committee realized that it would have been very desirable to collect some additional data, and that it did not have at that time sufficient opportunity to collect that data.

Nevertheless the Committee had been supplied with some admirable material with which to work by the Committee on Maintenance of the American Railway Association, and that material has been made use of largely in connection with this report. I think it only fair to say that the report is not signed by three members of the Committee. Those members concur in the report except as to the recommendations on the standard bridge clearance diagram and the general clearance diagram, but they could not bring their views on those two clearances to coincide with those of the remainder of the Committee. The conclusions are found on page 431 of Bulletin 184. I would suggest that these conclusions be read and that then the recommendations be taken up in order. I was agreeably surprised on my arrival this morning at being informed that we would have some lantern slides in connection with these recommendations; so that all the members present can get a visual idea of what is intended, and therefore a much clearer understanding.

(A stereopticon view was then shown upon a screen.)

Mr. G. W. Kittredge (New York Central) :—The chairman has suggested that the conclusions be read. This Committee's report is a very important one, and it seems to me that the body of the report should be very carefully discussed first, and then the conclusions discussed afterwards. It may save time.

(Mr. A. J. Himes, member of the Committee, then proceeded to discuss the slides thrown upon the screen.)

Mr. Kittredge:—I would like to ask how these distances compare with the distances that have been recommended by this Association's Committee on Electricity. I cannot carry all these distances in my mind. I know that your Committee on Electricity has spent a great deal of time and effort in getting desirable and proper clearances near the levels of tracks and third rail.

Mr. Kittredge:—Are the clearance lines of the Electricity Committee closer to the track?

Mr. Brooke:—I understand these are further out.

Mr. Kittredge:—Then what is the necessity for having two distances—

Mr. Brooke:—They are further out or the same.

Mr. Kittredge:—The question that arises in my mind is why should we show two distances from the center of the track to three inches above the top of the rail? There would be confusion. Some person might get hold of the wrong plan and injury would result from its use.

Mr. Himes:—If in getting hold of the wrong plan—I do not see how any harm would result.

Mr. Kittredge:—What I refer to is getting hold of the plan that is nearer.

Mr. Brooke:—In that case it would be the third rail plan, would it not?

Mr. Lindsay:—The railway postoffice regulations of the United States Government prescribe the distance from the center of the track to the point of suspension of the mail sack, and it would not be possible to have six-feet clearance and support the mail sack at the proper points. I think that diagram is in error. I understand the Committee, that when the arm drops, there shall be the clearance.

The President:—I wonder if Mr. Lindsay does not make a mistake when he says the Government has prescribed that distance. That is news to me, and I think it is news to other people here. On the Pennsylvania System that dimension has not been prescribed by the Government, but has been prescribed by ourselves.

Mr. W. A. Christian (Interstate Commerce Commission):—I do not believe 6 feet sufficient clearance from center of track, when mail bag is hung as shown in the diagram.

Often a freight train runs on schedule time ahead of a mail train, and cases are on record where freight engine crews have accidentally been hurt or killed by striking mail bags placed too near the track of roads operating Mallet and Mikado engines having an extreme lateral cab measurement of 11 feet, and for this reason the clearance should be more than 6 feet from center of track.

Mr. Brooke:—There are roads which have narrow cabs and narrow coaches and mail cars. It would be difficult for those roads to have mail cars that would pick up a sack placed at a greater distance. While the Committee realized that the 6 feet seemed to be quite close—a close clearance, under present practice—it also realized that it is pretty difficult to design a catcher and a crane of the type now generally used, which, if applied to the narrow equipment would successfully catch the sacks placed at a greater distance. If the road has wide equipment and wide engines, it is at perfect liberty to place the crane farther away so as to give greater clearance. These are minimum clearances in each case, and it is the view of the Committee that only minimum clearances should be recommended. All of these clearances apply to new construction.

Mr. W. C. Cushing (Pennsylvania Lines):—The clearances shown violate the state law of Ohio. The law of Ohio is that the clearance from the side of the cab to the nearest part of a mail crane shall be not less than 18 inches, so that, taking 5 feet as the minimum half width of the cab, the clearance distance from the track center shall be at least 6 feet 6 inches.

Mr. Brooke:—As I say, that is the minimum clearance. In Ohio it would be necessary to make that greater. The Committee had in view that in some cases that clearance would be unnecessary, and there are a great many roads where the 6 feet clearance to the nearest point of the sack seems to be in general use.

Mr. Christian:—Would the minimum clearance be on the side of safety?

Mr. G. A. Mountain (Canadian Railway Commission):—The regulation of the Canadian Board is 7 ft. 1¾ in. to the center of the track. That was adopted in conference with the Canadian Board, and I think it would work out satisfactorily.

The President:—Is that to the end of the pointer or to the side of the mail sack?

Mr. Mountain:—I have given you that information as I can. I haven't the documents with me. My idea is that it is from the end—whatever it is that sticks out. We have regulations for all of those clearances. We do not deal with anything below 4 feet. Above that we require 6 feet from the gage side to the nearest rail. On high and intermediate switchstands we require 6 feet from the gage side. We have a regulation establishing 2 ft. 6 in. from the side of the cab to the nearest point. That has worked very satisfactorily and has been in operation since 1910.

The General Order of the Board of Railway Commissioners for Canada is as follows:

"It is ordered that every railway company subject to the legislative authority of the Parliament of Canada, operating a railway by steam power, using mail cranes, be, and it is hereby, forbidden to erect, place or maintain, on or after the first day of January next, any mail crane along its line of railway, at a distance less than seven (7) feet one and three quarter (1¾) inches from the center of the track to the extreme point of the arm of the crane when in position, or at a height less than ten (10) feet ten (10) inches from the bottom of the rail to the top of the arm when in position.

Mr. Kittredge:—Mr. Himes has stated that this does not encroach upon the clearance diagram as recommended by the Committee on Electricity. The point that I want to make is that there shall not be clearance lines of two committees that are not coincident. They ought to be coincident. There ought to be only one clearance diagram recommended by this Association, and where two are now shown, or different reports, one or the other should be eliminated.

Mr. Cushing:—I am in full accord with these views.

Mr. W. M. Camp (Railway Review):—I think the point raised by Mr. Kittredge ought to be cleared up a little. As I understand it, the clearance diagram brought out by the Committee on Electricity took account not only of the position of the third rail, but of all equipment which might possibly be run over that piece of track. Is that right?

Mr. Kittredge:—Yes, sir.

Mr. Camp:—Such being the case, that clearance diagram provides for any kind of equipment operated on a steam railroad or an electric railroad.

Mr. W. H. Courtenay (Louisville & Nashville):—I would say it would be unwise to make the clearance 16 feet.

Mr. Himes:—(After technical explanation of the view, referring to screen.) To-day we are obliged to come forward with a recommendation for a clearance and this Committee has recommended 16 feet. A year ago, when the vote was taken, a number of gentlemen said they voted against fifteen feet because they wanted it sixteen. The Association has a variety of proposals from which to choose, and I think the Committee has done its work. That work now is before the Association.

Mr. Kittredge:—In regard to the slide just shown, I was wondering why the Committee recommended one clearance line for a single-track tunnel and another line for a double-track tunnel. According to the slide the clearance line for the double-track tunnel would not be safe for a man standing on the edge of the car.

Mr. Brooke:—The last slide was not intended entirely as a recommendation. These tunnel lines are the tunnel sections which have already been adopted by the Association, and that last slide was intended to show the relationship of this proposed clearance diagram to these tunnel lines. In the Bulletin the diagram is entitled, "Proposed Standard Clearances." That is misleading. It probably would be better to read "Study of Proposed Standard Clearance Diagrams."

Mr. Camp:—Referring to the diagram which Mr. Kittredge spoke about, the diagram of clearances presented by the Committee on Electricity, that is a safe diagram for any steam railroad. Now do I understand that this Committee has gotten up another diagram which at all points comes outside of the diagram of the Committee on Electricity, in order to be on the safe side, and made somewhat arbitrarily in order to sort of smooth the old diagram and take out the bonds and angles in it?

Mr. Brooke:—This is the only diagram that this Committee has recommended and this diagram does not infringe upon the clearance diagram of the Committee on Electricity. There may be some cases in which the diagram of the Committee on Electricity is inside of this diagram, but I think that would properly come under or is provided for by the exception which is noted on page 433. The Committee clearly recommends that there are a number of special cases where any recommended clearances would have to be departed from. There are many conditions, such as grade separation work and the construction of tunnels in certain materials, where it would be practically out of the question to conform to this clearance diagram and it was not the idea of the Committee to provide for them under the exceptions on page 433. Possibly it might have been well to have mentioned third-rail construction work in electric zones under those exceptions.

The President:—Mr. Kittredge now has in his hands the clearance diagram of the Committee on Electricity. I think it would be well for him to say what is covered.

Mr. Kittredge:—The clearance diagram recommended by the Committee on Electricity has been accepted by this Association and inserted in the Manual, and has been adopted by the American Railway Association.

The President:—I will ask you a question, to get down to the point. I have added up these figures, and it is five feet six inches from the center of the track to that line. Are you building structures five feet six from the center of the track? Is that what you recommend in that diagram?

Mr. Kittredge:—In certain locations, yes, sir.

The President:—Five feet six.

Mr. Kittredge:—Yes, sir.

The President:—What for locations out on the main line?

Mr. Kittredge:—In certain special locations where they would fill the requirement of the location.

The President:—That would not be a place where you are running main line through trains?

Mr. Kittredge:—No, sir. We have found in New York that it is very essential that we should have the benefit of every inch of space that can be gotten, and that is the justification for this irregular broken line. There are other things besides through bridges to be designed. There are third rails. Space has got to be reserved for automatic stop signals and every bit of space that is shown on the diagram of clearances as recommended by the Committee on Electricity has been found necessary, and therefore any change from that should be adopted only after most careful consideration of all conditions affected.

The President:—How do you arrive at your other clearances? Have you any clearance diagram that you work to?

Mr. Kittredge:—Yes, sir. Our clearance diagram throughout the work in the New York Central Terminal is 6 ft. 3 in. from the center of the track, corrected for curvature and superelevation.

The President:—It seems to me that these clearance diagrams are for two separate and distinct purposes, and we ought to understand what we are doing.

Mr. Kittredge:—This clearance diagram, as gotten up by the Committee on Electricity, indicates, besides the diagram for structures, a clearance diagram for equipment.

The President:—It does not suggest anything for bridges, does it?

Mr. Kittredge:—We have made a great many bridges in connection with this diagram. We have a great many bridge structures; in fact, all of our upper track in the Grand Central Terminal is carried on a floor designed in accordance with bridge construction. We have columns, plates, gussets and all sorts of things designed in accordance with this clearance diagram.

Mr. Brooke:—Is it not a fact that this clearance diagram for electrified territory is but meeting special conditions? If a road is to electrify outside of a big city like New York, out in the mountains, or on the plains, it probably would not conform to that clearance diagram at all. So this is entirely for special conditions in congested territory. I think it is entirely proper to provide for that by an exception to the general recommendations and, if necessary, such an exception can be placed in the form of a note on the general clearance diagram, but we should not take the clearance diagram of the Committee on Electricity and apply that an outside territory away from cities where we have plenty of room. That is the point of the Committee. Of course, the Committee recognizes that in New York and other large cities some such clearance diagram as this is necessary, and it was not its intention to present this diagram to be used in those districts.

Mr. Camp:—As I understand it, the diagram will provide safe clearance anywhere. Am I right about that?

The President:—I am afraid not.

Mr. Camp:—That is to say, it will protect the equipment, but this Committee is getting at a clearance diagram which will protect a man hanging on the side of a car.

The President:—Yes, sir.

Mr. Camp:—It seems to me there might be a demand for a two-purpose diagram, one which will prevent the equipment from hitting anything at the side of the track, and the other to protect the life of a man on the side of a car.

Mr. Himes:—The diagram proposed by the Committee on Electricity is exceedingly irregular, and for a person who is engaged in the design of ordinary structures for which the clearance diagram is needed and useful, it would be regarded as a waste of time to follow such a diagram. It has been the thought of Committee XV and this Committee that if a more regular diagram were selected which afforded in every respect a clearance as great as that provided by the Committee on Electricity, the work of designing would be facilitated.

Mr. Kittredge:—I have heard the argument, but still I think it is without force. There are structures to be designed, many of them, where the clearance diagram, as reported by the Committee on Electricity, is absolutely essential, and I still believe it would be unwise for this Association to recommend and spread broadcast two clearance lines when only one is necessary.

Mr. Cushing:—I am entirely in sympathy with Mr. Kittredge's position in this matter. I object to looking in two places for a clearance diagram. I think it is entirely proper to have only one clearance diagram, and I think we should let that clearance diagram state the clearances that must be provided for the different objects, and not have two separate diagrams to think of, when one is designing structures. I believe that this Committee ought to embody the work of the Electricity Committee with is own and present one diagram to the Association for that purpose.

Mr. Kittredge:—The statement, made by the Chairman of this Committee, that the clearance submitted by the Committee on Elecrticity would be applicable to a particular place like New York, should hardly go unchallenged. That diagram was made up from the information received from 65 different roads, as shown on pages 928, 929, 930 and 931 of the Bulletin. Those roads are scattered all over the country, North, South, East and West, and are not in any one particular locality.

The President:—I notice, on page 422, of the Bulletin, that the New York Central says it has 5,032 miles, and inside clearance 7 ft. 6 in. from the center of the track. What does that mean?

Mr. Kittredge:—I do not know. I was going to ask that question myself, when we came to discuss the report.

The President:—But this was gotten from your road.

Mr. Kittredge:—I do not know. I understand that this was furnished by the American Railway Association. I do not know where it came from originally.

Mr. Courtenay:—I would like to make some further argument against the clearances recommended by the Committee. These clearances are excessive and they are dangerous for this Association to adopt. They will get the railroads into trouble. The legislatures may get hold of them and proceed to frame a law stipulating that within a stated number of years all structures shall be made to conform to these clearances, which, of course, would necessitate tearing the lining out of tunnels, enlarging them and rebuilding a great many new bridges. I do not think that this Association should go on record as advocating these clearances.

The President:—As I understand it, the discussion relates to this proposed general clearance diagram, on page 435. I understand it is not satisfactory to some of the members here. Will someone kindly make a motion suggesting what he thinks ought to be done with this diagram?

Mr. Courtenay:—My motion would be radical. I move that this Association do not attempt to establish such clearances.

The President:—A motion has been made and seconded—I do not know whether to declare it in order or not. This matter has been referred to us by the American Railway Association. That Association has asked us to make a recommendation. What we do here to-day is not going to bind the railroads of this country. As I stated in my address yesterday morning, any action that we take must be approved by the American Railway Association and anything that we do is merely in the way of recommendation. Can we take the position that we are not ready to make a recommendation in regard to what the clearances should be on our railroads? That, as I understand, is the way that you put the motion. The motion is now before you for discussion.

Mr. Brooke:—This Association has already adopted a number of clearances. It has a bridge clearance diagram; it has a clearance for single and double track; it has a clearance diagram for electric zones, and I do not recall what others. I do not believe that we should say that we should not recommend clearances of any kind. This Committee received, when this work was assigned, a number of diagrams, and those diagrams have been shown on the screen with the clearances recommended by the Committee added, diagrams of low and high switchstand platforms, signal stands, etc. We were asked to recommend clearances for those various objects.

The Committee has carried out its instructions in that respect and it has relied largely upon information furnished by the Committee on Maintenance of the American Railway Association, which was furnished, as I understand, through a circular letter sent out by the American Railway Association. The information tabulated on pages 441-443 is an attempt to place in a more concise form some of the information secured. This information secured by the American Railway Association showed recommended clearances and actual practice of a number of roads for the various objects shown on the screen. The Committee had in mind that information would be published in connection with this report, but it has been withheld for good reasons.

I would emphasize the fact, and a constant effort has been made to make that clear, that these recommendations apply only to new construction and that it is not the sense of the Committee that they should in any way be retroactive, so that clearances now in existence will not be affected. This Association has adopted standards for rail sections and various other things. When the American Railway Association standard rail sections were adopted, it was the intention that they apply only to rails to be rolled from then on. It did not imply that the rail in the track was not perfectly safe to use, and I do not think any railroad ever considered taking up rail of good section to relay with another section because the latter section was adopted later. This is a guide for future work and does not mean that something that does not comply with it now is not to be continued and is not good practice. That is the view of the Committee.

The President:—Mr. Courtenay's motion is that this Association take no action and make no recommendation in regard to clearances.

Mr. Courtenay:—I wish to say a few words further. The force of all that has been said by the Chairman of the Committee is conceded, but there has been recently pending in the legislatures of several states bills with the idea of enacting laws requiring railroads to provide such clearances as are suggested by this Committee. These proposed laws limit these larger clearances to structures to be built hereafter, and seek to require the railroad companies within a limited term of years to bring all existing structures to these clearances. That is a very formidable thing for the railroads of this country.

Mr. Kittredge:—I shall vote against Mr. Courtenay's motion. We ought to make our recommendations when we are ready for them, and certainly with the information before us to-day we are not in shape to make such a recommendation. We ought to be able to formulate our views and back them up. We are in the habit of doing so in respect to other things on the various railroads in this country with which we are connected, and there is no reason why we should not do it in regard to clearances, but we are not in good shape, at this particular time, to attempt anything of that sort, so I will have to vote against the motion.

Mr. R. H. Ford (Rock Island):—I believe it would be unwise for this convention to agree to Mr. Courtenay's motion. The report should be referred back to the Committee with instructions to confer with the Committee on Electricity as well as any other committee dealing with clearances, and their conclusions reported next year.

Mr. W. H. Finley (Chicago & Northwestern):—I would be sorry to see this motion passed, although I am inclined to agree with Mr. Courtenay that the clearances proposed are excessive. I think it would be rather cowardly on the part of this organization to say that we were not prepared to go on record as to what the clearances should be. That question has come up frequently before railroad commissions and other bodies. Usually the first thing they want to know is what the railroads have done themselves, what they have agreed on. We have been in a rather bad position from the fact that there has been no agreement on this subject. If we are not prepared to do it, or cannot do it, it will result in legislatures or the railroad commissions doing it for us.

Mr. C. M. Larson (Railroad Commission of Wisconsin):—I want to say a few words in line with what Mr. Finley has just said, that the deferring of action or the failure of this Association to make recommendation will not prevent the legislatures from passing laws on this subject. I consider it most unwise for this Association to leave the subject in this unsettled condition.

It is true, as Mr. Courtenay said, that the commissions and the legislatures do look a great deal to this body for information, as they should. We ourselves who are connected with the Wisconsin Commission undoubtedly give a great deal of consideration to what this body does. However, I believe that the deferring of action will not prevent drastic action by legislatures, and it may have the contrary effect. I believe that recommendations of this Association will assist them in passing better laws than they will be able to pass if such recommendations are withheld. I do not say that I would urge that any action should be taken until the Association is positive as to what it desires to recommend, but I do not think it would be wise to take the position that it should not make any recommendations on the subject of clearances.

Mr. Kittredge:—There is a bill before the United States Congress which, among other things, provides that there shall be a clear space of not less than 36 inches between the side of the engine, car or vehicle, and any side obstruction, and a free space of 6 feet above the top of any engine, car or vehicle and any overhead obstruction. It provides that the Interstate Commerce Commission shall upon full hearing and for good cause extend the time within which these provisions can be carried out, but that any employé injured or killed by reason of failure to provide these clearances shall not be deemed to have assumed any risk thereby occasioned. It provides a penalty of $500 for each time that any locomotive or car is operated where the clearances are not as required by this law.

That indicates the necessity of action. This is a bill before the United States Congress, now in committee, and it is being urged to be brought out of committee.

Mr. Brooke:—I had in mind saying the same thing about the proposed national legislation concerning clearances, and in connection with Mr. Courtenay's remarks, to state that the Association is following the action of a number of states on the clearance question. Some of the states have already adopted laws which I think provide equally as great, or greater, clearances than those proposed by this Committee. I recall seeing a clearance diagram of the state of Minnesota, I think it was, in the Railway Age Gazette about two weeks ago, which was very much the same as this diagram.

(Mr. Courtenay's motion was lost.)

The President:—The motion is lost. There is a gentleman who made a motion to have this report referred back. Does he wish to renew that motion?

Mr. Ford:—I move that the matter be referred back to the Committee with instructions to confer with the Committee on Electricity and all other committees dealing with clearances, to be reported upon next year.

The President:—In the meantime you will have laws fixed governing the clearances.

Mr. Brooke:—I believe it is in order for the Chairman of the Committee to say that he addressed a communication to the chairmen of the committees on Roadway, Track, Buildings, Iron and Steel Structures, Electricity and Yards and Terminals on June 11, 1915, outlining the proposed work of this Committee on the subject of clearances and requesting that those committees be represented at a meeting held in Detroit. Some of the committees were represented, others were not, but the representatives of the committees except in one or two cases did not take any active part in the work of the Committee, and when the report of that meeting, which is largely the report which is before you to-day, was sent out, the chairman of this Committee received communications from very few of these committees and they did not object to the work that had been done. I apologize to the Committee on Signals for not inviting it to take part in the discussion, but I will gladly do so now.

Mr. E. G. Lane (Baltimore & Ohio Southwestern):—It seems to me we ought to take action on that clearance diagram. As I understand it the clearance shown by the Committee is the minimum. If we do not adopt something, the legislatures will.

Mr. Himes:—I am opposed to the reference of the report back to the Committee, and if you will bear with me a moment I will tell you why. The various legislatures of the country are grappling with this problem. Legislators generally are not informed as to the respective merits of the different phases of the problem. If this body of men here to-day is not able to make a recommendation in regard to clearances for railroads, I do not know where there is a body of men on the face of the earth which is able to do it.

I think it is distinctly and appropriately a duty of the Association to pass on this question. This country is founded on the theory of democratic government. We do not have imperial edicts. We are supposed to get together and talk things over and arrive at a sane and reasonable conclusion, and it has been found generally that when a great question is presented to the whole body of the people, and they are well informed on the subject, their decision is right, it is correct, and that is the foundation of our government. If the action of the state legislatures is not wise in this matter, it will be because they have not been well informed, and that will be because the men who have the knowledge and ability and are able to inform them, have not done so. That will apply particularly to the case of the national legislature.

Mr. Chas. S. Churchill (Norfolk & Western):—There is one very strong argument why this matter should not be postponed. It is mentioned in the first paragraph of the report. We are asked by the American Railway Association to make a recommendation. We ought to go ahead, discuss this report and find out whether or not it meets the views of those here and then send it to the American Railway Association as soon as possible, as we have been requested to do. We are not asked to put this in the Manual at this time. We should go on and complete this discussion and find out all we can about the subject, and perform the duty assigned to this Association.

Mr. Kittredge:—If the pending motion should be passed, it would stop discussion. That would be lamentable. I want to vote against the motion and urge the other members to vote against it. If there is any possibility of the report being referred back, I want to first discuss it at considerable length. Rather than let the question go without discussion, I would run the risk of being called out of order and discuss it.

Mr. Brooke:—I am of the opinion if the matter is referred back to the Committee at this time it would be what some of us in the operating department call "passing the buck."

I believe we can make some progress by taking up the several recommendations and considering them in order. I suggest that be done.

Mr. Kittredge:—In order that I may have some enlightenment and so discuss these recommendations more intelligently, I ask in regard to Appendix B what that statement is and by whom these things were recommended.

The President:—I will answer that by saying that the American Railway Association sent a circular letter to all the members of that association and asked for replies to certain definite questions. The railroads in that association replied to those questions and this is the tabulation of the replies received from the railroads.

Mr. Kittredge:—There is a footnote which says: "Where no recommendations are made the present practices of the railroads are shown." What figures in this table represent recommendations and what represent present practices?

Mr. Brooke:—That is not indicated, but I would say, roughly, that 25 per cent. of the figures show present practice, and the other 75 per cent. recommendations.

The President:—I will answer for your own road, if you would like to have it answered.

Mr. Kittredge:—I should be glad to have that done.

The President:—In your overhead clearances you say present practice is as follows: Distance from center line of track to the side clearance, 7 ft. 6 in. The overhead is 22 ft. Your recommended practice is the same as the present practice.

Mr. Kittredge:—Is it indicated who made that report?

The President:—No, it is not. You will have to get that when you go back to New York.

Mr. Kittredge:—With reference to minimum clearances on page 432, high switchstands, I move that for high switchstands it shall be provided that there shall be no encroachment on the adopted clearance diagram.

Mr. J. B. Carothers (Baltimore & Ohio):—We were asked by the American Railway Association to answer these questions regardless of any diagram. The Committee attempted to do that. That is one of the objections we have to having this referred back. We worked on it for a long time and called into consultation every committee interested in clearances and offered them the opportunity to sit with us, and this is the answer we arrive at, and it seems to me we ought to answer the American Railway Association in the way they ask.

Mr. A. S. Baldwin (Illinois Central):—Will we not save time by proceeding to the kernel of this question, that is, what horizontal and what vertical clearances shall be recommended and adopted?

The President:—The Committee has adopted a clearance diagram, shown on page 435, and answered the questions in line with that diagram.

Mr. J. B. Jenkins (Baltimore & Ohio):—I move that we take up the consideration of the general clearance diagram first.

The President:—Mr. Kittredge made a motion, which is before the house.

Mr. Kittredge:—I will be glad to withdraw that if you will discuss the clearance diagram. If you vote on the motion that the report be referred back to the Committee I will not withdraw it.

The President:—The Chairman of the Committee made a motion to take this up in this way, and he is willing to withdraw his motion, if you will withdraw your motion, Mr. Kittredge, we can talk to the proposed clearance diagram on page 435.

(The motions were withdrawn.)

Mr. Kittredge:—I would move that, in so far as the clearance diagram reported by the Committee on Electricity already adopted by this Association and by the American Railway Association, is concerned, that this clearance diagram now under discussion be made to correspond. We will make progress in that way rather than to figure on each 3 in. or 6 in. or 12 in. of elevation.

The President:—If I understand it correctly, this clearance diagram, which the Committee proposes, has a horizontal distance of 8 feet from center of the track where the maximum width is desired. If that suggestion is adopted by this Association that will fix this clearance diagram as 11 feet wide instead of 16 feet wide. Am I correct?

Mr. Kittredge:—Not as I understand it. The clearance diagram of the Committee on Electricity on page 927 of the Manual, the distances given there are from the gage of the rail, and from the plane of the top of the rail. The Committee on Electricity made a recommendation that above the points shown all dimensions should be discussed by the general Association and made to fit in with the bridge or other clearance diagram.

Mr. W. M. Camp:—It should be clear by this time that the diagram which this Committee proposes is for a different purpose from that which was presented by the Committee on Electricity. The diagram presented by the Committee on Electricity is one which will let the equipment through. The diagram now before the Association is to let the equipment through with a man hanging on the side of the train or standing on top of the car. Am I right about that?

The President:—The two diagrams are for different purposes.

Mr. Baldwin:—The American Railway Engineering Association diagram on page 927 of the Manual, as I understand it, is the same as adopted by the American Railway Association. There are two diagrams, practically, one for equipment, which is to regulate the outlines of equipment, and another for structures, which is to regulate the outline of structures to which that equipment is to be related. It only goes a short distance below the base of the rail and does not affect the main question now, and that is, What shall be the main clearance of bridges and structures on railroads. That has been adopted by the American Railway Association for the entire country, and regulates the construction of equipment so that equipment will not be built that will interfere with electrical railway structures when equipment is interchanged between different lines. I think this diagram should be adopted, but it does not affect the question at issue now, and that is, What shall be our main horizontal and vertical clearances.

Mr. Larson:—I believe we are much less interested in the distance between an obstruction and the center of the track than between an obstruction and any part of the moving equipment. Was any attempt made to fix the clearance on the basis of a distance between equipment and obstruction?

Mr. Brooke:—It is stated in the report that the recommendations are based on what the Committee considers the average size of present-day equipment. That would be 10 feet outside width of cars. That would give 3 feet of space between the equipment and this proposed clearance. To that extent the Committee had that point in mind. The Committee also has a conclusion that it is entirely futile to prescribe clearances for objects placed along the track unless the size of the equipment is described. To that extent the Committee covered the point which you have raised.

Mr. Larson:—Unfortunately there is some equipment wider and higher than that. Some freight cars in Wisconsin are 15 feet 9 inches high.

(Mr. Kittredge's motion was put to vote and carried.)

Mr. Brooke:—I move that the clearance diagram shown on page 435 be accepted for that part below 24 inches above the rail.

Mr. S. P. Brown (Mt. Royal Tunnel & Terminal):—How about high passenger platforms? You would have to come within about 5 feet 6 inches.

Mr. Brooke:—This diagram is subject to some exceptions, which are shown on page 433, which provide for high platforms.

Mr. Brown:—How about overhead catenary construction on electrically operated roads?

The President:—That is covered in other places.

Mr. John G. Sullivan (Canadian Pacific):—I want to call the Committee's attention to one point that was previously voted on and approved, but different from what it is now, in a similar discussion, and I am speaking from experience when I say that this will cause you trouble if it is ever adopted by legislative bodies, and that is the point from which you are measuring your clearance—I know it is logical, that is, where the clearance should be measured from—from the top of the rail, but you will create a condition that will make your structures later illegal. The distance on this diagram of 8 inches above the top of the rail for lower clearance and a distance of 4 feet from the top of the rail to the maximum clearance is proper, but the minimum overhead clearance should be measured from the base of the rail. After the law was enacted in Canada the Railway Commission interpreted that law to mean the base of the rail, and it is now in the statutes in that manner. If you put in a rail an inch higher in a tunnel or on a bridge or any other structure, the small amount of difference is immaterial, but it has the effect of making the structure illegal. Furthermore, in designing the bridge, the bridge engineer does not always know what height of rail you are going to use; you do not give him the top of the rail as the place to measure from in measuring down to foundation, or the base seat of the bridge, and these measurements of 22 feet to 16 feet should be measured from a fixed point, which is the base of the rail. That action has once been approved by this Association.

Mr. C. E. Smith (Consulting Engineer):—I have not been able to find in this Bulletin that any minimum clearances are submitted for adoption.

Mr. Brooke:—If you will refer to page 431, paragraph 6, you will see that it says, "The logical course is to prescribe minimum clearances only and to place no restriction whatever as to maximum clearances." Then the note on page 433, opposite No. 14, says, "General Clearance Diagram—for new construction." Then follow a number of exceptions, 1 to 9. The exceptions prove the rule. The diagram as shown on page 435 is the minimum clearance diagram, and then there are nine conditions, which are really the conditions proposed to be covered, where all limits as to minimum clearances are removed.

Mr. Smith:—It seems to me it would be proper to refer this matter back and have the diagram on page 435 reported again, the Committee to bring in a recommendation as to the minimum clearance under the conditions 1 to 9 on page 433.

The President:—We passed on the matter of referring this back to the Committee.

Mr. W. M. Camp:—We have already voted that the proposed diagram here presented and the diagram already in the Manual be harmonized from a point two feet above the rail upward. We have a motion before the meeting that to provide for the lower part of the diagram, from a point two feet above the rail downward, we shall adopt this diagram which is before us. Are we certain that the revised diagram above this two-foot point will connect with the one below? How about that?

Mr. Brooke:—We might have to join it with the horizontal lines.

The President:—As Mr. Brooke says, there might be a short horizontal line that might connect these two.

Mr. Sullivan has made a very pertinent suggestion, if you will pardon me in referring to it, and one you will bear in mind when discussing this question and voting on it.

Mr. Kittredge:—I ask if this clearance diagram above the 4-foot line corresponds with the diagram in the bridge clearance.

Mr. Brooke:—It does not; the bridge clearance diagram has a principal horizontal width of 14 feet. This has 16.

Mr. C. A. Morse (Rock Island):—I think we ought to try to get a vote on this question that is before the house, for several reasons. One of them is that about three years ago there was a bill before Congress calling for side clearances of 6 feet 11 inches, and overhead clearances of 20 feet. I think possibly due to the commercial bodies taking up the question of expense, the bill was sidetracked at that time. It lay dormant for about three years. Now they have presented a new bill, in which they ask for 36 inches outside of all equipment, and 6 feet above the top of all equipment; in other words, their demands have grown in three years three feet two inches in width and about two feet in height. The people who are pressing this legislation make it plain that they were set to one side on the previous bill and that they intend to force the issue this time. Among the reasons they give is, they state that at the time the other bill was up that the railroads said that they were interested in clearances, that they were increasing their clearances in new construction and they would do something along these lines. Now they go to Congress and say they have waited three years and the railroads have done nothing, and they intimate for that reason they propose to have Congress do something. I feel that some action by this Association at this time along the lines requested by the American Railway Association would be of great benefit to those who have to handle this question before Congress.

Mr. Finley:—I think it is necessary for us to do something. I have spent about a year in arguing with the Utility Commission of Illinois on fixing a ruling practice of 7 feet. Before that was passed it took about a year to discuss the matter with the various committees representing the Brotherhood of Trainmen. They asked for greater clearances, vertically and horizontally, than had been asked for up to date by the state legislatures or any public utility body.

I think we should pass on this matter by recording our opinion as to what should be the clearance. The unfortunate thing is, we are called upon to establish clearances and there is nothing established governing the width of rolling stock. The trainmen say they want 36 inches between cars on adjoining tracks or any lateral obstruction.

I hope Mr. Cushing's motion will prevail that a 7-foot minimum be permitted.

The President:—How do you feel about this 16 ft.?

Mr. Finley:—Personally, I think it is excessive. I think in establishing any clearance rules and regulations of this kind we should bear in mind that we are establishing minimum clearances. If any road wants to adopt larger clearances, it is their privilege to do so.

Mr. H. R. Safford (Grand Trunk):—I want to support Mr. Sullivan's suggestion by a motion that all vertical measurements, from the top of the rail to the extreme top of the structure, and dimension from the top of the rail to the point where the clearance reduces in the upper part of the structure, should be referred to the base of the rail.

Mr. W. C. Cushing:—I want to speak on the motion and advocate a vote against it, for the reason that I think the question involved is too large. It embraces too many things at once. I think it would be a great deal better to vote on the minimum clearances, and then to take care of all the other variations from it and the exact points where these measurements are to be made later. I would like to see established first the minimum side clearance, and then the minimum overhead clearance, the minimum side clearance extending from a point about four feet above the base or top of the rail, to a point about 15 feet, so as to get that minimum dimension fixed, without attempting to accept the diagram as a whole.

Mr. Sullivan:—I agree with Mr. Cushing, but the trouble would be if we adopted as tentative this print it would go out all over the country and be taken as a guide, and not the special prints which would be issued later, and if there is an error, it will be followed by the legislatures.

Mr. Kittredge:—In talking to the diagram on page 435, it is labeled, "Proposed General Clearance Diagram." That title ought to be changed to "Minimum Clearance Diagram," if we are going to vote on minimum clearances. I am in accord with what Mr. Cushing has said about including too much. The diagram should not be adopted as a whole. There are some dimensions that are not objectionable, others that are. I seriously object to a minimum clearance of 8 feet.

Mr. President:—Mr. Brooke, who made that motion, will withdraw it, and we will proceed along the lines suggested by several of the members.

Mr. Cushing:—I move that the minimum side clearance from a point 4 feet above the top of the rail, or, if you please, 4 feet 7 inches from the base, to a point 15 feet above the top of the rail be 7 feet. In a thorough consideration of this subject before the Commission of Ohio we satisfied ourselves that there was ample safety in that minimum clearance.

Mr. Kittredge:—Do I understand the motion is subject to the exceptions named on page 433? We have a great deal of construction with clearances of only 6 feet 6 inches. I am willing to vote on Mr. Cushing's motion if these exceptions apply.

Mr. Cushing:—This motion refers to new work exclusively and is not to be retroactive. There are certain structures which may be allowed within these clearances which can be specifically mentioned later, but if we try to consider all of them simultaneously we will not reach any conclusion. For instance, mail cranes cannot be put out any farther than about 6 feet 6¼ inches. That distance complies with the laws of Ohio, which have fixed these distances, and they are pretty generally used by railroads now.

Mr. Himes:—I ask Mr. Cushing if he were to build a bridge on his road whether he would build it with a minimum clearance between the trusses of 14 feet?

Mr. Cushing:—Answering that question, I will say no. I am voicing the views of a committee, representative of all the roads in the state of Ohio. After careful consideration, and viewing the matter from every aspect, the general feeling was that 7 feet should be named as the minimum. I have personally different views. Our recommendation to our own company is 7 feet 6 inches, but not 8 feet, nor 8 feet 6 inches. We did satisfy ourselves that 7 feet was amply safe.

Mr. Lane:—If you take your personal injury reports it will be found that 7 feet is too narrow.

Mr. Mountain:—We have had several accidents in the case of bridges 7 feet wide, serious and fatal accidents. With reference to reconstruction, a great many bridges in Canada today are 14 feet, and when a bridge is rebuilt it is rebuilt 16 feet.

Mr. C. H. Stein (Central of New Jersey):—Do I understand that, if this motion is passed it will replace the bridge clearance diagram on page 482 of the new Manual, which indicates that from a point 4 feet above the top of the rail to a point 18 feet above the top of the rail the side clearance is 7 feet? We should try to harmonize these two conditions, and I believe that Mr. Cushing's motion should be so framed that it will be in accord with the bridge clearance diagram, or we should reconsider the bridge clearance diagram in order to have this new one act as a substitute.

Mr. Cushing:—If any of the rules or practices we now adopt are contrary to what is in the Manual, they must necessarily be substituted in the Manual for what is there at present.

Mr. Baldwin:—I think it would be unfortunate if Mr. Cushing's motion were passed. There are 30 per cent. of the railroads in this country which have a clearance of 16 feet. I am sure it is the desire of most of the railroads that nothing will be done, if it can be avoided, that will embarrass those roads that have a narrower clearance. At the same time, it is a condition we face and not a theory. It is a fact that all over the country the states are going into this subject of clearance and we are going to have legislation on it.

There are two ideas with which this subject may be approached. One is that we will make the clearance as narrow as possible with the idea that we will hold it. Another is that we may recognize what is the best clearance and try to mold legislation to meet that condition, and mold it so that it will refer to future construction and not be retroactive. I very much fear that if we at this time adopt radical action here and make these clearances too narrow that the result will be just exactly the opposite of what we are working for. My opinion is we will help the railroads more which have the narrower clearances by adopting a clearance that is to a very large extent used, and then throw the whole weight of the Association toward holding that to future construction than we will if we adopt a narrower clearance.

Mr. Brooke:—I will state that is just the view which the Committee took in connection with the 16-foot width in this diagram.

Mr. Cushing:—Those are my views, too. Nobody has proved that a 7-foot clearance is dangerous, or that it is not amply safe.

Mr. Safford:—I will state as a matter of information that the Canadian railroads for nearly five years have been acting under a requirement fixed by the railroad commission practically on the basis of the diagram recommended, and it has not been found oppressive.

Mr. Finley:—In investigating this matter I could not find any evidence of many accidents or loss of life from the 14-foot clearance on bridges. I think possibly more than 60 per cent. of the bridges in the United States are not more than 14 feet wide and we have had that clearance for years.

Mr. C. E. Smith:—I hope Mr. Cushing's motion will prevail, for the reason that a larger minimum might be insisted upon, and if so it will entail new construction in many instances at very largely increased cost that would not be necessary if 7-foot were permitted. I do not believe there are many of the members who use 7-foot side clearance as a standard or who do not believe that 8 or 10-foot would be better, but 7-foot minimum should be permitted. There are many large bridges in the Southwest located on cylinder piers, the trusses in many cases having 14 feet side clearance, and it would not be possible to build new trusses on the old piers with 16-foot clearance. If a larger clearance is insisted on, it would be necessary to go to very much greater expense. I understand some such condition as that recently brought about a clearance of 7 feet 6 inches on the Council Bluffs bridge. In the case of the Chicago, Milwaukee & St. Paul, between Minneapolis and South Minneapolis, there is a right-of-way 66 feet wide, fully occupied by five tracks, four spaces 13 feet wide and two 7 feet side spaces. It is recognized it is desirable to have more side clearance, but to insist on more than 7 feet side clearance in that case would involve the expense of getting additional right-of-way, and that would necessitate tearing down the walls of a good many buildings. That would involve a great deal of expense to that company.

I hope Mr. Cushing's motion will prevail, that a minimum be permitted, and I think it will be the consensus of opinion of the members that a larger clearance than that will be used.

Mr. Himes:—I will answer Mr. Smith in this way—I had occasion once to operate trains through a bridge where the clearances were small. I cannot tell how small. They were so small that I consulted our General Counsel to see whether or not he thought it was safe to operate through these bridges. He was of the opinion that we should not operate under those conditions. We did operate, and we did not have any accidents. We took pains to see that we did not have any.

Mr. J. L. Campbell (El Paso & Southwestern):—I believe it would be a mistake for this convention to adopt the motion before the house. It is not primarily a question of dollars and cents, although that is the viewpoint from which we see it first. We are now dealing with a question of safety to human life and I apprehend that the public will not be satisfied with too close a margin. I am afraid that 7 feet would appear too narrow and that they would not accept it. Such action on the part of this convention would be radical on the wrong side. It is obvious that a clearance of 8 feet is safer than one of 7 feet. This Association should realize that the public is deeply interested, that we shall have to reckon with it, and that it will finally largely determine what the clearance should be. Consequently, we should recommend a clearance which is reasonable and ample. Moreover, we are not proposing clearances to be applied to existing structures. We are considering clearances that should be provided in new construction and in reconstruction of old work. It will be the part of wisdom for this Association to accept the larger margin of safety to human life.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I think there is a misunderstanding on the part of Mr. Smith. He seems to have overlooked the exceptions to the diagram. He suggested that because of the structures which now exist, which would prevent the reconstruction of the road, they might have to dispense with one of the tracks or buy additional right-of-way. Exception No. 6, on page 433, would apply to that case. I think, as one speaker said, that this is a condition and not a theory which we are confronted with, and I think we had better choose the least of a good many evils. Furthermore, I believe our Committee has worked this thing out in a much more careful way than this convention can ever do it, and, if I am in order, I move the adoption of the report.

Mr. Morse:—I do not quite understand this idea of going before the public with a recommendation of something you do not believe in yourselves. I believe we should be sincere in this thing. We talk about 7-foot clearances, when they have had 7-foot 6-inch clearances built for

25 years. Our cars have increased in width in the course of 25 years, and you cannot go before Congress and public service commissions and put up a proposition that this Association recommends a 7-foot side clearance when they are not using it. I think we have got to be sincere. In California, the Commission required 7 feet 6 inches simply because it was a new proposition, and the side clearances of the Southern Pacific were 7 feet 6 inches. Minnesota went to 8 feet, Illinois to 8.5 feet. The trainmen and the people behind this bill have gone 36 inches beyond the biggest equipment. I feel we will never get less than 8 feet, and we are likely to get 8 feet and a half, or something greater, and we should meet them half-way in trying to bring about constructive legislation rather than to obstruct it.

Mr. A. C. Irwin (Chicago, Milwaukee & St. Paul):—We should approach this proposition, not from the standpoint of how we are going to influence legislatures, but as we think is the best way in which it should be decided. It seems that those who are against Mr. Cushing's motion hang their reasons on the question of safety. It has been definitely proven, not only by statistics, but by the experience of men in the railroad business that the element of safety connected with this matter is insignificant.

I was on the Committee last year when this subject of clearances was under consideration. I was also present at the Detroit meeting when opinions were taken individually from those present, as to what were proper side clearances. In all the discussion there was not a single valid reason offered why 8 feet should be recommended by the Association as a minimum clearance. It seemed to be the general thought that since the Board of Direction had been handing this back to different committees that they wanted some sort of larger clearance, but no reason was shown why such clearance was desired.

It is only necessary to follow the proceedings of the Association to see very clearly that the matter of safety is insignificant. The references in this report demonstrate that of the accidents reported by the Interstate Commerce Commission less than 2 per cent. of the total occurring to passengers and employés were occasioned by coming in contact with any obstruction either on the side of the track or overhead. There are cases, of course, in which, no matter what you do, men will be injured in the performance of their duties on a railroad. The hazard is there. You cannot prevent it in any way other than by training the men.

Since the percentage of accidents in this respect is so small, why do you want to go on record in advocating something that will not improve your case? To illustrate the point in regard to how accidents take place, I once saw a fireman badly injured by coming in contact with a baggagetruck that had been thrown on the station platform for loading baggage from the baggage car. There was no obstruction within 20 feet of the tracks on the side, and yet this man was injured. The personal element is what enters into the proposition. That is the thing we should spend the money on rather than to try to remove all obstructions from the side or above our tracks.

We have heard it stated that legislation will be largely influenced by what this Association does. That is not the point. We are not trying to do any such thing. This is a minimum clearance we are to vote upon. Do you want to confine yourself so that your judgment will be hemmed in by such minimum clearance, or do you want to leave yourself to choose under the situation that confronts you what clearances you want?

Table 1, page 436, shows per cent. of total accidents to employés resulting from coming in contact with side or overhead construction. When we consider that some of these accidents occurred at temporary structures, others at unavoidably small clearances, and many from carelessness and violation of strict orders, it is very apparent that the benefit to be derived from increasing the present recommended clearances is small indeed. It is not clear that any benefit whatever would accrue, since a variety of clearances requires that the employé have in mind the smallest, and not some standard which is much greater than the majority of those in actual existence. The standard should therefore be the smallest and the employé taught to avoid this. Greater than the standard could then be used with safety.

I have never heard or read any sufficient reason why this Association should recommend any change in the present side clearance for a bridge diagram. Use of a greater side clearance where conditions warrant is expected and understood; but the use of a smaller, even where absolutely necessary, puts the user at a disadvantage. The recommended clearance, as a minimum, should therefore be small, leaving to the requirements of conditions and operation the fixing of proper side clearance, and not limiting the fulfillment of the requirements of these conditions by some arbitrary dictum not based on good reason.

I will be opposed to future consideration of this subject by this Association except as an investigation and study of those elements of economical operation and personal and collective efficiency which alone will yield definite and beneficial results. The guidance to legislators which our work should afford could be best summarized in the statement that little is to be gained, and that considerable damage may result from ill-advised clearance legislation.

I sincerely hope that Mr. Cushing's motion will prevail.

(Mr. Cushing's motion was lost.)

The President:—How about Mr. Safford's motion?

Mr. Brooke:—The Committee is willing to accept that, and measure from the base instead of the top of the rail.

Mr. Lindsay:—The present bridge diagram, as I understand, calls for a clearance of 7 feet from the center of the track above the usual height. I move that it be 7 feet 6 inches.

The President:—Do you mean that the maximum width be 15 feet, instead of 16 feet, as provided by the diagram?

(Mr. Lindsay's motion was put to vote. Eighty-four members voted in favor and 78 opposed.)

The President:—We will now take up the vertical clearances, and have a vote on the recommendation of the Committee that the overhead clearance be 22 feet 6 inches from the base of the rail, and the figure that is now 16 feet be 16 feet 6 inches from the base of the rail.

(The recommendation of the Committee was put to vote and carried.)

The President:—We will ask for a vote on the adoption of the diagram as a whole, as revised by these votes that have been taken.

(The motion carried.)

(The Chairman then read the exceptions to which the recommended clearances will not apply.)

Mr. McDonald:—I move that in No. 6 the words "reconstruction work" be eliminated and the words "new construction" be inserted in their place.

(The motion carried.)

The President:—If there is no further suggestion, these exceptions will be approved.

Mr. Churchill:—I move that the two words in the third line from the top of page 432, "and reconstruction," be stricken out.

(The motion carried.)

Mr. Camp:—I suggest that these recommendations be changed to conform to the diagram which we have just adopted. That is purely a mathematical matter.

The President:—Will not these minimum clearances have to be changed to correspond with what has been done all the way through here?

Mr. Churchill:—Yes, slightly; that can be done by the Committee.

The President:—There are two other things which will have to be voted on, one is No. 13, "Parallel Tracks—for new construction."

Mr. Lindsay:—I move that we adopt paragraph 13. I assume that includes superelevation.

(The motion carried.)

Mr. W. H. Elliott (New York Central):—As to subject 4, on page 432, "Signal Stands," I would like to call the attention of the Committee to the fact that while it is practicable to provide the required clearance for high signals, for dwarf signals, which have to be placed on the right-hand side of the track to be governed, the clearance available is dependent upon the dimensions of the maximum equipment diagram. With 13-ft. centers most dwarf signals come inside of the clearance diagram and must be kept outside of the maximum equipment diagram. In making recommendations with reference to Section 4 this should be borne in mind.

Mr. Campbell:—I suggest that the locations of these multitudinous structures could be amply covered by a general specification that no part of any of them should fall within the clearance diagram.

The President:—That could be covered in that way, or you could have a motion passed now that these recommendations in regard to minimum clearances, from 1 to 14 inclusive, with the exception of 13, be made to harmonize with the action we have taken in regard to the general clearance diagram.

Mr. Jenkins:—I hope that idea will not prevail, and that this will be considered separately, because there are a number of these small structures that can very readily be placed at a greater distance from the track than 7 feet 6 inches without any extra expense, and without any hardship to the railroad companies; I think that for such small structures we should prescribe a greater distance than that given in the clearance diagram, and each one should therefore be considered separately.

The President:—Anyone can move them out as far as they want outside of the minimum diagram.

Mr. Irwin:—As I understand it, we now have a clearance diagram, a minimum, providing for 7 feet 6 inches from the center line of the track, side clearance, and connected with a clearance diagram as adopted by the Committee on Electricity. Referring to recommendation No. 5, on page 432, low platforms, do these platforms come into the lines of the clearance diagram adopted by the Committee on Electricity?

The President:—You must not put them inside of that. You must put them outside, and you can go as far outside as you want.

Mr. Irwin:—That calls for low platforms with a minimum distance of five feet from the center of track. Is that inside or outside the diagram?

The President:—It is outside.

Mr. Irwin:—Conclusion No. 5, which is proposed for adoption as a resolution, reads, in part: "Any attempt to establish a clearance diagram will be wholly futile." We have done the futile thing.

Mr. Churchill:—I wish to refer to a certain paragraph in the report, and have a few changes made, more in the line of making it perfectly clear that *new construction* and recommended practice is all that is referred to, and I think the Committee will agree with every one of them. We find that paragraphs may sometimes be taken out of reports and quoted by themselves so as to convey a wrong meaning. For that reason we must be very careful in every part of this recommendation.

Referring to page 427, second paragraph, third line from the bottom, I would substitute for the word "standard" in that line the words "their own adopted." That will make it read, "necessity or expedient their own adopted clearances will be adhered to." I want to avoid the use of the word "standard," because somebody will take it as a prescribed standard applying to all the roads.

In the next paragraph, at the end of it, "generally accepted" these words, "as good practice in new construction."

On page 430, the last paragraph, substitute for "clearance standards" in the first line the words "recommended clearance standards."

On page 431, in the first line of conclusion No. 6, substitute for the words "prescribe minimum clearances only" the words "recommend minimum clearances for new construction only."

The object is to clarify and make plain that the Committee confines its report to new construction, and also to adhere to the practice of this Association to simply recommend good practice.

The President:—The Committee is willing to accept the suggestion.

Mr. McDonald:—I do not know that we will have time to discuss the conclusions on page 431, but I move that Conclusion No. 5 expresses the sense of this meeting, that is, that any attempt to establish a clearance diagram will be wholly futile unless there be established at the same time a corresponding maximum width for the size of equipment.

The President:—I think possibly that conclusion might be worded a little better. Mr. Irwin has made a good point.

Mr. McDonald:—It is the sentiment I want.

The President:—We understand the sentiment, and we will leave it to the editors to clear up the words so as to convey the meaning we wish to convey.

Mr. Brooke:—I offer an amendment to the last motion that these conclusions on page 431 be adopted with the modifications already brought out.

Mr. McDonald:—I agree to that.

(The motion carried.)

Mr. A. W. Carpenter (New York Central):—I move that on page 433, under No. 14, "General Clearance Diagram," which now reads, "Clearance diagram shown on page 435 is recommended," we add "corrections should be made for curvature and superelevation of track."

(The motion carried.)

The President:—That completes the work of this Committee. Have you any suggestions to make for next year's work? If not, we will leave this matter to the Committee on Outline of Work and excuse the Committee with the thanks of the Association for the work they have done.

DISCUSSION ON ROADWAY.

(For Report, see pp. 311-322.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON ROADWAY.

W. M. DAWLEY.

The President:—The next is the report of the Committee on Roadway, which will be presented by Mr. W. M. Dawley, the Chairman.

Mr. W. M. Dawley (Erie):—The Board of Direction, in addition to the subject of making a critical examination of the Manual, assigned the following subjects to the Roadway Committee. (Mr. Dawley read Subjects 1, 2 and 3.)

On the first subject the Committee has not received a sufficient number of replies to its request for roadbed cross-sections from the railroads to be able to pass judgment on the question at this time and would ask that the various railroads send in the cross-sections now in use and their suggestions as to increase in width of roadbed necessary to accommodate the increased depth of ballast, say 24 inches, as recommended by the Ballast Committee.

The subject of "steam shovels and steam shovel work, including electric and air shovels, drag-line excavating machinery, locomotive cranes, general specifications for manufacture, methods of handling, and blank forms to be used;" we have sent out 138 letters asking for information and have had so far 78 replies, 64 of which are satisfactory and 14 not so satisfactory. We expect to receive more information, and when it has been digested will be able to make a report, but at the present we have not enough information on hand to submit specifications. It will take more time to develop that.

The Sub-Committee on "unit pressures allowable on roadbed of different materials" is not able to make a report at this time other than to report progress, as the work in this line now being done by the Special Committee on Stresses in Railroad Track has not been carried far enough to enable us to draw conclusions. This cannot be done until further tests have been made.

The Sub-Committee on "prevention and cure of water pockets in roadbed" have received a large number of replies to inquiries, a number of experiments have been tried, some of which promise to give good results. Some of the most promising have not been in service long enough to base conclusions on results obtained so far, but we think that within the next year we will be able to present to the Association some suggestions for the prevention and cure of soft spots in roadbeds and some conclusions which will be of value.

For next year's work we recommend that the same subjects be reassigned to the Committee.

The President:—You have heard the statement of the Chairman of the Committee on Roadway. They have no finished work to offer us for adoption this year.

I desire to call your attention to two of the appendices that have been attached to this report, one by Mr. Samuel B. Fisher, on the subject of "The Profile of Quantities," and the other by Mr. J. R. W. Ambrose. These are interesting and instructive. If there are no further suggestions in regard to this Committee, they will be excused with the thanks of the Association for their work.

DISCUSSION ON BALLAST.

(For Report, see pp. 323-368.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON BALLAST.

C. W. Baldridge.
Chas. S. Churchill.
L. A. Downs.
R. H. Ford.
H. E. Hale.
C. E. Lindsay.
Hunter McDonald.
G. J. Ray.
H. R. Safford.
C. H. Stein.
John G. Sullivan.

The President:—The first order of business this morning is the report of the Committee on Ballast. Mr. Hale, the chairman of the Committee, will present the report.

Mr. H. E. Hale (Presidents' Conference Committee):—One of the subjects given to the Ballast Committee this year was the efficiency of various stone and gravel ballasts.

This information is given in Appendix B, on page 357. We only had five tests and your Committee is of the opinion that this work should be extended, and a considerably larger number of tests made in order to come to some definite conclusion as to the proper proportion of various sizes of gravel which would make first-class ballast.

This is a progress report, as we have not been able to get sufficient information to make definite recommendations.

On page 324 there is one conclusion which the Committee desires to present. It is as follows: "It is generally conceded that stone ballast, as defined by the Manual, is the most efficient ballast, and experience has demonstrated that the other ballast materials (using the definition for each as appearing in the Manual) should fall in the following order of efficiency: (1) stone; (2) broken slag (not granulated); (3) gravel; (4) chats; (5) burnt clay or gumbo; (6) cinders."

I would like to move that the above be approved by the Association and inserted in the Manual.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—I understand that this is to be inserted in the Manual?

The President:—That is the intent of the Committee.

Mr. Ray:—As a matter of information I would like to ask why the Committee came to the conclusion that broken slag should be placed ahead of gravel ballast.

Mr. Hale:—That is a matter of opinion of the Committee. It was difficult to obtain any definite information, because the slag and the gravel are used under different conditions, and in order to compare them it would be necessary to have them used under similar conditions.

This is the order of efficiency, in the opinion of the Committee, but we have been unable to get any definite data on the order of efficiency.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I ask the Committee whether they considered different kinds of stone—there is trap rock, granite and limestone, each of which has, under certain conditions, an advantage over the other.

Mr. Hale:—Our work was not carried to that extent. The physical tests for stone ballast give the test which the Committee recommends and the preference which should be given in each test as to the best ballast. This conclusion was given careful consideration by your Committee and it was felt that it was a help in the direction indicated, even though it could not be put in very definite terms. For example, there are certain cases where gravel might be better than stone, under certain conditions, and that is why we put this in very general terms as a guide and a guide only.

Mr. Ray:—The Committee has seen fit to qualify the broken slag by saying "(not granulated.)" If this is to stand and go into the Manual, there should be some qualifying statement about the gravel ballast. As the Chairman of the Committee has said, there are cases where gravel ballast may be superior to broken stone ballast. No one will question that the stone should come first in order, but there are cases where the broken stone ballast available may be far inferior to the gravel ballast available, and if gravel ballast is to be rated as inferior to slag ballast, it should be made clear that washed and crushed gravel should not be considered as gravel ballast.

We have had considerable experience with both slag and gravel ballast, and we now have over 100 miles of our main line up on washed and crushed gravel. We have crushers at the washing plant for crushing the large sizes. The crushed gravel is elevated and again passed through the washer. We do not consider that our crushed and washed gravel is very much inferior to any of our best broken stone, and our track ballasted with the gravel is as good as our stone track and easier to maintain. On a portion of the same division we placed from 6 to 12 inches of slag as a base, before we put in the broken stone. I assure you we would not think of using the slag in preference to the washed gravel ballast. I am certainly opposed to the order as proposed going in the Manual. I see that Mr. Rice is one of the members of the Committee. I am surprised that he does not go after this statement. Mr. Rice's entire line is up on washed gravel, and I assure you that any one riding over the Richmond, Fredericksburg & Potomac Railroad would never question the efficiency of their washed gravel.

The President:—I think the question that has been raised by Mr. Ray is a very vital one. The question is whether this order of the different kinds of ballast is the proper one and whether it is based on definite data. We can hardly afford to adopt conclusions, unless we have some data to back them up, or to back up our judgment.

Mr. Hale:—The Committee has some information in regard to comparative tests of stone and gravel ballast on the Baltimore & Ohio some years ago, in which a stretch of track of stone ballast was compared to a stretch of track of gravel ballast of approximately the same length. It appeared from the investigation that when the traffic had increased a certain amount it cost more to maintain gravel ballast than stone. However, we have not been able to obtain exact figures up to the present time.

The President:—If you can give us some data in regard to the relation between broken slag, and the data is definite, that may help us.

Mr. Hale:—Your Committee has not been able to obtain definite information in coming to this conclusion, but the Committee was unanimous in feeling that a classification of some sort, even in general terms, would be a help, and for that reason the Committee recommended it.

Mr. H. R. Safford (Grand Trunk):—It seems to me that this discussion has grown out of a little misunderstanding. The term "efficient" is used here. That is a pretty broad term, involving geographical and economic conditions that enter into costs. The table, as expressed here, would seem to be correct from the standpoint of durability. If instead of the use of the term "efficient" if the Committee intend to mean durability, the table should stand. I do not believe that the Committee can present a table showing grades of ballast from any other standpoint than durability. They can never get a table that will meet with our entire satisfaction.

The President:—Have you any information in regard to the comparative durability of stone ballast and slag ballast?

Mr. Hale:—We have not been able to get the information on two stretches, where we felt that conditions were equal.

Mr. Ray:—I spoke of a comparison on our railroad where conditions are the same; so far as efficiency and durability are concerned, we have some sections now that have been upon screened gravel ballast for the past 25 years, and there has been no new ballast put in on some sections in 15 years. It is as good track as one would want to ride over. We have not had similar experience with any slag ballast that we have used. I wish to move that this entire conclusion be referred back to the Committee for further consideration.

Mr. Chas. S. Churchill (Norfolk & Western):—In seconding that motion I wish to state that the whole trouble arises from lack of descriptive matter referring to these different materials. There are many kinds of slag. We have pulled some kinds of poor slag out of track. However, slag that comes from the reduction of ores that contain considerable silica is very high in value for ballast. Pittsburgh slag, for example, does not equal for ballast purposes the high silicious slags from some ores. It is necessary to have some description written of the quality desired for slag that is to be used for ballast, just as it is necessary to have some descriptive matter also for gravels that make good ballast. Some gravels make good ballast in their natural state, others do not.

I think this table is likely to be misleading. The Committee is all right in their views, but I think that we ought to adopt this motion.

Mr. Hale:—We are very glad to get the suggestions of the Association, and the Committee would be glad to get any assistance from the Association in making this more definite and more practical. The Committee, however, feels that some classification, either for "durability," if that is a better term, or for economy, should be made as a help to those who will use the Manual. If the Association prefers to give it further consideration, the Committee will be glad to make further investigation.

(The motion carried.)

Mr. Hale:—In connection with efficiency of gravel for ballast, in the opinion of your Committee, ballast is much improved by washing. The Committee wish to call attention particularly to the part of the plant which separates clean sand from the clay. In certain stretches of this pit there was a considerable mixture of the clay with the gravel and sand, and the clay is successfully separated from the gravel and sand.

Another subject given the Ballast Committee was methods and cost of applying ballast. On page 325 you will see that a mechanical tamper has been in experimental use on about 17 roads, and we were fortunate enough to get reports from various roads as to results. I think the Association will be most interested in the cost, top of page 326. The Committee felt that the difference in the cost of tamping, as reported, was of much interest, and on page 329 and following pages the Committee reproduce several cuts which had been printed before, but reproduce them together to show the whole process. The conclusions of your Committee on mechanical tamping (page 338), with the information they had available, are as follows (reading conclusion).

The President:—We will accept that conclusion.

Mr. L. A. Downs (Illinois Central):—The Chairman passed over hurriedly the conclusions on page 325, and I want to ask if that motion that was made by Mr. Ray covered the bottom of page 324 and the top of page 325?

Mr. Hale:—Yes, sir. It covers the whole thing.

Mr. Downs:—I would like to say, top of page 325, in the case of washed gravel, that the same reason that Mr. Churchill mentioned as to the bottom of the other page, was the fact that their conclusion was not based on any facts that they presented here. The reference made to the Brookhaven gravel on the Illinois Central, which I am familiar with, would hardly apply to any other gravel pit that I know of, and it would not be fair to make conclusions based on that gravel pit, as it would with others that had loose, free gravel. This is hard cementing stuff, a little better than dirt, and when it was in the track it had to be dressed in the same cross-section as dirt ballast. Drawing any conclusion on the washing plant at Brookhaven would not be right.

The President:—The whole matter has been referred back to the Committee.

Mr. Hale:—In that connection the Committee asked Mr. D. W. Thrower, of the Illinois Central, who was a member of the Committee, to make an investigation, check up and correct the report, which he did, and he was requested to take it up with the Illinois Central officials, to see if it was satisfactory before putting it in the report.

In regard to ballast formers, your Committee was of the opinion that considerable expense might be saved by the use of ballast formers, not only for forming the shoulders, but possibly the path. We have a report on one ballast former from the Atchison, Topeka & Santa Fe. We have given photographs of the device and its results, which are of considerable interest. We have also illustrated on pages 343 and 344 formers which are used and are operated by air. The conclusions of your Committee in regard to those are as follows (reading conclusions, p. 344).

The President:—As I understand this conclusion, it is not a final conclusion of the Committee. If I have the proper understanding of it, we will simply accept this as information. Is that correct?

Mr. Hale:—That is right. The next subject given to the Committee was methods and cost of applying ballast by contract. This appears on page 345. We refer to a report made by Mr. John Evans, Division Engineer of the Michigan Central, which is reproduced in Appendix A on page 534. It covered approximately 90 miles of double-track and some additional mileage. An outline is given of how the contract was written up and the various parts covered by the contractor. On page 356 the price in the contract is given.

Mr. John G. Sullivan (Canadian Pacific):—We have had considerable ballasting done by contract on new work, but I have never seen any ballasting done on contract under the ordinary maintenance of the road. The ballasting of new work by contract costs less than it does to ballast a line in operation, and the reason why it costs more in new work is that the men are bunched, ready to let a train through. I was wondering how the specifications are written, and how long the contractor is permitted to delay a train, if at all.

Mr. Hale:—On the Missouri Pacific, where the ballasting was done by contract, it was done under the same rules which govern ballasting by any force. I cannot answer for the Michigan Central. The same conditions prevailed with the contractors that would prevail with a regular ballast gang.

There were the usual disputes which arise under any contract, but they were settled.

Mr. R. H. Ford (Rock Island):—I am familiar with the contract and methods used for ballasting on the Missouri Pacific Railway, to which Mr. Hale has referred, and perhaps can answer Mr. Sullivan's inquiry. The Missouri Pacific contract was a very comprehensive one. It provided for the loading, hauling, unloading and applying of several kinds of ballast over approximately 2000 miles on various parts of the system. It differed from the Michigan Central contract, which I understand was for application only.

No trouble was experienced in the movement of the contractor's trains. Systematic service was required and obtained in this work, both from the contractor, who got his trains loaded, unloaded and moved over the lines with his own power, as well as from the Operating Department, who dispatched them.

The contractor's men handled the trains in pit service, while regular road crews were assigned for line service in about the usual way, the contractor's line operations being handled through an Assistant Trainmaster specially designated by the railway company for the purpose. Some of the work required that ballast be moved over three operating divisions. Regular schedules for ballast trains were inaugurated, their main-line rights being in about the same relation that fast freight service bears to tonnage trains or better. The contractor performed his work through a local Superintendent, who was given jurisdiction over a section of the line (usually one or more engine stages) in order that he might be kept in touch at all times with his trains through the Assistant Trainmaster, as well as with the work at the pit and on the section being ballasted. Foremen of track gangs were required to be as familiar with train movements as regular employés, so that the track might be kept in proper condition for the passage of trains. In three years' contract operations I do not recall an instance of any difficulty arising from this source.

Contract ballasting is a radical departure from the ordinary methods in vogue in railroad practice to-day, and especially so where the hauling and applying is included. For various reasons there is a hesitancy on the part of operating officers to consent to the movement of contractors' trains over their lines, and perhaps a natural apprehension that complications must ensue. But this is not the correct viewpoint, and ultimately may result in the expenditure of a great deal of money unnecessarily.

I have spent considerable time in the past investigating and studying the comparative results obtained in ballasting by contract and by Company forces, and am convinced that under proper inspection the results secured by contract ballasting are better and cheaper than is usually the case under the methods employed by the average railroad where the work is done by Company forces.

I have also had an opportunity to analyze the cost of this class of work, both from the standpoint of the contractor and of the railway, as I have at different times been associated with both. In the former case a complete analysis of the results of the contractor's operation was made, covering a period of two years and 300 miles of ballasted track, and under very similar conditions the cost of ballasting by Company forces on different divisions and under different supervisory officers on the same road. The margin, as a rule, was in favor of contract work.

The conclusions of the Committee, that "under certain conditions contract ballasting is satisfactory, while under other conditions it is not satisfactory," are, in my judgment, correct. Unless a railroad is prepared to undertake its ballasting operations as a special problem, organize for it, and co-ordinate the service in the same degree that it should for any other unit, where large sums of money are daily affected by the service, it would be much better to do the work by contract under intelligent supervision. Some roads can do this, but for various reasons others cannot; they are not in a position to follow up accurately the cost of the work with the degree of promptness that the successful contractor must and does do. In the latter case the organization is sufficiently elastic to respond immediately to any change in conditions. This is not the rule with the railway company.

Ballasting has been one of the most important factors in railway maintenance since their original construction about 70 years ago, but the methods employed have remained practically the same, although the conditions have completely changed. I believe that where railroads will analyze and compile carefully and impartially the entire cost of their ballasting operations, either more work will be done by contract or else more attention will be paid to its organization and efficiency both from the standpoint of first cost and future maintenance.

The President:—Do you know of any cases where the cost of doing the work by contract was greater than the cost of doing it under the regular railroad plan?

Mr. Ford:—Yes, I recall one division in particular where the total cost by Company forces for loading, hauling and unloading was considerably less than the contract rate. Local conditions were the direct cause of this, the railway company obtaining its material (chatts) loaded on cars direct from the sources of production at a very slight cost, making it impossible for a contractor to compete for loading. The haul was short, amounting to practically a switching movement, the total production, however, being sufficient to take care of the daily ballast requirements.

The rate per cubic yard in these ballast contracts was on the basis of an average haul of 90 miles. The contractor supplied his own equipment except ballast cars, which were furnished by the railway, as well as some other pieces of equipment, such as plows or Lidgerwoods, not required for its own services.

Mr. C. W. Baldridge (Santa Fe):—I would like to ask a question in regard to ballasting by contract. How long is the contractor required to maintain the track in good order? The reason I ask it is, I have in mind one case, at least, of an extra gang foreman who made a record for speed in ballasting and surfacing the track, and it became evident shortly afterward that for a period of about two years the section foremen were required to spend a good deal more time in resurfacing track on which the speed record was made than was necessary on any other track not so rapidly ballasted.

Mr. Hale:—The contract required a certain time, the exact detail I have not here, but generally until the work was accepted by the railroad inspector. The contractor was required to maintain the track until it was accepted, and there was a general time stated. Possibly Mr. Ford can report the exact time. I do not happen to have the information.

Mr. Ford:—It depended altogether upon the amount of traffic and condition of the track. Previous to the applicaion of ballast the contractor was required to skeletonize the track and make his tie renewals, which was also done by contract. and of itself is of special interest. The ballast raise was made in two separate lifts, with a sufficient interval between them to permit the ballast to settle or shrink and allow the track to be lined to the center stakes; the second lift being for a final surface, after which the track was dressed to the ballast section. The inspectors for the railway were expected to study traffic conditions and co-operate with the local transportation and maintenance forces, as well as with the contractor, in order that he might work out an economical disposition of his forces, so that there would not be too much open (skeletonized) track ahead, or too much remaining unfinished after dumping, and, on the other hand, to see that the interval between the first and second lifts was sufficient to obtain proper settlement so that the surface might be better maintained thereafter. This of course required modification from time to time on account of roadbed or weather conditions. No fixed rule can be laid down for this except a thoroughgoing knowledge of local conditions and the results desired, all of which is so important if the track is to remain in good service and be maintained thereafter at a proper cost without undue expense.

Mr. C. E. Lindsay (New York Central):—That is, as I understand it, the inspector is, in the last analysis, responsible for the safety of the operation, and if there was an accident we could not expect to hold the contractor.

The President:—I presume that would be the case if the contractor's men complied with the orders of the railroad company's representative.

Mr. C. H. Stein (Central of New Jersey):—I ask, in view of the conclusions of the Committee, to what do they ascribe the ability of the contractor to do this work more cheaply than the railroad company can do it with its own force?

Mr. Hale:—The conditions which bring that about are the same as the conditions in any other contract. The contractor is able in many cases to work more economically than the railroad under certain conditions, particularly where the railroad is not able to form an organization and the contractor is able to form the organization promptly. In one instance it was due to the fact that the contractor was at liberty to pay a higher rate to common labor. The railroad did not want to raise the rate for common labor at that particular point, as it might affect the whole system, and they preferred to let the contract—this was for maintenance work—temporarily, and to permit the contractor to raise the rates of pay to common labor, and then turn the completed work back to the railroad company later. In another case the efficiency of the contractor's organization had much to do with it, but where the railroad has a better organization, a more efficient one, probably there is not the profit or gain that there was in certain cases with which we were dealing.

Mr. Hale:—The next subject was to report on the economical and efficient depth of ballast, cooperating with Special Committee on Stresses in Railroad Track.

Your Committee was able to obtain some very interesting information or partial information, which it was not able to get in shape to give to the Association, namely, the depth of ballast found in valuation work by the Government. This was taken up with the various Valuation Engineers, but on account of the work only being partially completed we were unable to get many reports. However, we have received a few, and they indicate a much larger depth of ballast under the track than was supposed by the officials in charge of the railroads in many cases, and that will probably be borne out by the valuation men who are here to-day.

On the Missouri, Kansas & Texas Railway, for instance, it was supposed in places they had three inches of ballast under the ties, whereas they found they had 9 or 10 inches.

In the case of the Kansas City Southern Railway, it was supposed that they had six inches of ballast, and in many cases they found as much as 18 inches, and in some exceptional cases more.

At the bottom of page 347 there is some very interesting information referring to the Pennsylvania Railroad.

This is also found to be the case on the Boston & Maine. Outside of Boston, where they have peat bogs and very bad subsoil, the depth of ballast was found to be as much as 5 feet.

We have an interesting report of the use of washed gravel on the Richmond, Fredericksburg & Potomac, and full details of the gravel washing plant are given.

On page 353 appear the conclusions of the Committee.

The Committee hopes to have much more information on this subject to present next year.

The President:—Please tell us wherein that differs from our present recommendation.

Mr. Hale:—In the latter part, in the case of roadbed which will not be deformed by the application of live load, the minimum depth of ballast recommended is 12 inches, instead of 24, as previously recommended in the Manual.

Mr. McDonald:—I ask the Committee whether it intends, with reference to the first part of that paragraph, that there shall be 24 inches of clean ballast, or does the Committee take the view that what the Interstate Commerce Commission has found is real ballast?

Mr. Hale:—I presume, Mr. McDonald, it means the same kind of ballast that we mean when we adopted the previous recommendation.

Mr. McDonald:—Then I suggest that the word "clean" be inserted ahead of the word "ballast."

The President:—The Committee will accept that.

Mr. Ford:—I have given this considerable study, and I cannot bring myself to believe that the Committee is on the right track on this question of the depth of ballast. The prevailing impression seems to be that depth of ballast should be the same irrespective of its quality or existing sub-surface conditions. I am sure this is not correct.

As to the question of clean ballast, it is manifestly impossible to keep the ballast clean. The Rock Island first ballasted its line from Chicago to Joliet in 1851 and has been ballasting ever since. What is true of that railroad is true of many other railroads. There is no doubt that all of the railroads in the country under the main tracks will find the amount of ballast in varying degree. That does not bring out the fact that we have got to continue to apply ballast. The application of ballast is because the ballast in the track gets foul entirely apart from its sinking into the roadbed.

It seems to me that clearly-defined and well-developed lines of investigation will ultimately bring out the fact that to secure all the advantages that ought to be obtained from ballasting, a different line of investigation and study has got to be undertaken; this, in my judgment, will go a long way toward settling the question of what the depth of ballast ought to be. I believe we are going at it from the wrong angle.

Mr. Churchill:—I move that all these conclusions be received as information, and not go into the Manual. My reasons for offering this motion at this time is that the Committee on Track Stresses is working on this same subject, and while perhaps the Committee on Ballast may be working along the proper lines, we do not know as much about this subject as we will know at the next convention. I think it will be better to hold it open for another year.

The President:—Conclusion No. 2 is the one referred to in Mr. Churchill's motion. The motion is that this be received as information and referred back to the Committee for further consideration. There are certainly further investigations being made, and we should not adopt any conclusions to go into the Manual until we are sure they are complete and final.

As to conclusion No. 3, that is a matter to be referred to the Board of Direction. The Board has indicated that it has not money to appropriate for this purpose. We are in sympathy with you. It is possible that the work being carried on by the Committee on Stresses in Track will develop the same information this Committee is trying to develop, and I believe that this Committee is represented on that Committee.

As regards the recommendation for next year's work, that is referred to the Committee on Outline of Work. The Committee is excused with the thanks of the Association for its work this year.

DISCUSSION ON TRACK.

(For Report, see pp. 369-392.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON TRACK.

J. A. Atwood.	G. J. Ray.
J. L. Campbell.	L. S. Rose.
J. B. Jenkins.	H. R. Safford.
C. E. Lindsay.	C. H. Stein.
Hunter McDonald.	John G. Sullivan.
H. T. Porter.	A. O. Wilson.

The President:—The next business is the report of the Committee on Track. The report will be presented by Mr. J. B. Jenkins, Chairman of the Committee.

Mr. J. B. Jenkins (Baltimore & Ohio):—The report of the Committee on Track this year covers quite a wide range of subjects involving a great deal of Sub-Committee work.

In regard to the first subject, the revision of the Manual, we had covered the ground so thoroughly last year that we thought it inadvisable, in view of the coming edition of the Manual, to make any additional changes this year except those which are specifically recommended in the Committee's report.

The second subject, economics of track labor, has been very carefully covered and this Committee is doing excellent work. We have no results to present this year; in fact, we have laid out a program of work that will take at least ten years to cover, and probably some time longer. It will be another year before we have our first definite results. By an examination of the report you will see the lines along which we are progressing.

We feel that the work of this Sub-Committee on economics of track labor is of great importance to the railroads in bringing about a more efficient and a more economical distribution of money for maintenance purposes, and we have asked the railroads to set aside special record track sections in order to make investigations as to the relative influence of different conditions and different physical features which will affect the cost of maintenance work. Many roads have responded to our requests and agreed to set aside special record track sections, but, unfortunately, those roads which have responded lie within a single belt in which the climatic conditions are not greatly different; that is, the rainfall is nearly the same. The belt in which we are getting these record sections starts at the Gulf and runs northward west of the Mississippi River, and then curves to the eastward, almost in the line of the ordinary cyclonic path, going down the St. Lawrence Valley.

In the South Atlantic and East Gulf states, west of the Missouri River and in the Northwest we have practically no special record of track sections and we would appeal to the railroads of these sections to set aside sections of track in which records shall be kept that will be available to this Committee.

I move that the report on economics of track labor be received as a progress report.

(The motion carried.)

Mr. Jenkins:—In connection with the appeal I made to other railroads to respond to our request, I would like all of you at your leisure to read very carefully the circular on page 372, which was sent out during the year to all the railroads, and see if you cannot do something to help us along. We have obtained excellent responses from many of the railroads, but some of the roads are holding back and not giving us any help.

I will next refer to the report on tests of tie plates subject to action of brine drippings, which appears on pages 391 and 392, in regard to which we can only submit a report of progress. We have done a great deal of work in getting ready for these tests, which have actually begun since the writing of this report. I also ask that this be received as a progress report.

Referring to pages 373 to 375 of the report, you will see that the Committee has made a serious attempt to ascertain the relation between worn flanges and worn switch points. So far, we have not been able to formulate any rule that will guide the track foreman in deciding when the proper time has arrived to take out a switch point. We have tried out two rules which look to us as being reasonable, and in both cases we found that a great many switch points ought to be taken out which the rule says should be left in, and in many other cases we found switch points that should be left in which the rule says should be taken out. We really have very little to report on this, and the gist of the report is found in the next to the last paragraph, on page 375.

I would ask the adoption of this report.

(The motion carried.)

Mr. Jenkins:—The Committee will withdraw the request to be relieved from further consideration of this work, if the Board of Direction wishes us to continue it.

Referring to the report of sub-committee No. 6, on page 385, the sub-committee has presented a design for a double switch lug. We wish to make several amendments to this design, first by striking out the thickness dimension of ⅜ in., showing no thickness dimension whatever.

The President:—Leave it optional?

Mr. Jenkins:—Leave it subject to other notes. We wish to amend the note in the upper left-hand corner to read, "lug to be of same thickness as single lug and otherwise reinforced if desired." We wish to amend the title to read, "Suggested double switch lug to permit the switch to be thrown by either rod." Instead of asking the adoption of this double switch lug, we only wish to offer it as information.

The President:—This will be received as information.

Mr. Jenkins:—We wish to present for adoption and publication in the Manual, typical layouts for Nos. 8, 11 and 16 double crossovers for 13-ft. and 15-ft. track centers: General plans, found on the insert opposite page 390 and typical layouts of frogs for these crossovers, found in the second, third, fourth, fifth and sixth inserts opposite page 390. No amendments to offer to those drawings.

Mr. John G. Sullivan (Canadian Pacific):—I would like to ask some information. Do they mean by "typical layout" the position of the frog or the design of the frog?

Mr. Jenkins:—The position.

Mr. Sullivan:—On page 388 there is evidently a good design of a guard rail, which I think will be asked to be approved, under conclusion 6, on page 392.

Mr. Jenkins:—Yes.

Mr. Sullivan:—The good feature of this guard rail is the curving of the guard rail for a distance in order to make an easier approach. I see no attempt made to so design the frogs. Of course there are no figures given, but from the drawings it would appear the frogs were made with a very abrupt entrance. If these layouts covered the design of the frog as well as the position on the ground, I would object to their approval.

Mr. Jenkins:—The drawings of typical layouts of these crossovers are merely diagrammatic.

The President:—I think this is intended to get uniformity in regard to the location of the frogs. For instance, take the top layout, the first one. There is the dimension, 151 feet, 4½ inches from point of switch to point of switch in the upper track. That might be 150 feet, it might be 155 feet, and there would not be any great harm done, but we understand that this is an effort to standardize these dimensions.

Mr. Jenkins:—In regard to the typical layouts for 13-ft. centers, the essential thing about this is the unsymmetrical arrangement. If you have two tracks between 12 and 13-ft. centers, you cannot have a symmetrical arrangement because the throats will come so nearly opposite the points that you cannot protect the latter. The unsymmetrical arrangement permits the guarding of every point. If you have 12½ ft. centers you can use 7 and 5½ ft. distances from crotch frog to center of track and if 13½-ft. centers you can use 6 and 7½ ft., and in each case protect all points. If you have 12-ft. centers you would use the two sixes, and if 14 you would use the two sevens. After you get above 14-ft. centers, this necessity for making the crossing unsymmetrical no longer exists, but by using the unsymmetrical arrangements we can provide for 15 and 16-ft. centers with the addition of only one more set of standards. In other words, with our two sets for 13 and 15-ft. centers we have symmetrical arrangements for 12, 14 and 16-foot centers, with unsymmetrical arrangements for 13 and 15, and then, by introducing an odd crotch-frog distance on one side for any other distance between track centers that may be desired, we can use one of the standard arrangements for the other side.

(Recommendations 2 and 3 adopted.)

Mr. Jenkins:—Conclusion 4, page 392, recommends for adoption and publication in the Manual, typical layouts of Nos. 8, 11 and 16 double slip crossings with square switch points, 13 and 15-ft. centers. General plans. This is found on the seventh insert, drawings 1 and 2, and on the eighth insert, drawing No. 1. We want to amend all three of these by adding three notes:

Note "A"—"Where heel blocks are desired, a form allowing a reasonably free movement of switch rail should be used."

Note "B"—"When supported joints are preferred, the position of ties may be changed to suit."

Note "C"—"When heel blocks are not used, location of joints may be changed so that more than two joints will not be located in the space between the same two ties."

(Recommendation 4 was adopted.)

Mr. Jenkins:—The next is conclusion 5, recommending for adoption and inclusion in the Manual typical layouts of Nos. 8, 11 and 16, double slip crossings with staggered switch points. These plans are found in the seventh insert, drawings 3 and 4, and the eighth insert, second drawing. We wish to amend these plans by adding the notes "A," "B" and "C," by striking out the words "heel blocks" in the same place as on the other drawings, to further amend the drawing for the No. 8 by increasing the distance between the movable points to 10 inches, and changing the lengths of the movable points to 8 ft. 9 in. and 10 ft. 9 in. respectively.

(Recommendation 5 was adopted.)

Mr. Jenkins:—Conclusion No. 6 recommends for adoption and publication typical plans of frog guard rail found on page 388.

Mr. Sullivan:—The clamps are shown in the plan; in the cross-section they show a bolt. In plan 2 it is through the packing block and the bolt, shown in the section; is evidently not through the packing block.

Mr. Jenkins:—The short block in the center, that is a section through the center of the guard rail.

Mr. Sullivan:—The plan shows a clamp, not a bolt.

Mr. Jenkins:—No, take the upper drawing; the clamps are about four feet on each side of the center.

Mr. Lindsay:—I know it is not proper to consider definitions on the floor of the convention, but I would like to ask Mr. Jenkins if he has received my letter of March 10 as to his definition of frog guard rail at the bottom of page 387, and if the Committee desires to make a change in that.

Mr. Jenkins:—We will offer the definition as a separate conclusion.

Mr. J. A. Atwood (Pittsburgh & Lake Erie):—With reference to the four feet at the end of the guard rail, I think that should be a straight line rather than a curved line. The object is to give an easier approach for the flange of the wheel coming to the narrow part of the guard and the straight line gives a better approach than the curved line.

The President:—Do you make a motion to have it changed?

Mr. Atwood:—Yes, sir; I make a motion to that effect.

Mr. J. L. Campbell (El Paso & Southwestern):—I do not understand that this plan shows all details of the design of the guard rail. Apparently, on the face of the plan, the guard rail might not be adjustable in the matter of filler blocks. What is the idea of the Committee? Should the filler block and, consequently, the guard rail be adjustable or non-adjustable?

Mr. Jenkins:—We have not made any provision for taking up the wear by closing in. I do not know of it ever being done. It certainly would detract from the rigidity of the guard rail to attempt to do so.

Mr. Campbell:—Many guard rails are provided with adjustable filler blocks admitting a close adjustment of the guard rail. I believe the filler block should be so constructed that the guard rail can be adjusted. If the bolt shown in the center of the guard rail was replaced by a clamp, the latter would hold the guard rail more rigidly and securely. We have never found anything that would hold a guard rail of this kind satisfactorily except a heavy clamp.

Mr. H. T. Porter (Bessemer & Lake Erie):—The purpose is to attempt to show the fixtures that are used for holding the guard rail, the lengths and the flangeways. There is only one short filler block and you could use a two-piece filler block which is adjustable, if so desired. Guard rails do not wear very rapidly and we did not consider it necessary to take care of that adjustment at that point, but I would see no objection to making the change to show the two-piece filler block.

Mr. Lindsay:—The detail at the end of the 16-ft. 6-in. guard rail, showing the guard rail supported laterally by two bolts from the main rail, is objectionable. It places a strain upon the main rail at a point where it is weakened by two additional bolt holes. It is not essential that that point of the guard rail be firmly held, yet it ought to be supported, and I believe it can be supported equally as well without strain on the main running rail. I do not care to make a motion, but I would like to hear a discussion from others who have used this device.

Mr. Jenkins:—Referring to the point in regard to the filler block, the Committee is willing to add a note, that an adjustable filler block may be used.

Mr. Lindsay:—My objection is to the two bolts through the filler block at the extremities of the 16-ft. 6-inch guard rail, and the other also, at the ends, weakening the main running rail at a point where the guard rail receives its first blow and great shock. It is not essential to hold that guard rail immovable at that point, and it can be held by a rail brace equally well without weakening the running rail.

Mr. H. R. Safford (Grand Trunk):—I have had personal experience for a number of years with that type of construction. I have never had any occasion to regard that as weak. I have never had an example where there has been any filler. It is no worse a condition than that existing at a joint, and as far as I can see there can be no objection. If it is wrong, it is well to hear about it.

Mr. Lindsay:—I have had no experience, and that is why I ask for information.

Mr. Porter:—In reply to Mr. Lindsay's remarks, that where we have the filler, which is intended for a foot-guard principally, is the place where the guard rail first gets its shock, I have not ridden over any track where I thought that was the case. The wheel is generally pretty close to the clamp before it has any effect on the guard rail. At the end of the guard rail is the foot-guard. We have tried to make ample and careful provision to take care of the men liable to get a foot caught in guard rail, and the bolt is considered a very simple means of keeping that foot-guard in and preventing it sliding or working out of place. The security of the foot-guard depends upon its fitting closely to the guard rail and the main rail because if it is allowed to get loose, a man might catch the sole of his shoe. The bolts need not be as large there as the bolts they use at the ends of the rails, and as this is not near the end of the rail, the weakening of the rail I do not think is a serious matter. The worst feature of it is the expense of having to drill a hole on the ground, and this is a very good plan of foot-guard. It gives protection against getting loose, and I do not think does any harm. Except when a car is derailed, there is no likelihood of the guard rail being struck at that point and the wheel is as likely to go inside of the guard rail as outside.

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—In answer to Mr. Lindsay's remark about the bolts at the end of the guard rail, there is the advantage of having the shock taken up by the end bolt rather than have the guard rail move a little bit and tear the bolts out in the middle. You have a short arm when the shock is taken up at the end of the guard rail. I have seen the arrangement tried with spikes at the end, and bolts in the middle.

Mr. A. O. Wilson (Seaboard Air Line):—We had a standard on the Seaboard, very similar to this, fastening guard rails by bolting through blocks at the ends. We have abandoned that design, because we never could keep bolts through the blocks. On our new work we adopted a patented guard rail, but on our renewals we are using curved guard rails, curved at each end with a straight section in the middle similar to this guard rail, and guard rail clamps, using four rail braces on each guard rail, two on each side of the guard rail clamp, spiking the same down. This we found gave very much better results than when the guard rail held by bolts.

Mr. C. H. Stein (Central of New Jersey):—I would like to ask the gentleman, did he use ⅞-in. bolts? If he did, it is not surprising that they loosened. We have been using, for a great many years, four bolts in the guard rail, with a rail brace at each end of the guard rail, and so soon as we adopted the 1⅛-in. bolt our troubles ceased.

Mr. Wilson:—We use a ⅞-in. bolt.

Mr. Campbell:—We use two one-inch bolts at the end of the guard rail similar to this and we find it the best arrangement and are satisfied with that part of the guard rail.

Mr. Lindsay:—Will Mr. Stein tell us what size hole he put in his running rail, and did you use a nut lock?

Mr. Stein:—1 3-16-in. lock nut, ⅜ in. square.

The President:—Are you ready to vote on this standard that has been offered by the Committee under item 6 for adoption and publication in the Manual?

(The motion carried.)

Mr. Jenkins:—We wish to offer for adoption and publication definition of frog guard rail, page 387. In this connection I will say I did receive Mr. Lindsay's letter and did not like his definition at all.

Mr. Lindsay:—Then it is up to me to read my criticism. I said to Mr. Jenkins: "I would like to make the following comment concerning the definition of 'Frog Guard Rail,' as given on page 387 of Bulletin 183, January, 1916. The proper function of a frog guard rail is to prevent the wheel flange from taking the wrong side of the frog point. According to the definition your Committee gives the wheel flange might be clear of the frog point, but on the wrong side of it.

"I suggest the following: 'A rail or other device to guide the wheel flange properly by the gap in the gage line in front of the frog point," or 'A rail or other device to prevent the wheel flange from taking the wrong side of the frog point.'"

Mr. Jenkins:—Mr. Lindsay's substitute would not cover the function of the guard rail to keep the wheel from striking the point, which it might easily do, without taking the wrong side. Furthermore, if the guard rail keeps the flange of the wheel clear of the points it certainly cannot get on the wrong side.

Mr. Lindsay:—I have seen cases where the wheel took the wrong side of the guard point and never touched it. The guard rail was properly placed, but the wheel on the opposite side climbed over the guard rail.

The President:—What did you find, when you investigated, was the cause of it climbing over?

Mr. Lindsay:—The locomotive, improper clearance.

Mr. Safford:—I do not think that definition ought to be changed. I do not think there is any confusion in our minds as to which side of the point the flange ought to go.

(Mr. Lindsay's amendment was lost, and the definition of the Committee adopted.)

Mr. Jenkins:—We offer for adoption and publication in the Manual the specifications for frog guard rail found on pages 390, 391, beginning bottom of page 390 and concluding at top of page 391.

Mr. Sullivan:—I object very much to limiting the foot guards to one particular kind of wood, which is pretty hard to get in some sections.

The President:—Do you offer some addition?

Mr. Sullivan:—That covers some legal points. I would want to do some thinking about it.

Mr. Jenkins:—The Committee is willing to revise that, making it read "Sound hardwood."

Mr. Lindsay:—What does the Committee understand by No. 2 rail, in the first specification?

Mr. Porter:—No. 2 rail is described in the rail specifications.

The President:—Any further discussion? If there is no objection the specifications will be accepted and will be printed, considered adopted by the Association and included in the Manual.

Mr. Jenkins:—We offer for adoption and publication in the Manual the proposed screw spike, page 384. In the title omit "American Railway Association standard" and so as to read "proposed screw spike."

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—My criticism of that design is that in three or four years the head will get rounded so that you cannot remove the spike. As the result of that difficulty we adopted a design suggested by Mr. Atwood, of the Pittsburgh & Lake Erie, having a hexhead.

Mr. Lindsay:—I have had but little experience with screw spikes, but it occurs to me that the design of the head is very small, for the same reason that Mr. McDonald gives, there is no reserve metal for corrosion. The outer edge of that head is very thin as it is drawn and as I figure it out, it projects only 11-16 from the circle of the spike. It seems to me we ought to have a more generous head on a device of that kind.

Mr. McDonald:—I neglected to say that the hexhead, which I meant was the full size of that circle, an inscribed hexagon the diameter of that circle.

The President:—2¼ in.

Mr. McDonald:—Yes, sir; I think about an inch thick.

The President:—The Committee is willing to take these criticisms under consideration and bring back a recommendation next year.

Mr. Jenkins:—The Committee offers for adoption and publication in the Manual the change in specifications for ordinary track spikes, found on page 381.

Mr. Lindsay:—I think it would be advisable to make the test by pressure.

Mr. Ray:—If the head of the spike breaks off it is not by applied pressure, but by blows, whether from the hammer or shock at the base of the rail. I think the old specification was so intended. This is merely a change in the wording to make it plain.

The President:—Mr. Ray is correct. When you take the old specification, the question is not raised. They simply amplify the specification a little. Are there any objections to accepting this proposed change in the specifications? If not, we will accept this as the will of the Association.

Mr. Jenkins:—The Committee wishes to add another recommendation for next year's work: "Consider the advisability of increasing wheel base on freight car trucks."

Mr. Lindsay:—Why? What is the object?

Mr. Safford:—That is the outgrowth of a suggestion which was transmitted through me to Mr. Jenkins. It emanated from an officer of one of the leading railroads of the country, in charge of equipment. He is under the impression that the relation of the length of truck on freight cars to track conditions, and vice versa, is a subject that ought to be carefully considered. He believes there is some merit in a longer wheel base, and without giving his reasons for it, he convinced us that it ought to be studied and upon that we have made this recommendation. The Master Car Builders will ask us to cooperate with them.

The President:—Is this matter now up with the other associations?

Mr. Safford:—Not officially.

The President:—This is not a matter for us to discuss, is it? The design of equipment?

Mr. Safford:—No; it is not so much a matter of design of equipment as to see what effect, if any, upon the track such a change would be. It is entirely an informal matter, does not come to us officially, yet it seems to me it might be considered by the Committee on Outline of Work.

The President:—The Committee will consider that.

Mr. Jenkins:—Next is Sub-Committee No. 5. The Sub-Committee has done some very thorough work. They came to a conclusion, but the Track Committee has not had time to consider it thoroughly enough to make a recommendation. The Track Committee sees no reason why the flange of the car wheels should not be thickened as desired, and this can be done without any increase in the flangeway by closing in a little on the distance between the gage of the wheel and the gage of the track, so as to allow a little less play. A development has arisen which may possibly put off any further consideration of this. The Committee of the Master Car Builders' Association will probably report in such a way that further consideration will not be necessary, but in this connection there develops as a side issue a new subject, whether it would not be very advantageous to increase the check gage distance on car wheels. The back of the flange of the wheel often strikes the guard rail and there seems to be ample room on the other side, between the flange of the wheel and the point of the frog. The back of the flange striking the guard rail and throwing the guard rail out to a distance greater than 1¾ inches, as you will find to be the case with most of the guard rails throughout the country, results in not having proper protection for the frog point. If we can prevent the flange striking the guard rail we will have a more satisfactory condition. If the difference between the gage of the wheel and that of the track is less, it will accordingly lessen the nosing on tangents and the oscillation on curves. There seems to be every reason why this subject of the increase of check gage distance on wheels should be studied.

The President:—Is that not a detail as to increased flanges?

Mr. Jenkins:—The increase in the check gage distance, it appears from our study, involves the variation in the manufacture and the allowable wear of the parts, conditions which will be corrected by increasing the check gage distance. The Committee has not acted upon this phase of the subject, but I think in case the question of increased thickness on flanges is dropped, that the Committee should study the subject of increasing the check gage distance.

Mr. McDonald:—If I am in order I want to suggest some subjects for this Committee or some other Committee to consider, according to the decision of the Committee on Outline of Work. The first is that this Committee shall investigate the extent to which the frogs and switch points which have been adopted as standard are now being used. The second is, specifications for the classification of relieved rail. The third is, recommend the limit of safe wear of rail on curves.

The President:—The suggestions will be considered by the Committee on Outline of Work. The Track Committee is excused with the thanks of the Association.

DISCUSSION ON BUILDINGS.

(For Report, see pp. 313-318.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON BUILDINGS.

C. E. Lindsay.	M. A. Long.
G. J. Ray.	

The President:—The next report to be considered is that of the Committee on Buildings. It will be presented by the Chairman, Mr. M. A. Long.

Mr. M. A. Long (Baltimore & Ohio):—The report will be found in Bulletin 183, page 393. The first subject is the revision of the Manual. We submit, in addition to "engine houses," that the following should be added: "When there is an engine house without turntable and no 'Y' track or other means of turning provided, such engine house should preferably be equipped with a smoke jack at each end of each stall."

The President:—This is a conclusion which has been offered to us, to be included in the Manual. Are you willing to accept that conclusion? Not hearing any objection, it will be accepted.

Mr. Long:—The second subject is, the question of freight house scales. Your Committee has boiled this down to what we consider hard pan and we offer this report as written for publication in the Manual as a whole.

The President:—I presume some of you read this report, just as I did, and assumed that this was being offered as information. They now ask you to adopt it and have it included in the Manual.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—It seems to me it is hardly right to ask the Association to adopt these conclusions for the Manual when there is no indication in the report that such action would be requested. I move that this be received as information or go back to the Committee for further consideration.

The President:—The Chair had the same notion, but did not wish to act arbitrarily in the matter.

If there is no objection this will be referred back to the Committee. In order to save time, the Chairman of the Committee informs me that he proposes to do the same thing with the recommendations in regard to various types of pits, and it seems to me that should take the same course. If there is no objection by the Association, that is what will be done. This will be referred back to the Committee and they can resubmit conclusions.

Mr. Long:—No, the Committee boiled this down to keep the printed matter as small as possible.

The President:—Any suggestions to be made by any member of the convention in regard to the work of the Committee for the coming year?

Mr. Lindsay:—Referring to Fig. 3 and Fig. 5 in the report, I suggest that the subject of clearances be given careful consideration.

Mr. Long:—These are merely diagrams and it is supposed that they will, in making up the detailed drawings, work with reference to the clearance diagram.

The President:—The Committee is excused, with the thanks of the Association.

DISCUSSION ON ELECTRICITY.

(For Report, see pp. 399, 400.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON ELECTRICITY.

C. E. Lindsay.	S. N. Williams.

The President:—The report of the Committee on Electricity will be presented by Mr. C. E. Lindsay, in the absence of the Chairman and Vice-Chairman of the Committee.

Mr. C. E. Lindsay (New York Central):—It has nothing but a progress report, yet it has made progress. On the subject of clearances it has brought up to date the data regarding overhead clearance on various electrified roads of the United States. On the subject of transmission lines and crossings it has collaborated with the joint committees of the other associations. On the subject of electrolysis it has continued its investigations with the national joint committee. It makes the recommendations which are printed in the report. It asks for further time.

The President:—The Chair understands that the Committee simply presents the information to the Association and makes no recommendation. Do you wish to make any suggestions in regard to the work of the Committee?

Prof. S. N. Williams:—Does the recommendation on page 400, "that the subject of report on water power for electrical railway operation be considered," cover the same ground as given the Committee on Conservation of Natural Resources?

The President:—That is a matter that will be taken care of by the Committee on Outline of Work. The report of the Committee will be received as information, and it is excused with the thanks of the Association.

DISCUSSION ON GRADING OF LUMBER.

(For Report, see pp. 407-411.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON GRADING OF LUMBER.

C. E. Lindsay.	R. A. Rutledge.
Dr. Hermann von Schrenk.	

The President:—Dr. Hermann von Schrenk, Chairman of the Committee on Grading of Lumber, will present the report of that Committee.

Dr. Hermann von Schrenk (Consulting Timber Engineer):—I will not take the time to read the entire report, but if you will turn to the summary on page 414, you will see that we make two recommendations. The first is that we recommend for adoption as standard a new definition for quality of Southern yellow pine timbers. In explanation I wish to say this is a matter which has now been under discussion on the part of the various technical and engineering societies of this country for the last three years. It has been generally recognized that one of the chief difficulties in the grading of structural yellow pine timbers has been the lack of definite scientific definitions. Specifications have called for longleaf pine for a great many years, but there has been no method for assuring one's self as to whether material furnished was longleaf pine. Under the lead of the United States Government, the technical committees of the American Society for Testing Materials for the last five years have been going into this matter and they presented a concrete and comprehensive report at the annual convention last year. Under instructions from the Board of Direction of this Association, your Committee, a number of whom were members of this other organization, considered this matter during the last year and we have also corresponded with the Chairman of the Committee on Bridges and Trestles, and came to the conclusion that it was a desirable thing to recommend the new classification for adoption. There is practically nothing that we have heard that can be said against such a procedure, except possibly the question involved in the lasting power of the different species of wood, which will be included under the first grade called "dense" pine.

In that connection we are of the opinion that the chances which we are taking in including the strongest pieces of shortleaf and loblolly pines (which will probably not amount to more than 5 per cent.), are far less than the chances now being taken because of our inability to exclude poor pieces of longleaf pine.

A glance at page 409 will convince anyone of this fact. "It will be found that the modulus of rupture in these four pieces of longleaf pine varies from 11,100 to 4,600 lbs."

In the new classification the strength characteristic is one which will assure our getting pieces like the classes represented in the upper photograph having the higher modulus of rupture. I would accordingly move that the definitions as printed on page 408 to top of page 411 be adopted as standard by this Association.

The President:—Will you tell us in a few words wherein these differ from those which are already the standard of the Association?

Dr. von Schrenk:—At the present time we have practically no definition for a high-grade botanical classification of timbers. Our present rules simply define longleaf pine as the timber which comes from the botanical species of longleaf pine. We say for timber of the shortleaf or loblolly variety that if it has the characteristics of the longleaf pine it shall be considered equal to longleaf pine. We have no method of determining how that shall be judged.

The present rule has abandoned the terms "longleaf," "shortleaf" and "loblolly pine" for the reason that it would be confusing if they had been retained, and substitutes therefor two grades, "dense pine" and "sound pine," dense pine to include the strongest species of what has hitherto been known as botanical longleaf, and a small percentage of the dense piece of what we regard as equivalent to longleaf, namely, shortleaf and loblolly, and excludes the weaker pieces of longleaf, which have hitherto been accepted.

The only addition is to give a perfectly definite physical method of measuring and identifying the high-grade structural pieces of timber so that there will be no misunderstanding as to what class of timber has been received.

The President:—It is my understanding that the definition you are offering begins at the middle of page 408 and includes all the remaining matter on that page and about one-third of the matter on page 411.

If there is no objection to adopting the definition it will be considered that it has the approval of the Association, and it will be printed in the Manual as a substitute for what we have now.

Mr. R. A. Rutledge (Santa Fe):—I understand there has been a regrading in the specifications of the Southern Pine Association within the last year, which has just been printed. Is this along the same line as that?

Dr. von Schrenk:—Yes, the Southern Pine Association has taken the rule as adopted by the American Society for Testing Materials and adopted it as their own.

The President:—Not hearing any objection, it will be adopted.

Dr. von Schrenk:—The second recommendation is with regard to grading rules for hemlock lumber. These rules were printed as information in Bulletin 174 last year; we have revised the rules and have made certain omissions, which will be found specified on page 411. These omissions are largely of a typographical nature and deal with contractual relations which we do not believe have any place in a general specification, such as we have hitherto adopted with regard to other classes of lumber.

The recommendation which we now make is, that having received various suggestions we now move that the grading rules as printed in Bulletin 174, with the omission of paragraphs 3, 4 and 6, be adopted as standard.

The President:—Hearing no objection, it will be considered that the Association approves this course.

Dr. von Schrenk:—The further part of our report is simply submitted as information. Your Committee, in cooperation with a similar committee of the American Society for Testing Materials, has drawn up a specification for bridge timbers to be creosoted, which is found on page 411. We call special attention to the fact that these specifications are essentially the same as the specifications now found in the Manual for untreated timber, except we have omitted all sap restrictions, believing it to be desirable for timbers to be creosoted that as large a ring of sapwood around the heart as can be furnished.

We present this specification as information, with the request that it be carefully considered and criticised by the members during the coming year.

The President:—My understanding is if there are no criticisms offered during the year you will come next year with a recommendation that this be included in the Manual?

Dr. von Schrenk:—Yes, sir.

The President:—This report will be received as information. Those who wish to criticise it will do so later. There is no further report from this Committee, except their recommendations regarding the work for next year, and this will be referred to the Committee on Outline of Work.

Mr. C. E. Lindsay (New York Central):—Do I understand that you have adopted the proposed specifications shown on page 412?

The President:—No; they are submitted as information. You will have an opportunity during the year to criticise them. If you do not criticise them during the year, the specifications will be presented probably in this same shape next year for adoption.

The Committee is excused with the thanks of the Association.

DISCUSSION ON RECORDS AND ACCOUNTS.

(For Report, see pp. 415-419.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON RECORDS AND ACCOUNTS.

W. A. CHRISTIAN.

Mr. W. A. Christian (Interstate Commerce Commission):—Under the heading of Revision of the Manual, your Committee makes no recommendations other than those made last year.

As to the conventional signs, your Committee hesitates to recommend any changes, but have submitted a few tentative symbols for discussion. These are shown on page 416.

Your Committee offers this matter as information and requests your criticisms. If the symbols shown are not satisfactory, the Committee would appreciate suggestions for substitutes.

The President:—If the members have any criticisms to offer on these symbols they should do it promptly, while it is fresh in their minds, giving the Committee the benefit of any suggestions they wish to make.

This is all the Committee has to report, and it will be excused with the thanks of the Association.

DISCUSSION ON WOOD PRESERVATION.

(For Report, see pp. 447-482.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON WOOD PRESERVATION.

EARL STIMSON.	DR. HERMANN VON SCHRENK.

The President:—The next business will be the report of the Committee on Wood Preservation. The report will be presented by Mr. Earl Stimson, Chairman.

Mr. Earl Stimson (Baltimore & Ohio):—Your Committee beg leave to submit reports on three of the subjects assigned by the Board of Direction, the first being water sampling in creosote oil. Dr. von Schrenk, to whom we are largely indebted for this contribution, will present that portion of the report.

Dr. Hermann von Schrenk (Consulting Timber Engineer):—Our report on water sampling can be briefly summarized by the statement that one of the great difficulties that has been found in the creosote industry has been the lack of definite methods of sampling tank cars. Two years ago a special committee was appointed by the American Society for Testing Materials, at the request of many tank-car shippers. That Committee has considered the subject for two years, and has brought in a report which says practically that there is no way of sampling tank cars. Our Committee was of the opinion that possibly all methods for doing this had not been exhausted, and we made an arrangement with some of the manufacturers to load tank cars and actually put water into them. We followed the tank cars under the worst possible conditions of temperature and climatic conditions from the point of manufacture to the railroad plant. In our present report we summarize the preliminary results obtained from this first test.

We offer a table or graphic method for evaluating samples from a tank car, and give the results of analyses of a number of samples. It is the hope of the Committee that by next year these experiments will have been conducted on a larger scale, at probably a half-dozen points, with different materials, and we will be able to give more definite information on the subject. The reason for our presenting this data at this time is that the various companies may try out this data and give us the benefit of any result they see. We believe we are on the right track in solving a rather vexing problem.

Mr. Stimson:—The second subject assigned is on the relation of the amount of preservative and the depth of penetration to the resistance of materials against decay. We have made a progress report on this subject. The subject will be continued next year and we then hope to offer definite conclusions.

The President:—The report will be received as information, and the Committee will be excused, with the thanks of the Association.

DISCUSSION ON RAIL.

(For Report, see pp. 483-600.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON RAIL.

J. A. Atwood.
A. S. Baldwin.
G. J. Ray.
John G. Sullivan.
M. H. Wickhorst.

The President:—We will now take up the report of the Committee on Rail, and it will be presented by Mr. J. A. Atwood, the Chairman of the Committee.

Mr. J. A. Atwood (Pittsburgh & Lake Erie):—In presenting the report of the Rail Committee, we wish to present our recommendations in a little different form from that in which they are printed on page 487. We offer the following amendment:

That the following specifications be received and held under consideration during the coming year with a view to final action next year:

(1) Specifications for Quenched Carbon and Quenched Alloy Steel Joint Bars, recommended above.

(2) Specifications for Medium Carbon Steel Track Bolts with Nuts, recommended above.

(3) Specifications for Quenched Carbon and Quenched Alloy Steel Track Bolts with Nuts, recommended above.

We wish to submit this report as a progress report.

Mr. Wickhorst will now make some statements with reference to the work of the Committee.

Mr. M. H. Wickhorst (Engineer Tests, Rail Committee):—The statistics of the rail failures for 1914 were issued in a recent Bulletin, and the compilation of the rail failures for 1915 is well under way. The general average for 1915 for the whole country, including both Bessemer and Open-hearth rails, is given in table herewith, showing the failures for 100 track miles from the date laid until October 31, 1915:

Year Rolled.	Year's Service.					
	0	1	2	3	4	5
1908						398.1
1909					224.1	277.8
1910				124.0	152.7	198.5
1911			77.0	104.4	133.4	
1912		28.9	32.1	49.3		
1913	2.0	12.5	25.8			
1914	1.2	8.2				
1915	0.9					

It will be noted that there has been a reduction in the number of failures with each successive year's rolling, and the detail statistics show this to be due partly to the gradual replacement of Bessemer rails by

Open-hearth rails, and partly to the improvement in the record of both Bessemer and Open-hearth rails.

Probably the question of most interest at the present time is the question of transverse fissures. Bulletin 184 contains a report of a Subcommittee giving the state of information on the subject of transverse fissures. I will say briefly that the report mentions types of fissures and gives a bibliography on the subject up to date. The literature on the subject of transverse fissures dates from the time of Mr. Howard's report on the Manchester wreck on the Lehigh Valley Railroad; it was in that report that the term "transverse fissure" was first used.

Some definite statements can be made. although the problem is far from being solved. These transverse fissures seem to occur practically indiscriminately in all rails of the ingot and with rails of perfectly good chemistry, so that we have reached the stage, I think, where these two questions can be eliminated from the problem.

The next subject for solution is the question whether the fissures are in any way due to the physical condition of the material. There is very little work which has been done on that, which is sufficiently definite, so that no conclusions whatever can be drawn, but this point has been shown up in the few results available, namely, that the ductility of the metal in the rail section is generally good in all parts of the section except in the interior of the head. However, these results were obtained from material that has been in service, and whether the material was originally that way or not, the work so far does not in any way show.

The question we are up against now for solution, at this stage of the game, is, What was the physical condition of the material in the interior of the head? If that is perfectly normal, why, then, the problem has been advanced a little further, and we must look for service conditions entirely as the cause of the trouble. If, on the other hand, that material is deficient in ductility, then we may look for the source of the trouble in that condition. After we have definitely settled that point, which may take quite a while to do, we will be ready to proceed more effectively toward a remedy.

Mr. A. S. Baldwin (Illinois Central):—I ask Mr. Wickhorst if he thinks the forms of report gotten out by the Rail Committee and now, I believe, pretty generally used, or else used in some modified form by the railroads, has had any influence on the percentage of breakages as reported; in other words, my general idea has been that the systematizing of the reports would probably show a greater number of failures than had been shown before, and if that is the case, and there has been still a gradual decrease in the percentage of failures, it is all the more in favor of the actual conditions.

Mr. Wickhorst:—Yes, that is the impression I have formed. It is also true that the reports are coming in much more complete than formerly, and in a much more satisfactory condition.

Mr. John G. Sullivan (Canadian Pacific):—There is one subject I would like some information on which is rather important. About ten years ago we began to use high carbon joint bars, and we had to punch them hot. Eight years ago we made specifications requiring these bars to be punched from the inside out, the object being to get a good bearing for the head of the bolt and nut. I note in paragraph (b), page 489, that all bolt holes shall be punched in one operation without bulging or distorting the section. In punching a bar hot that is an impossibility, and I was wondering if the Committee had any information as to what mills would punch the bars from the inside out. This year the mills have refused to comply with our specifications.

The President:—Is there any objection to punching from one side or the other as long as the specification is complied with?

Mr. Sullivan:—No, but that is an utter impossibility. You cannot drive a punch into hot metal without some flow of the metal. I think the Committee should study that question, and if they find it cannot be done, that they specify these bars be punched by a method which would give a good bearing for the nut and the head of the bolt.

Mr. Baldwin:—I will state that in the design of a new angle bar used by the Illinois Central Railroad, I felt the point raised by Mr. Sullivan was an important one, and so specified when the specifications were first put out. One company agreed to it without objection. Another company objected to it, although they had taken the contract, and said there was really nothing gained by it. I was skeptical at first about it, but they sent me a number of samples and we inspected the samples and measured them accurately and compared them with the bars punched from the inside, and we came to the conclusion the question was immaterial and we have not been insisting upon it. Some mills prefer to punch from one side and some from the other, and I do not believe there is any material difference.

Mr. Sullivan:—We found a difference, especially as the bars get heavier.

The President:—The Committee would like to have information of the experience of members on this point so that the matter may be given consideration during the year.

You have heard the amendments to the specifications presented by the Chairman of the Committee.

(The amendments were adopted.)

Mr. G. J. Ray (Delaware, Lackawanna & Western):—I would like, as a matter of information, to find out to what extent Mr. Wickhorst found the failures progressive in the rails of any particular year. We have found with the open-hearth rails rolled in 1908 to 1910, inclusive, that the failures have increased very rapidly as the rails aged in service. In 17,500 tons of rail rolled at one mill during 1910 there were no failures at all the first year the rail was in the track. During the second year the rail was in service there were 19 failures in the 17,500 tons. During the third year about 40. The fourth year about 80, and the fifth year 169 failed. In other words, they nearly doubled each year. The rail in question was a 20 per cent. discard rail, and the "A" rails were all laid separately on slow track. In other words, all rails below the "A" rails were in reality 40 per cent. discard rail. We have had more transverse fissures with the B, C, and D rails than with the A rails.

The President:—Of all mills?

Mr. Ray:—Yes, generally speaking, although in the case of some mills we have more failures than others, and the rail rolled at the same time at other mills show no transverse fissures. I mention this to learn if Mr. Wickhorst found that progressive failure in the rail.

The President:—How many years does this cover?

Mr. Ray:—Five years. The same thing was true with our 1908 and 1909 rail, all of which has now been taken out of service.

The President:—If there are no further suggestions you have to make to this Committee, it will be excused with the thanks of the Association.

DISCUSSION ON ECONOMICS OF RAILWAY LOCATION.

(For Report, see pp. 603, 604.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON ECONOMICS OF RAILWAY LOCATION.

JOHN G. SULLIVAN.

The President:—The next business is the report of the Committee on Economics of Railway Location. The report will be presented by Mr. John G. Sullivan, the Chairman of the Committee.

Mr. John G. Sullivan (Canadian Pacific):—The Committee must apologize for not doing much work this year. There was considerabble work done last year. At a meeting held yesterday it was decided to ask the Association to bear with the Committee and reassign the subjects that were assigned last year and we will promise to do better.

The President:—I like to hear from a Committee that has the courage to ask for more time, once in a while. Are there any suggestions you have to make to this Committee? If there is no discussion and no suggestions, the Committee is excused.

PART 2

MONOGRAPHS

Written for

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

NINTH SESSION

which was to have been held in

BERLIN, 1915.

SECTION 1.—WAY AND WORKS.

QUESTION III.

SPECIAL STEELS.

USE OF SPECIAL STEELS, BOTH FOR THE TRACK GENERALLY, AND IN PARTICULAR FOR THE TRACK APPLIANCES (POINTS, CROSSINGS, ETC.)

Reporter:

America.—Mr. W. C. Cushing, Chief Engineer Maintenance of Way, Pennsylvania Lines.

PREFACE.

The writer of this report received a letter dated May 29, 1912, from Mr. L. Weissenbruch, Secrétaire Général of the Permanent Commission of the International Association of the Railway Congress, informing him of his selection as "reporter" for America on the subject of "Special Steels" (Question III) for presentation to the Congress, which was to be held in Berlin in 1915.

The initiative being taken by Herr Béla Vész, a list of queries was prepared by the reporters for all countries on the same question (Question III), in coöperation, and issued by the General Secretary to the railway members of the Congress Association.

The roster of reporters on Question III was as follows:

(1) Countries belonging to the "Verein Deutscher Eisenbahn-Verwaltungen."—Herr Béla Vész, Inspektor der kön.-ungarischen Staatsbahnen, of Budapest, Hungary.

(2) France.—M. Mesnager, ingénieur en chef des ponts et chaussées, professeur et directeur du laboratoire d'essais de l'école des ponts et chaussées, et répétiteur à l'école polytechnique, of Paris, France.

(3) America.—Mr. W. C. Cushing, Chief Engineer of Maintenance of Way, Pennsylvania Lines, of Pittsburgh, Pa.

(4) Other countries.—M. Sand, vice-président de la direction générale des Chemins de fer fédéraux suisses, of Berne, Switzerland.

From the information given in the answers to the queries in the circular, and from additional correspondence, the writer's report was prepared and forwarded to the General Secretary at Brussels, Belgium, March 30, 1914, and its receipt at its destination was acknowledged by him.

None of the reports has been published in the Bulletin of the Congress, but that of M. Sand had been set up in type, and a proof copy sent to the reporters.

The writer has been informed by a member of the Permanent Commission that the organization of the General Secretary in Brussels has been broken up by the great war now being waged in Europe, and that consequently it will be quite proper to publish the report in the Bulletin of the American Railway Engineering Association.

The report is a compilation of results obtained from practices and tests of American railways, and, in addition, describes some practices rather minutely in order to clear up some misapprehensions on the part of foreign Engineers.

W. C. Cushing.

Pittsburgh, Pa., January 8, 1915.

REPORT

By W. C. Cushing,

Chief Engineer Maintenance of Way, Pennsylvania Lines.

REVISIONARY.

When Mr. Cartault, one of the distinguished Reporters on Question III, "Points and Crossings," at the Sixth Session of the International Railway Congress, at Paris, in the year 1900, submitted the subjoined "conclusion" which was adopted by the Congress, spring frogs were at the high tide of their successful use by the railways of the United States:

> "Spring crossings or other appliances which do away with the gap at the frog are not used by the European railways to whom we have applied for information. Such crossings are used in the United States, but the data available are not sufficient to enable us either to criticize or recommend them. Interesting investigations could be made on the subject, and there is no doubt that it would be a considerable step in advance if such a crossing were worked out, which was solid and strong, and satisfied all the requirements of modern traffic."

As a matter of fact, such frogs, which were "solid and strong," had been worked out for the railways of the United States, and had been in use by the most important administrations for many years, that is, from the period between 1870 to 1880, although several patents date back to 1858.* Some types of them were illustrated by Mr. Cartault in his report.† They have given in the past excellent satisfaction, and for many locations their use is yet very desirable, for they close the gap of the frog at turnouts and crossovers (see Figs. 1 and 2, illustrating the track terms used in the United States and Canada), thus making the main track rail practically continuous through the frog, with the resultant good effects of smooth riding, and diminished wear and tear to the rolling stock and the track. When passing through the turnout, there is the usual gap, but this movement is less frequent and at slower speed than on the main track. For use in freight assembling yards, the "double or twin spring frog," or "sliding spring frog," with both wing rails movable, thus closing the gap on either side, according to the route of the wheel, has been devised, and is extensively used with great economy and satisfaction. One type was illustrated by Mr. C. W. Buchholz, Reporter on Question III, "Improved Rail Crossings," at the Seventh Session at Washington, in 1905.‡

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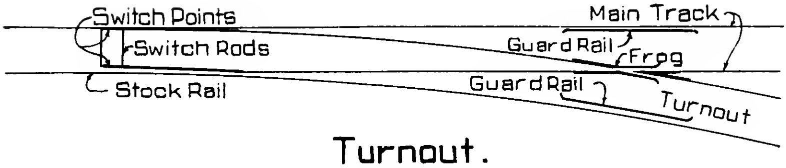
*International Ry. Cong. Proceed. Seventh Session, 1905, Vol. 1, p. 14, Question III.

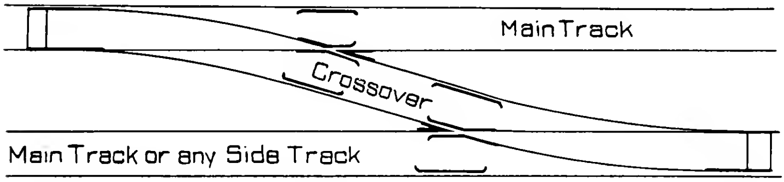
†International Ry. Cong. Proceed. Sixth Session, 1900, Vol 1.

‡International Ry. Cong. Proceed. Seventh Session, 1905, Vol. 1.

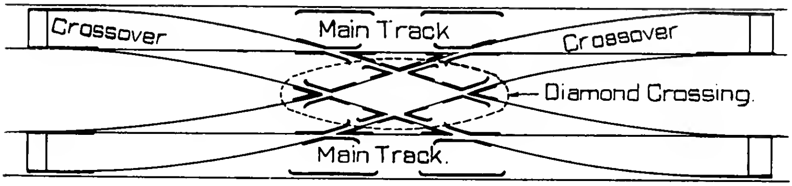
DIAGRAMS ILLUSTRATING
TRACK TERMS
IN USE IN
THE UNITED STATES AND CANADA.



Turnout.



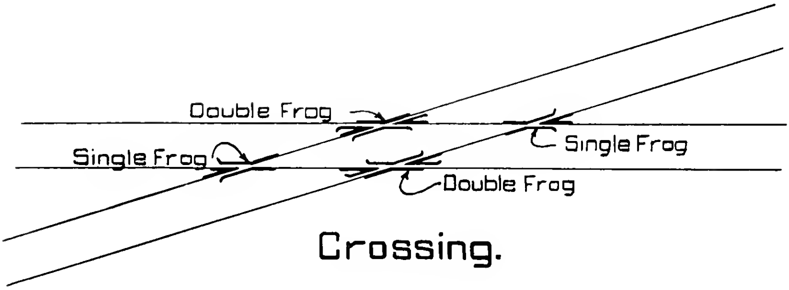
Crossover.



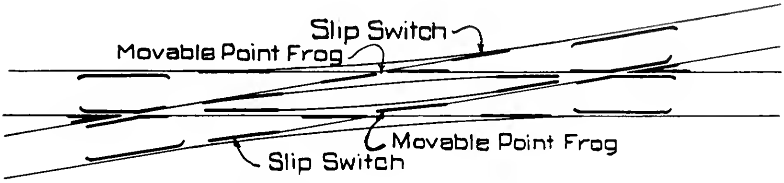
Double Crossover.

Fig. 1.

DIAGRAMS ILLUSTRATING
TRACK TERMS
IN USE IN
THE UNITED STATES AND CANADA.



Crossing.



Double Slip Crossing.

Fig. 2.

At that session, at Mr. Buchholz's suggestion, a resolution was adopted by the Congress that the spring frog could be used with perfect safety on all main lines carrying heavy traffic with axle loadings on the locomotive of over 50,000 lbs., and with loads on the rolling stock as high as 40,000 lbs. per axle.

Thus, the value of the spring frog was finally recognized by the Congress, but nevertheless its use does not seem to have been extended to European countries, possibly because of its limitations. It cannot, of course, be used for crossings where the service required under a heavy train at high speed is most severe, and it was not advisable to use it at turnouts and crossovers where the switch points were moved or operated by an interlocking machine in a tower or cabin, because the train speed was apt to be too great.

In consequence, therefore, of the increasing weights of rolling stock, and the rapidly expanding use of interlocking plants for controlling switch-point movements since about 1890, on account of the growing density of traffic and the necessity for greater safety, as indicated by Table I, attention had to be turned towards the invention of new appliances or material for the places where the spring frogs could not be used. Crossing frogs with sliding wedges, and turnout frogs with movable points, to close the gap during the passage of wheels have been invented and tried to a limited extent, but have not yet come into general use. The most attention has, therefore, been given to the improvement of the material used in frogs, and as such improvement is equally necessary for rails, its suitability for both uses has been considered at the same time. This has led to the trials of "special steels" and "special process steels" for the solution of the difficulty, and it was the desire of the Congress Association to learn of the progress made in this study by the different railway administrations which caused the Permanent Commission to assign the subject of "Special Steels" to your reporters.

In making up Table I, three of the Eastern railways which have a very heavy and dense traffic have been selected, in order to show the magnitude of the business and its enormous increase. It is always on such lines that the necessity for changes and improvements in appliances first becomes apparent. The Table also shows the maximum axle-loads of freight and passenger locomotives for each five-year period since 1890 (when known), and the locomotives in use in 1890 and at the present time are illustrated in Figs. 3 to 12, in order to give a graphical representation of the great advances made, thus making it still clearer why better and stronger appliances have become necessary. The 1912 passenger locomotive of the Pennsylvania Railroad is not in general use, but several are now in service, and it is the intention to continue their construction.

The usual plan of sending a list of questions to the several railway administrations has been followed, and this list is reproduced in Appendix A.

The names of the companies to which the questions were sent by the General Secretary of the International Railway Congress Association are given in Appendix B. Those whose names are prefixed by the letter R have sent replies. Information was also requested by your Reporter from some of the frog and switch manufacturers, listed in Appendix C, and their responses have been generous.

In neither case did a tabulation of the answers seem to be the best plan to follow in presenting the data, but the information has been made use of in the following discussion and liberal quotations made. The experience had by the different railway administrations has been reported chiefly by the United States, as very little information was obtained from the Central and South American countries, and only two railways in Canada were requested to furnish answers, the Grand Trunk and the Quebec Central.

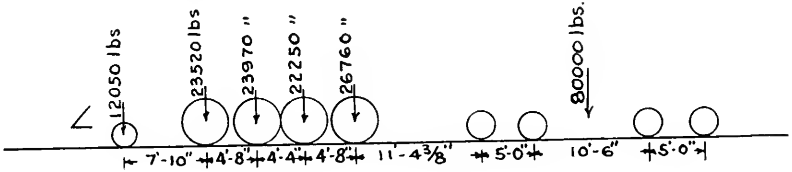
TABLE I.

DENSITY OF TRAFFIC ON DIFFERENT RAILROADS.

Year	Frt. Ton--Miles	Increase	Per Cent.	Passengr.-Miles	Increase	Per Cent.	Max.Axle-Loads of Locomotives in Pounds	
							Freight	Passenger
Pennsylvania Railroad (Parent company only).								
1890	6,994,332,633			778,818,917			26,760	32,800
1895	8,151,343,461	1,058,010,828	15.1	712,072,950	-66,745,967	-8.5	31,300	39,050
1900	11,922,671,210	3,770,327,749	46.3	918,198,602	206,125,652	28.9	40,100	48,175
1905	16,885,485,241	4,962,814,031	41.7	1,305,299,112	387,100,510	42.1	49,162	61,600
1910	20,279,992,323	3,394,507,082	20.1	1,693,943,849	388,644,737	29.8	52,700	61,600
1912	22,012,606,174	1,732,613,852	8.6	1,838,352,119	144,408,270	8.5	59,725	67,550
Increase over 1890		15,018,273,542	214.7		1,059,533,202	136.0		
New York Central & Hudson River Railroad (Parent company only).								
1890	2,973,598,069			557,727,282			35,000	32,000
1895	3,329,206,079	355,608,010	11.9	686,589,144	128,861,862	23.1		
1900	6,117,572,625	2,788,366,546	83.8	848,704,035	162,114,891	22.1		
1905	8,421,437,108	2,303,864,483	37.7	1,463,889,939	615,185,904	72.1		
1910	9,276,710,584	855,273,476	11.0	1,770,667,550	306,777,611	20.9		
1912	9,668,031,269	391,320,685	4.2	1,808,739,999	30,072,449	1.7	56,000	60,000
Increase over 1890		6,694,433,200	225.1		1,251,012,717	224.3		
Philadelphia & Reading Railway, including Coal Traffic.								
1890	1,567,967,901			207,820,387			32,000	44,740
1895	1,779,498,764	211,530,863	13.5	233,236,661	25,416,274	12.2		
1900	2,648,336,764	868,838,000	48.8	275,418,845	42,182,184	18.8		
1905	3,741,297,240	1,092,960,476	41.3	361,675,888	86,257,043	31.3		
1910	4,606,584,190	865,286,950	23.1	411,109,327	49,433,439	13.7		
1912	4,792,741,386	186,157,196	4.0	398,657,408	-12,451,919	-3.2	65,425	64,075
Increase over 1890		3,224,773,485	205.6		190,837,021	91.8		

NOTES:- A freight ton mile is one ton of freight hauled one mile.
A passenger mile is one passenger carried one mile.

Fig. 3. Pennsylvania Lines West of Pittsburgh. Freight Locomotive. Class H-2. Type of the Year 1892. Boiler Pressure, 140 Lbs. Tractive Power, 22,870 Lbs. Total Weight, Including Tender, 188,550 Lbs.



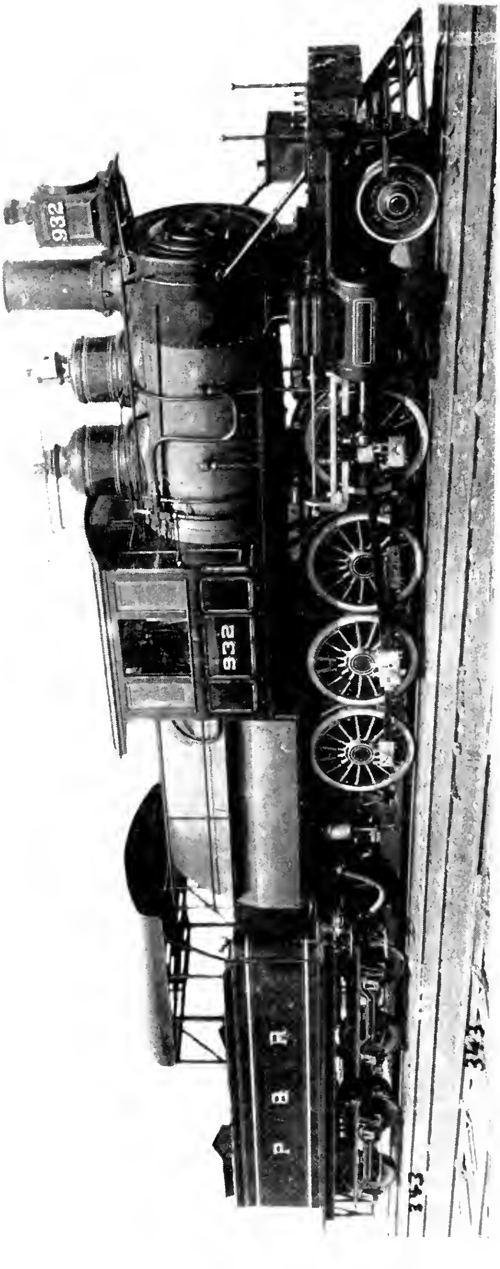


Fig. 4. Philadelphia & Reading Railway. Freight Locomotive. Type of 1890. Class 12-A. Boiler Pressure, 145 Lbs. Tractive Power, 23,670 Lbs. Weight, Exclusive of Tender, 129,025 Lbs.

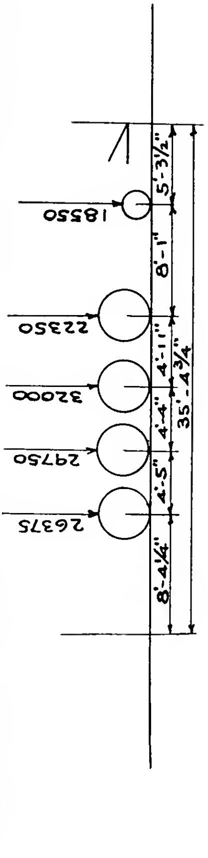


FIG. 5. PENNSYLVANIA LINES WEST OF PITTSBURGH. PASSENGER LOCOMOTIVE. CLASS D-10. TYPE OF THE YEAR 1892. BOILER PRESSURE, 160 LBS. TRACTIVE POWER, 17,060 LBS. TOTAL WEIGHT, INCLUDING TENDER, 183,000 LBS.

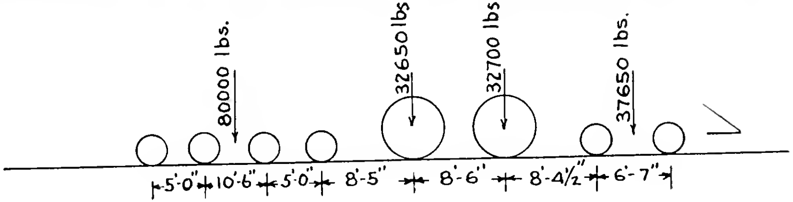
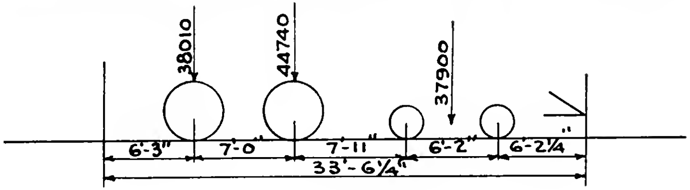


Fig. 6. Philadelphia & Reading Railway. Passenger Locomotive. Type of 1890. Class D-5-c. Boiler Pressure, 160 Lbs. Tractive Power, 19,262 Lbs. Weight, Exclusive of Tender, 120,650 Lbs.



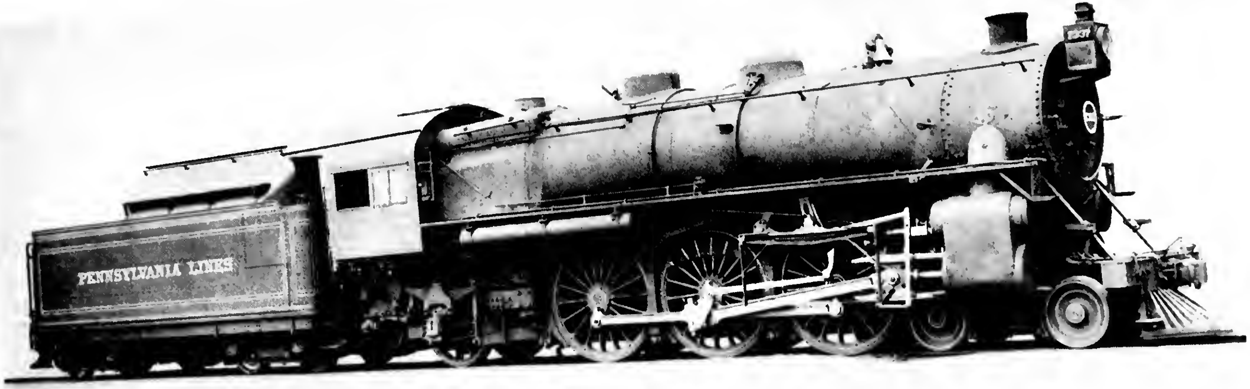
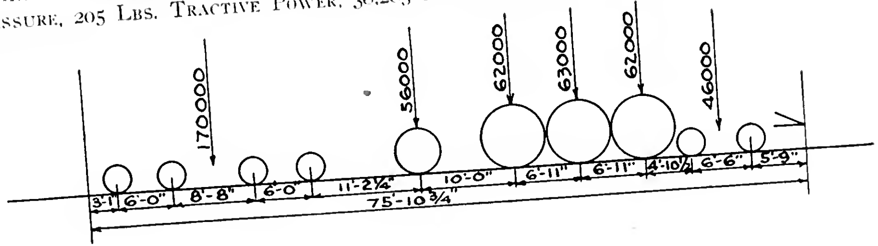


FIG. 7. PENNSYLVANIA LINES WEST OF PITTSBURGH. PASSENGER LOCOMOTIVE. TYPE OF 1912. CLASS K-3-S. BOILER PRESSURE, 205 LBS. TRACTIVE POWER, 38,283 LBS. WEIGHT, INCLUDING TENDER, 459,000 LBS.



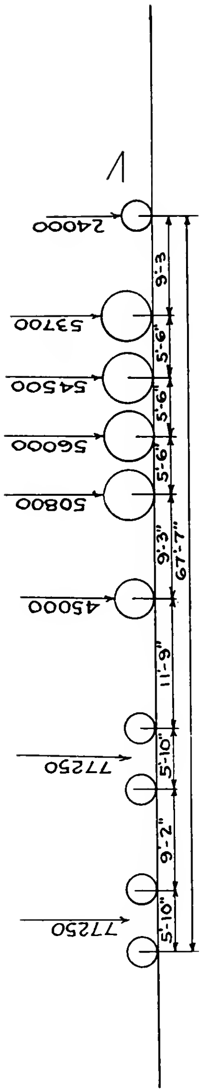
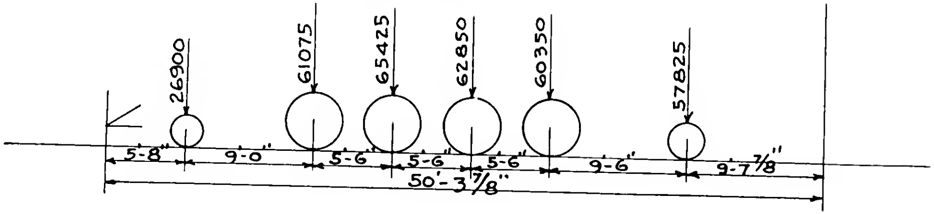


Fig. 8. New York Central Lines. Freight Locomotive. Type of 1913. Class H-5-H. Total Weight, 438,500 Lbs.

Fig. 9. Philadelphia & Reading Railway. Freight Locomotive. Type of 1912. Class M-1. Boiler Pressure, 225 Lbs. Weight, Exclusive of Tender, 334,425 Lbs. Tractive Power, 57,318 Lbs.



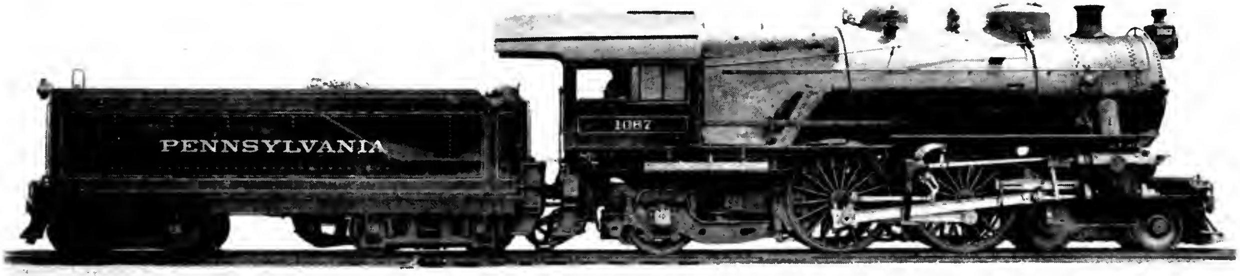
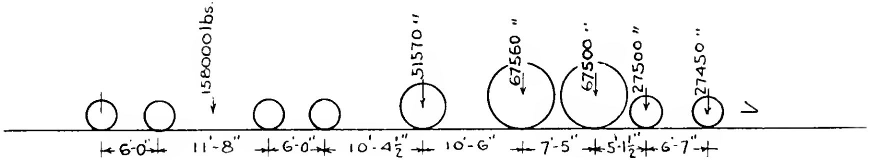


FIG. 10. PENNSYLVANIA RAILROAD. PASSENGER LOCOMOTIVE. CLASS E-6-S; ATLANTIC TYPE OF THE YEAR 1912. BOILER PRESSURE, 205 LBS. TRACTIVE POWER, 29,427 LBS. TOTAL WEIGHT, INCLUDING TENDER, 399,580 LBS.



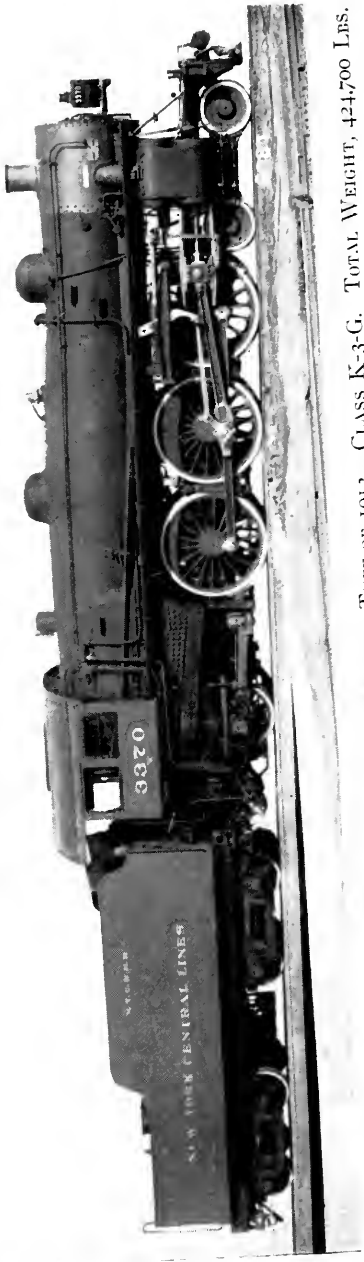


FIG. 11. NEW YORK CENTRAL LINES. PASSENGER LOCOMOTIVE. TYPE OF 1913. CLASS K-3-G. TOTAL WEIGHT, 424,700 LBS.

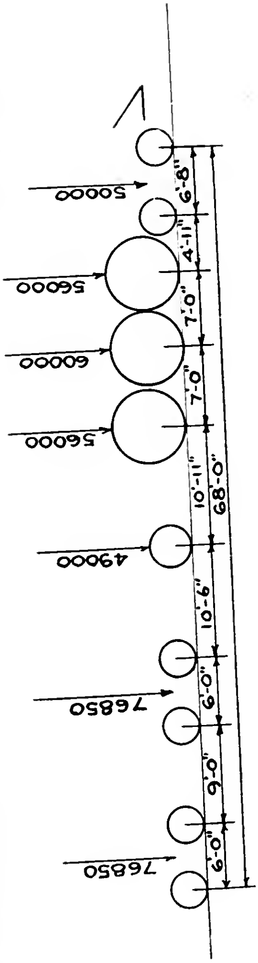
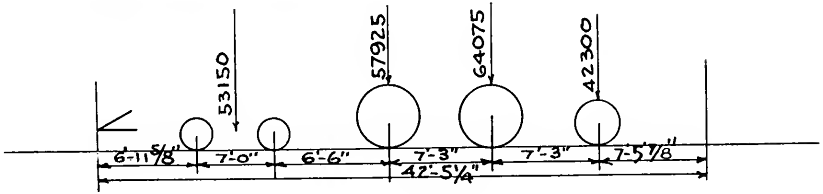


Fig. 12. Philadelphia & Reading Railway. Passenger Locomotive. Type of 1912. Class P-6-b. Boiler Pressure, 240 Lbs. Weight, Exclusive of Tender, 217,450 Lbs. Tractive Power, 32,089 Lbs.



KINDS OF SPECIAL STEELS.

The different kinds of special steels in use, or undergoing trial, may be divided under two heads:

A. *Special Alloy Steels.*
B. *Special Process Steels.*

A. Special Alloy Steels.—Under the first head are included Manganese, Nickel, Nickel-Chromium, High Carbon (that is, steel containing 0.75 per cent. of carbon or over), and High Silicon. Two or more of these have been combined, in some instances, as, for instance, high carbon with nickel and chromium. Silicon is present in all carbon steel rails.

B. Special Process Steels.—By this term is meant the steel products derived from special heat treatment, or by the addition of metalloids which do not appear in the test analyses of the resulting product. Such are the so-called Titanium-treated, Aluminum, Electric Process and Heat-treated steels.

The object of their use (Appendix A, Question 2-a) has been in all cases to bring about additional safety, economy in maintenance by reducing the number of renewals, and smoother passage for trains at high speeds, over the gaps of frogs, and at drawbridges.

It has been otherwise expressed in the following words by Dr. P. H. Dudley, Consulting Engineer of the New York Central Lines:

"1. To obtain metal of sufficient physical properties to sustain the increased wheel-load pressure intensities in the bearing surface of the head incident to the lessened deflection of the stiffer 75 lbs., 80 lbs. and 100 lbs. per yard rails, and reduced length of the area of the contact of the wheels on the rail heads.

"2. To obtain metal of high resistance to flange abrasion of the wheels upon curves.

"3. To obtain metal of a large *duration time factor* in the sections as girders to distribute the strains of the passing wheels without detail or sudden fracture in low temperatures."

Some of the special steels have been used, or are in use, for frogs of all kinds, switch-points, guard rails, drawbridge locks and rails, while others have found their field of usefulness principally for rails and bridge steel superstructures. (Appendix A, Question 3-a.)

A. SPECIAL ALLOY STEELS.

I. MANGANESE STEEL.

(a) Manganese Steel for Frogs, Switch-points, Guard-rails, Etc.

INTRODUCTORY.

At the Seventh Session of the Congress in Washington in 1905, at which the spring frog received its real recognition, the manganese frog was introduced to the session by Mr. Buchholz in the following words:*

> "Coming to that point, one of the reasons why the 'Fixed Frog' has become so much in disrepute is its rapid wear under the blows from heavy trains passing over the gap. Recent inventions introducing the 'Manganese Steel Frog' do avoid this rapid wear, and since everybody admits that in a long frog, when new, the shock of passing over it is hardly perceptible, this new material preventing wear has come to be considered a valuable substitute for the spring rail frog at all points of junctions where rapid movement from one track to another is necessary."

At that session many will doubtless remember the Manganese frogs which were exhibited at the National Railway Appliance Association's very complete display of all kinds of track material.

Since that time the use of Manganese for frogs and switch-points has grown very fast, and it was made the subject of his recommended conclusion by Mr. W. G. Besler, Reporter for America on Question III, "Junctions and Swing-Bridges," at the Eighth Session of the Congress, at Berne, in 1910, in the following words:

> "That at junctions and crossings, traversed at high speed, rigid frogs of 'Manganese' or other hard steel be used."

This conclusion was rejected by the section, but it was decided at the general meeting that "it is of great interest to place the questions of the material and of the construction of such crossings on the agenda for the next session of the Congress."

Frogs:

The special steel which is now most extensively used in the United States and Canada for frogs, crossings and switch-points, outside of those built up from the usual Bessemer and Open-Hearth steel rails, is Manganese. It is also being used experimentally in some South American countries, especially those where the railroads are under English management.

In the United States and Canada, it is no longer the practice for railway administrations to manufacture their own track material, although,

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*Proceedings International Ry. Cong. Assoc. Seventh Sess., 1905, Vol. 1, p. 5, Question III.

in former years, it was often the general custom of many companies. Now the manufacture of frogs, crossings and switch-points is almost entirely in the hands of manufacturers not connected with the railway companies. In some cases the railway company has a financial interest in one or more companies which manufacture frogs and switch-points for the general trade, and a few railway companies still make their own.

The reporter, therefore, has obtained a great deal of the detailed information herein given from those companies, and acknowledges his indebtedness to their kindness.

Nearly all of the frog and switch manufacturers are operating under the patents of Sir Robert A. Hadfield of Sheffield, England, or of Edgar Allen & Co., Ltd., Imperial Steel Works, Sheffield, England, represented in the United States by Edgar Allen American Manganese Steel Company.

The Hadfield patents are the earliest in use, and, as they were exclusively controlled in the United States by The Taylor-Wharton Iron & Steel Company and Wm. Wharton, Jr., & Co., Incorporated, affiliated companies, we must look to them for the early history of its development. The statement following is largely in the words of Mr. V. Angerer, Vice-President and General Manager of the latter:

"In 1892, the first heat of Manganese steel in the United States was run off by The Taylor-Wharton Iron & Steel Co. (present name), of High Bridge, N. J., as the sole licensees under the patents of R. A. Hadfield, the discoverer of Manganese steel and its peculiar properties. The castings made were for special purposes other than track work.

"In the latter part of 1893, Wm. Wharton, Jr., & Co., Inc., had its attention called to Manganese steel as manufactured by the Taylor Company, by Dr. H. M. Howe of Boston, and on August 28, 1894, a frog with a cast Manganese steel plate set in the center was installed at Fulton Street and Boerum Place, in the city of Brooklyn, which was then known as the worst place for rapid wear of track material under street railway electric cars, and is the first authentic use of Manganese steel in track work. The expectations for the superiority of this metal were more than fulfilled, and its use for street railway work rapidly extended.

"In 1899, Mr. H. B. Nichols, Engineer of the Union Traction Company of Philadelphia, designed a crossing for street railways over steam railroad tracks at grade with a solid cast Manganese steel rail of a heavy box section for the steam railroad track, but the doubts of the steam railroad engineers, on the score of safety, about the use of a 'casting' in their tracks under the traffic of heavy locomotives, had to be overcome. Not until after a committee of Engineers of the Pennsylvania Railroad and the Philadelphia & Reading Railway had witnessed a series of extremely severe tests was the permission obtained, and this installation constitutes the first instance of the use of Manganese steel in steam railroad tracks, but in a city street where the movement was slow.

"Almost simultaneously, however, through previous negotiations with the Engineers of the Pennsylvania Railroad, a solid cast Manganese steel frog was installed in the terminal tracks at the Broad Street Station, Philadelphia, on March 11, 1900, but it was located where the traffic was not severe, and was subsequently moved to a place where an ordinary Bessemer frog lasted less than three months. The record of service is given in Fig. 13. It was not until two years later that the performance of this frog, and some others which had been installed on other railroads, attracted sufficient interest for their more extensive introduction. The rail-bound, or built up, frog had in the meantime been designed to overcome in part the misgivings against the use of castings in steam railway tracks, and in part the short length of solid cast frogs, and in the years 1902 and 1903 the Pennsylvania Railroad installed nearly 3,000 of the rail-bound frogs and crossings, other railroads at the same time purchasing freely."

Fourteen of the Manganese frogs purchased in 1901 were still in use in the main tracks in 1912. At Moore, on the Maryland Division, are ten Manganese frogs, laid in 1903, which were still in use in 1912 and were estimated by the Track Foreman to have a life of eight more years.

"The first rail-bound Manganese steel crossing was furnished for the Pennsylvania Railroad at Dillerville, Pa., in June, 1902, where Bessemer frogs lasted about six months, and parts of it, and quite a number of frogs furnished in those years were still in use in 1913.

"The first Manganese steel-pointed switch, with long point, was furnished to the Interborough Rapid Transit Company of New York City, in July, 1905.

"The first movable point crossing with Manganese steel knuckle rails was furnished to the Philadelphia & Reading Railway in August, 1905.

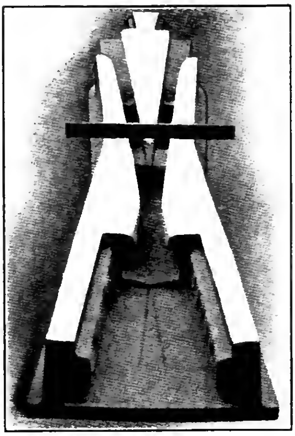
"The first movable-point crossing with Manganese steel knuckle rails and Manganese steel points was furnished to the Pennsylvania Lines West of Pittsburgh, Southwest System, in October, 1905."

Along about 1904, the first patent of Hadfield, simply covering an alloy with percentage of Manganese stated, expired, and anyone can now make the alloy, but if not properly heat-treated it loses its value for the purpose desired. Manganese steel frogs, switch-points and crossings are therefore now made by many other frog and switch companies, but only a few up to the present time have made their own castings. The greater number have purchased their castings from the Edgar Allen American Manganese Steel Co. of Chicago, Ill.

In the year 1913, the Manganese steel foundries of this country had a capacity of about 60,000 tons annually, and the most of the development had been within the past eight years.

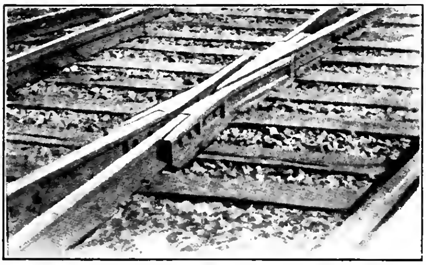
The prime characteristics of Manganese steel are of very great strength, toughness and resistance to abrasive forces, and these qualities

Manganese Steel No. 8 frog, 85-lb. rail. Put in track March 11, 1900. Removed from track April 27, 1904. *In service 4 years, 47 days.* Maximum life *of ordinary frog* in same place, *three months.* Photograph taken April 27, 1904.



Frog again removed from track September 2, 1906, after a period of *2 years, 64 days,* making *total service 6 years, 111 days,* or over *twenty-five times* as long as the Bessemer Steel Frog under same conditions. Wear of frog at point only amounts to 7-16 of an inch. Photograph taken November 5, 1906.

Amount of wear at point 5-16 of an inch when removed from track after having *outlasted nearly seventeen* ordinary Bessemer Steel Rail Frogs. Photograph taken April 27, 1904.



Same frog restored to perfect surface and condition, practically as good as new. Again put in service in same place June 30, 1914. Photograph taken October 22, 1904.

FIG. 13.

RECORD OF WEAR OF THE FIRST MANGANESE STEEL FROG ON THE PENNSYLVANIA RAILROAD.

are imparted by the increase of the Manganese and carbon contents in carbon steel to certain proportions, which were first made known to the scientific world by the Hadfields. The Manganese must lie between the limits of 8 per cent. and 35 per cent. If between 7½ and 5½ per cent. the alloys are extremely weak and brittle.* "The upper limit is partially determined by the cost of Manganese metal, which is 50 cents per ton unit, when the addition is made by means of ferro-manganese. Also the high carbon content of ferro-manganese interferes with the physical properties induced by the Manganese. When enough ferro- is added to make a steel with Manganese 20 per cent., the carbon begins once more to dominate and a steel results which is stiff and brittle when cold, and unworkable when hot."

Ferro-manganese is a compound containing about 80 per cent. of the element Manganese, and is mined chiefly in Russia. It is imported into the United States from (in order of rank in 1906) India, Brazil, Russia, Cuba, Germany, Japan, Belgium, United Kingdom and Canada. The proper chemical composition, therefore, compared with Bessemer and Open-Hearth rail steels, in order to impart the required characteristics, has been determined to be, in percentages, within the following limits:

TABLE II.

Kind of Steel	Manganese	Carbon	Phosphorus	Silicon	Sulphur
Manganese Steel......	11-13	1.0 -1.20	0.06-0.11	0.25-0.40	0.02-0.06
Bessemer Steel.......	0.80-1.10	0.45-0.55	Not to exceed 0.10	Not to exceed 0.20	
Open-Hearth Steel....	0.60-0.90	0.62-0.75	Not to exceed 0.04	Not to exceed 0.20	

The following limits are used by different manufacturers and railway companies:

TABLE III.

Manufacturer	Manganese	Carbon	Phosphorus	Silicon	Sulphur
Wm. Wharton, Jr., & Co....	10-13	1.00-1.40	Below 0.1	0.20-0.50	Below 0.03
Edgar Allen Am. Mang. Steel Company.........	11-13½				
Pennsylvania Steel Co......	12½	1.25			
St. Louis Steel Foundry Co.	12				
Frog, Switch & Mfg. Co....	12½	1.25	About 0.08	0.30	Below 0.02
New York Central Lines....	10.50-14.50	0.95-1.30	0.065		Not to exceed 0.05

---

*Journal Western Society of Engineers, Vol. 14-1909. W. S. Potter, page 212.

The physical characteristics, compared with Bessemer and Open-Hearth rail steel, are about as follows, although it is extremely difficult to obtain specimens which are truly representative of the steel, as it cannot be cut or machined:

TABLE IV.

Kind of Steel	Tensile Strength in pounds per square inch	Elastic Limit in pounds per square inch	Elongation, per cent in 2 inches	Reduction of area, percentage	Hardness by	
					Brinell	Scleroscope
Manganese Steel..	75000-102000	40000-58000	8-27	15-29	230	40-50
Bessemer Steel...	89000-126000	44000-62000	5-25	5-43	172-230	29-35
Open-Hearth Steel	115000 156000	54000-80000	9-16	10-30	230-300	32-43
Chilled Cast Iron						65-75

The above results are for cast Manganese steel. The figures for rolled and for forged Manganese steel are higher, as shown by the following, given by W. S. Potter, the originator in the United States of rolled Manganese steel for rails, in the "Journal of the Western Society of Engineers," Vol. 14, 1909:

TABLE V.

Kind of Metal	Tensile Strength in pounds per sq. in.	Elastic Limit in pounds per sq. in.	Elongation per cent in 2 inches
Cast metal...........................	82,000	45,000	30
Rolled metal.........................	135,000	60,000	35
Forged metal.........................	142,000	55,000	38

Somewhat higher results for the cast metal are given by the Central Railroad Company of New Jersey, as follows:

Tensile strnegth in pounds per square inch, 82,400 to 143,400.

Elastic limit in pounds per square inch, 81,600 to 112,400.

Elongation, 10 per cent. in 2 in.; reduction of area 19.40 per cent.; deflection under a 12-ft. drop of a 2,000-lb. tup, ¼ per cent. to ½ per cent.

With the carbon low and the manganese high, and quenched in water at about 1,000 degrees C., the elastic limit is low and the flow excessive for many duties.

With the manganese at 11 per cent. and the carbon 1.10 per cent., the elastic limit is higher than when the manganese is 15 per cent. and the carbon 0.80 per cent.

The specific heat is 0.145 at ordinary temperatures to 0.20 at 1,200 degrees C.

The heat conductivity between ordinary temperatures and 600 degrees C. is about ⅓ that of low-carbon steel.

In the case of electric conductivity, the resistance of Manganese steel rails is 3.4 times the resistance of Bessemer rails. At temperatures between 100 degrees C. and about 600 degrees C., the electrical resistance remains nearly constant.

In order to impart the above physical qualities to Manganese steel, and especially the great resistance to abrasive forces, special heat treatment is necessary, and it is in this heat treatment in which one manufacturer claims superiority for his product over another. It is his trade secret and is jealously guarded.

Manganese steel melts at about 1,330 degrees C., or 190 degrees below dead soft carbon steel.

*"The molding and core-making require more care and a higher degree of skill in their preparation than for iron or steel castings, for Manganese castings being so extremely hard and tough cannot economically be altered in shape, once they are made.

"Nearly all molds must be dried in an oven before pouring and all castings must be heat-treated."

Sands with a high percentage of silica are used for the molds, and in the cleaning or fettling room there must be every conceivable type of grinding apparatus, as the castings have to be ground instead of machined.

The shrinkage is excessive, being $\frac{5}{16}$-in. per foot, as against $\frac{3}{16}$-in. to $\frac{1}{4}$-in. in ordinary practice, and it is therefore very severe on the metal. Consequently, after pouring, they must be heat-treated to neutralize the shrinkage strains, which is done by annealing or heating to 800 degrees C. to 1,000 degrees C., and then quenching in water.

Manganese steel is only moderately hard, as shown by the scleroscope and Brinell results given above, but it is very strong and tough, and it is this combination of strength and ductility which gives to it its most important merit in resisting abrasive wear. A cast bar $\frac{1}{2}$-in. by 1 in. will stand bending, without cracking, 180 degrees around a rod 1 in. in diameter.

Abrasion tests conducted in a laboratory crusher by Wm. Wharton, Jr., & Co. showed a superiority of manganese over 0.50 carbon steel of 10 to 1 in grammes worn from a crusher jaw per 1,000 lbs. of trap rock per sq. in. of surface crushed.

Having finally recognized these valuable qualities of Manganese steel for track work, the railway administrations found they were coupled with high cost, and therefore instituted tests or experiments to determine the matter of economy in its use. In many locations in the United States, these economics have been well established, and Manganese steel is in regular use, but there are also many other places where the first cost will overbalance the economies. In all places of extremely hard service, such frogs are economical, and even absolutely necessary under present conditions, in order to avoid renewals where the traffic is so frequent that it is difficult to find an opportunity for repair work. The more difficult the place, the more economical and indispensable is Manganese steel. The Cleveland, Cincinnati, Chicago & St. Louis Railway Company finds in general that where frogs, switches and crossings made of Bessemer or Open-Hearth rail require renewal within about 20 months, it is economical

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*Manganese Steel and Its Application in the Ceramic Industries, by G. W. Kneisly.

to use Manganese instead, and the Pennsylvania Lines place the time at 18 months. These are not scientific ways of expressing relative wear so as to be of general service to others, but are suitable only for those special cases for which the rule was determined. In answering the circular of the reporters, the experience of various railway administrations is thus given:

The Northern Pacific Railway states that Manganese frogs will outlast Open-Hearth steel frogs under the same conditions by 6 to 10 times, and the Norfolk & Western from 3 to 6 times. The Lehigh Valley Railroad reports that Manganese steel frogs will outlast frogs made of Bessemer steel by at least three times, the Bessemer & Lake Erie by from 3 to 15 times, and the Pennsylvania Railroad by 20 times, the cost being only three times as great.

This information is of service also only to those who know the conditions of service, for it is necessary to be made aware of the annual cost or saving in each case of the frogs of different kinds in order to compare them accurately. This information is difficult to obtain, but some results of trials will now be presented, the results being preceded by a table (Table VI), showing the relative cost of frogs and switch-points made of Manganese, Bessemer and Open-Hearth steels about the beginning of the year 1914:

This table gives the relative cost of two distinct types of Manganese frogs:

(1) The built-up, or rail-bound, frog, and
(2) The solid cast Manganese steel frog.

The first (1) consists of Manganese steel for the point and those parts of the wings which receive the wheel treads surrounded by pieces of Bessemer or Open-Hearth rail, and all bound firmly together with bolts, as illustrated in the plans and photographs, Figs. 15 to 20.

The second (2) is made of a solid Manganese casting without any bolts, except those necessary to join the four ends with the track rails by splice bars, illustrated in the plans and photographs, Figs. 21 to 25.

Terminal Railroad Association of St. Louis:

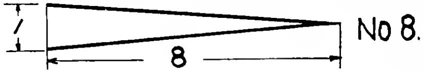
The first type (1) is the one most generally used by the railways, although for certain locations, where the speed of traffic is slow, the second type (2) is preferred, though of greater primary cost than the first, because it does away with the bolts. There is a certain feeling of mistrust (which may be removed later with experience) in its value for general use, because such great care is required in making the castings that defective material occasionally creeps in, and, should a fracture occur, there is sometimes nothing to hold the parts together. This has been remedied in some designs by riveting the frogs to a base plate. This distrust has been expressed in its answer by the Terminal Railroad Association of St. Louis, which is, as its name expresses, a large terminal for several railroads, consisting of many miles of track, traversed chiefly at moderate speed by a heavy traffic. Many frogs and crossings have been in use for

Table VI.

Cost of Frogs made of Manganese, Bessemer and Open Hearth Steels. Rail 100 pounds per yard; Section ARA-B*

Number of Frog	Manganese					Made of Bessemer Steel Rails		Made of Open Hearth Steel Rails.	
	Rail-bound or Built-up.			Solid Castings					
	Cost ‡	Total Weight of Frog +	Weight of + Manganese	Cost. ‡	Weight of Frog +	Cost. ‡	Total Weight of Frog +	Cost. ‡	Total Weight of Frog +
No. 8.	80-100	1800-1845	315-510	83-89	850-950	34-48	1500-1750	36-47	1500-1750
" 10	88-102	1900-2000	376-600	100	1110-1150	35-50	1540-1865	37-50	1540-1865
" 15	129-147	2400-2800	660-750	131-144	1500-1900	46-60	2000-2300	48-61	2000-2300
" 20	166-193	3100-3600	855-1110	163-220	1835-2500	57-73	2600-2800	60-76	2600-2800
Crossings at 60° Angle.	480 to 600	6265 to 8370	2430 to 2890	450 to 617	4100 to 4330	270 to 384	7630 to 8555	275 to 384	7630 to 8555

Frogs are numbered as in the following illustration.



Cost of Switch Points made of Manganese, Bessemer and Open Hearth Steels. Rail 100 pounds per yard; Section ARA-B.*

Length of Switch Points	Manganese			Made of Bessemer Steel Rails		Made of Open Hearth Steel Rails	
	Cost ‡	Total Weight of Points + and Rods	Weight of Manganese Tips +	Cost ‡	Total Weight of Points + and Rods	Cost ‡	Total Weight of Points + and Rods
18 Feet	79-103	1450-2330	100-170	46-68	1935-2300	48-69	1935-3300
30 Feet.	114-156	2300-3580	142-260	78-104	3100-3775	81-105	3100-3775

* The letters ARA-B mean the rail cross section or profile, type B, of the American Railway Association, illustrated in Fig.14

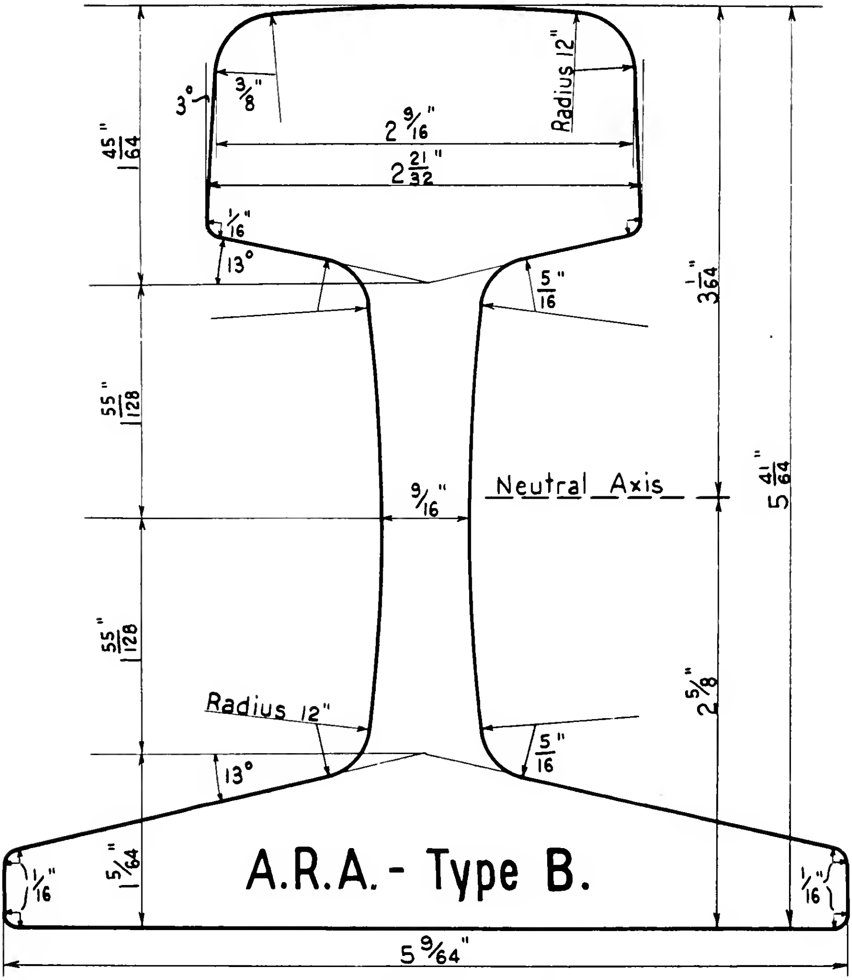
\+ Weight is in pounds

‡ Cost is in Dollars

Information is from three manufacturers

Figures vary within considerably wide limits on account of different lengths and details

Fig. 14



Area of Head = 3.95 sq. in. = 40.2% Ratio Periphery of Head to Area of Head = 1.64
" " Web = 1.89 " " = 19.2 " " " " Web " " " Web = 3.60
" " Base = 4.01 " " = 40.6 " " " " Base " " " Base = 2.49
" Total = 9.85 " " = 100.0 " " Total Periphery to Total Area = 2.37
Moment of Inertia = 41.3
Section Modulus, Head = 13.7
" " Base = 15.74

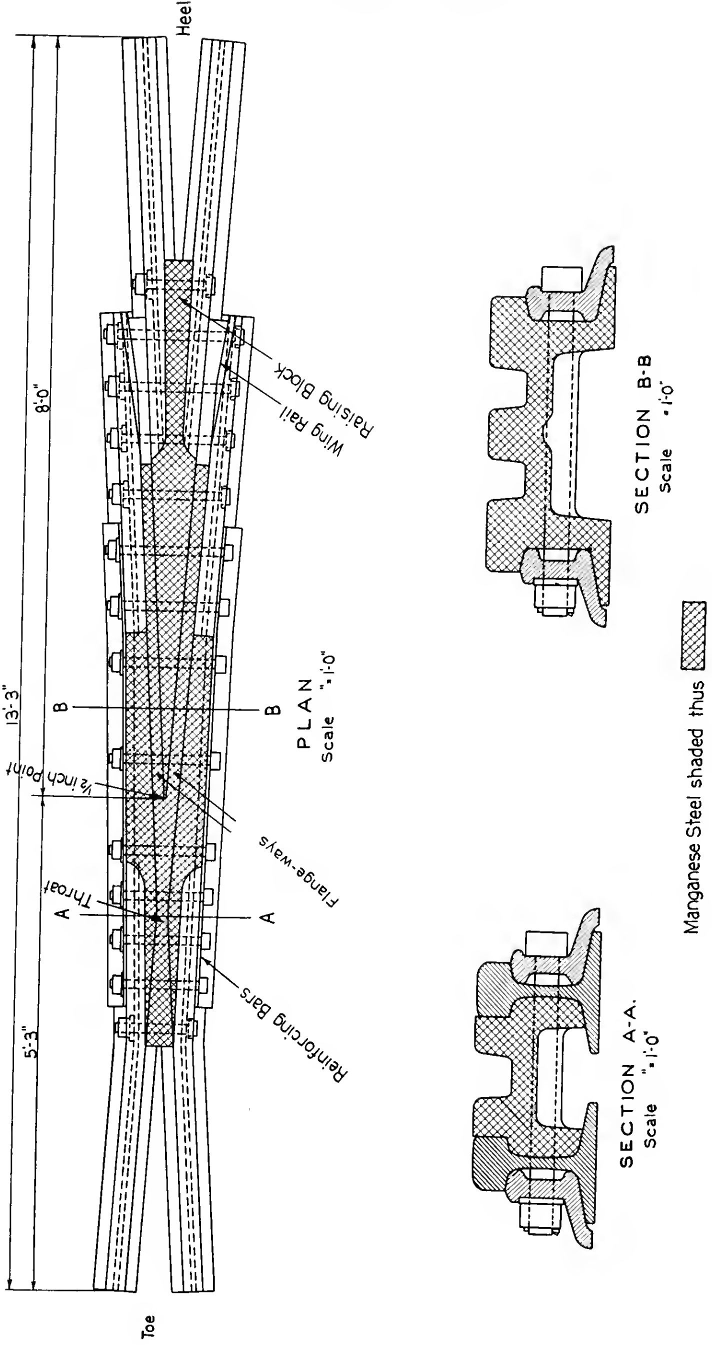
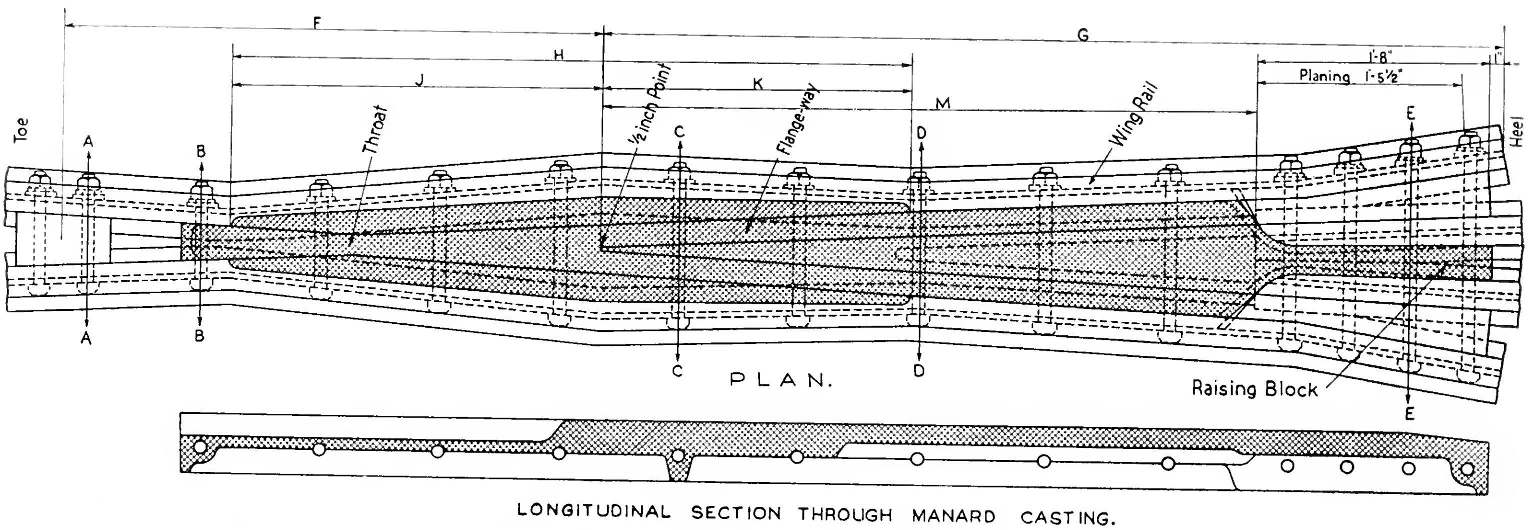


Fig. 15.
Rail-Bound Manganese Frog.

FIG. 16. No. 7 RAIL-BOUND MANGANESE FROG. WEIGHT, 100 LBS. PER YARD. RAIL SECTION, A.R.A. TYPE B.



Frog Number	H	J			K			F	G	M
		1¾" throat	1⅞" throat	2" throat	1¾" throat	1⅞" throat	2 throat			
8	3'-10"	2'-2"	2'-3"	2'-4"	1'-8"	1'-7"	1'-6"	3'-4"	5'-5"	3'-8"
10	4'-9"	2'-7"	2'-8½"	2'-9½"	2'-2"	2'-0¾"	1'-11½"	3'-9"	6'-4"	4'-7"
12	6'-3"	3'-0"	3'-1½"	3'-3"	3'-3"	3'-1½"	3'-0"	4'-2"	7'-3"	5'-6"
20	10'-1"	4'-8"	4'-10½"	5'-1"	5'-5"	5'-2½"	5'-0"	5'-10"	10'-11"	9'-2"

Manganese Steel shaded thus ▨

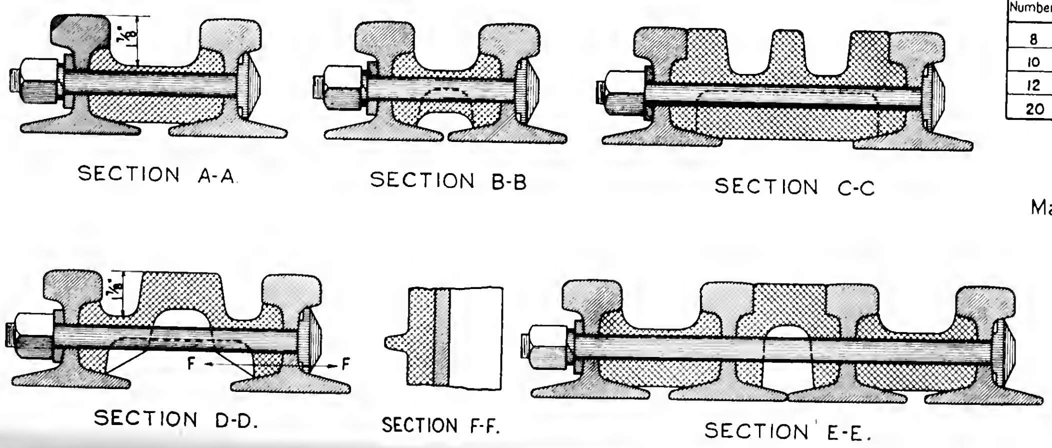


Fig. 17
Rail Bound Manganese Frog.

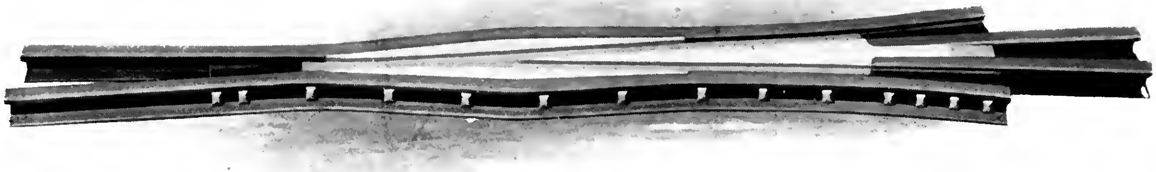


Fig. 18. No. 10 Rail-bound Manganese Frog.

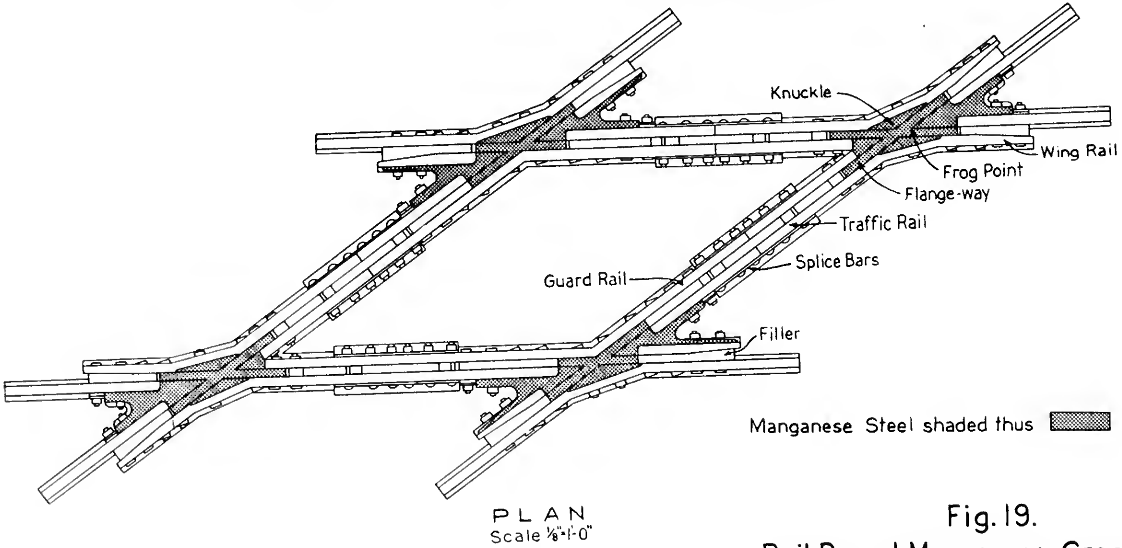


Fig. 19.
Rail-Bound Manganese Crossing Frog.

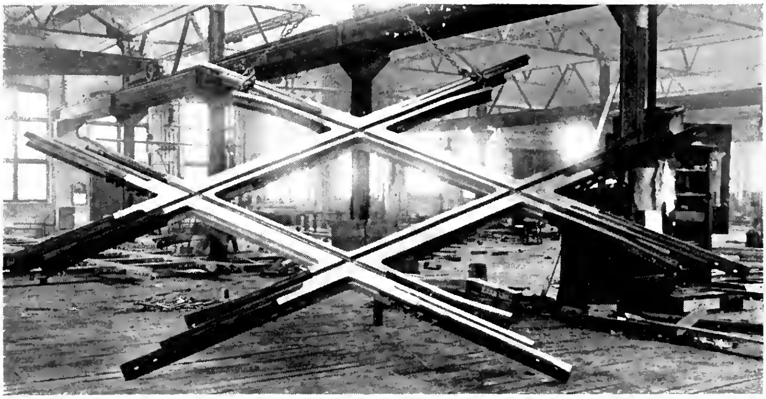


Fig. 20. Rail-bound Manganese Crossing Frog.

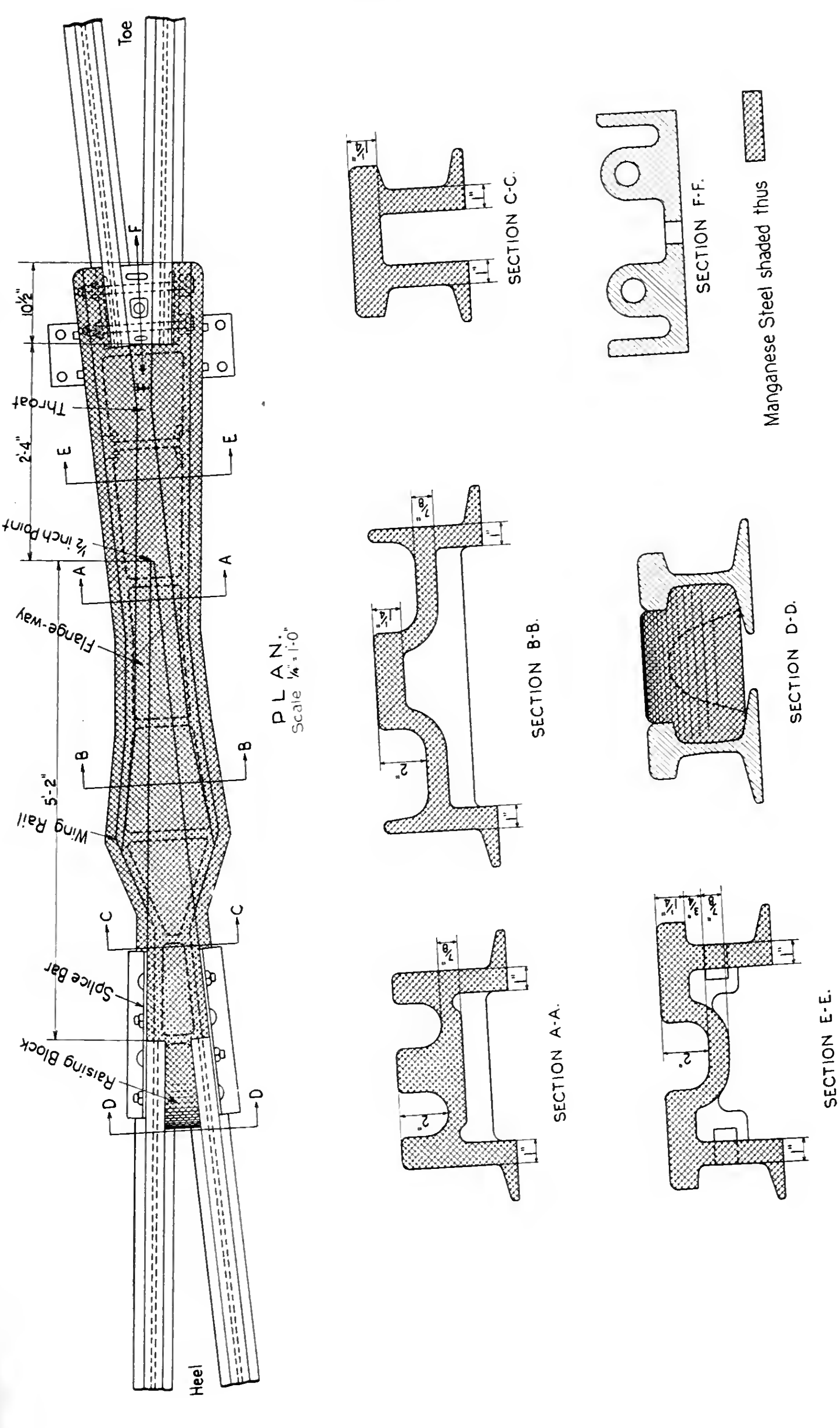


Fig. 21
Solid Cast Manganese Frog.

FIG. 22. SOLID CAST MANGANESE FROG.

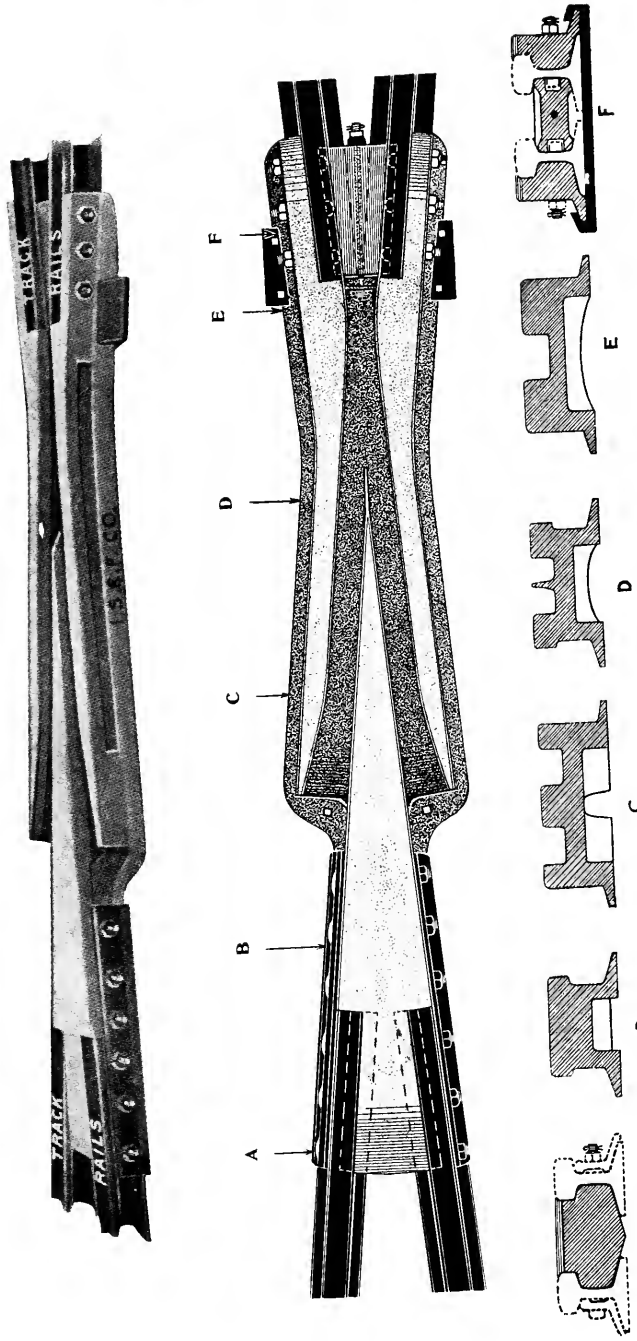


FIG. 23. MANGANESE FROG. MODEL "R-N-R."

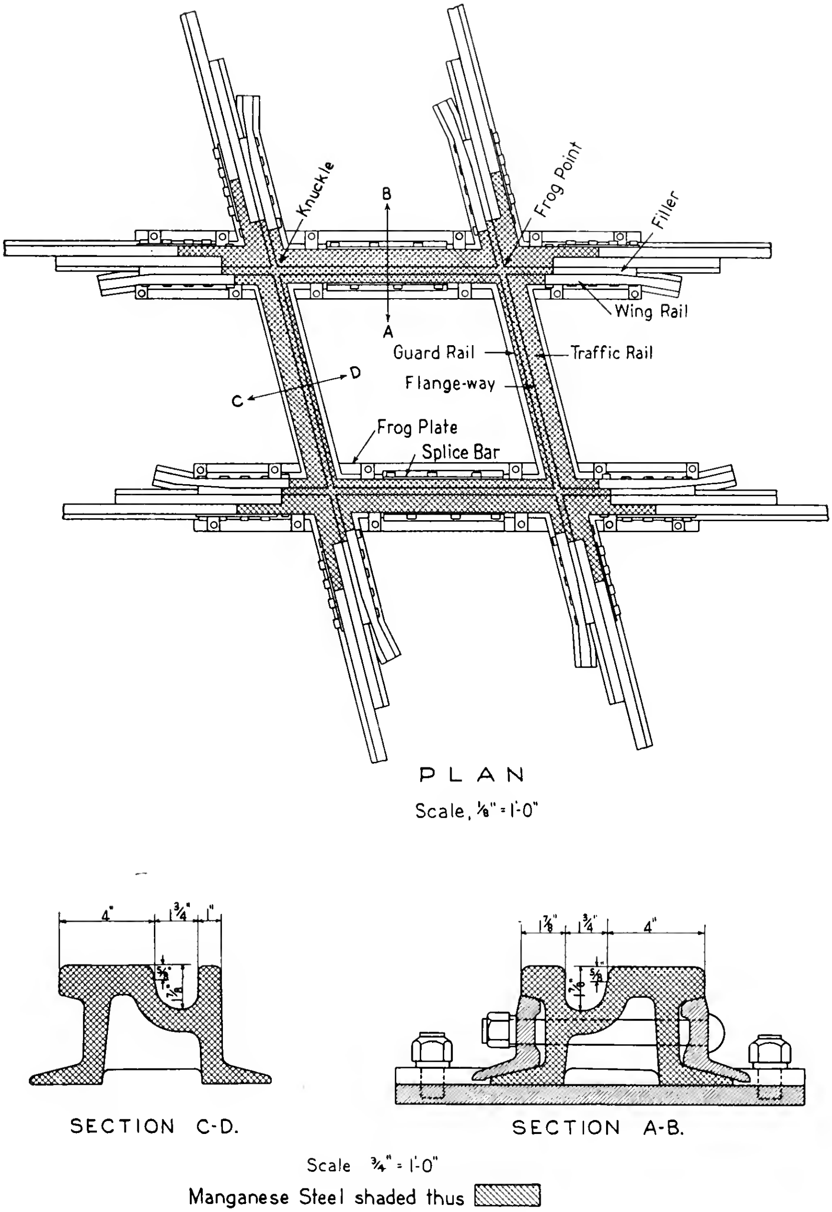


Fig. 24.

Solid Cast Manganese Crossing Frog.

Fig. 25. Solid Cast Manganese Crossing Frog.

the past 6 years, and a large number of them were of the solid cast type, but on account of having had more or less trouble with breakage, the officers in charge rather favor the inset, rail-bound, or built-up, work, three terms of synonymous meaning. The Manganese frogs last 3 or 4 times as long as those made of ordinary rail, under those conditions.

Pennsylvania Lines:

The Pennsylvania Lines have, for a long time, been keeping a record of the service of Manganese frogs, and Manganese tipped switch-points, the results of which are given in full detail in Appendix D. The object was to determine their relative economy in comparison with frogs and switch-points made from ordinary carbon steel, and to establish some rule or guide which would be of use to the officer in charge of maintenance, and enable him to decide in advance whether or not it would be economical to order a Manganese frog or switch-point for a given location. This report shows how it can be done with a certain amount of experienced estimating, and proves that the Manganese steel frogs are economical in many locations, principally where the service is severe.

Boston & Albany Railroad:

Some records of the service of Manganese frogs have also been kept on the Boston & Albany Railroad. "From 1891 to 1897 the frogs and switches were made from the special acid Bessemer steel rails of that company and of the New York Central & Hudson River Railroad with carbon 0.60 per cent. and phosphorus 0.06 per cent. These high carbon and low phosphorus rails were first rolled by the Bethlehem Steel Company in 14.5-in. square ingots, from which two 30-ft. rails were rolled, the ingots being bloomed in 11 passes, and the blooms reheated and finished into rails in 11 more passes. Other lots were rolled at Scranton by the Lackawanna Iron & Steel Company from 15-in. square ingots, making three 30-ft. rails. The ingots were charged hot into horizontal furnaces, bloomed in 5 passes, and rolled directly into pipeless rails under their own heat in 8 more passes, a total of 13, which consumed 3½ to 4 minutes, from the ingot to the finished rail at the saws. There was at Scranton from 0.6 to 0.7 of 1 per cent. of copper in the pig-iron which was remelted in cupolas for the Bessemer converters."

This was considered to be a very satisfactory rail steel, and the steel set quiet and was sound. The abrasion from the rails after 14 years' service has been very small, as shown in Figs. 26 and 27.

From 1899 to 1908, the low phosphorus ores available for Bessemer rails were very hard to obtain, the percentage having risen to the high limit of 0.10, and consequently the carbon was reduced to 0.45 to 0.55 per cent.

The frogs made of rails with the high phosphorus and low carbon wore so much faster than the former ones of low phosphorus and higher carbon, the smaller sections of which carried from 40,000,000 to 50,000,000 tons, and the 100-lb. section from 60,000,000 to 80,000,000 tons, that in 1908 six No. 8 and six No. 10, 100-lb. Manganese frogs were placed in the track. Four of the No. 8 frogs carried 49,000,000 tons before their renewal in 1913, and one 73,000,000 tons. Of the six No. 10 frogs, five were renewed in 1912, after carrying 49,000,000 tons each, and one is still in service, at the end of 1913.

Twenty Manganese frogs were placed in the track in 1909 and 8 were renewed in 1912, after carrying 38,500,000 tons, the location being more severe, on account of the higher speed.

There are 173 Manganese frogs in the main track and yard service, and 63 switch-points, tipped with about 30 in. of Manganese. The most of the Manganese centers and running surfaces of the wings, including flangeways, are cast in one piece. A No. 8 frog complete weighs about 1,620 lbs., of which 470 lbs. are Manganese.

New York Central Lines:

On the New York Central & Hudson River Railroad and on the Boston & Albany Railroad (controlled by the former), the majority of the frogs and switches are now made complete from the basic Open-Hearth rails, with higher elastic limits, of the 80, 100, and 105-lb. sections (see Fig. 28 for the latter), which are believed to resist the impacts with less deformation than the Manganese steel, but with greater loss of metal.

Some of the South American railroads have begun the experimental use of Manganese frogs.

Central Uruguay:

The Central Uruguay has recently obtained 8 reversible Manganese steel frogs, which are made of Hadfield's "Era" Manganese steel, for trial against the frogs ordinarily employed which have C. 0.35 to 0.45, P. not to exceed 0.06, Mn. 0.75 to 1.00, Si. not to exceed 0.06 and S. not to exceed 0.06.

Buenos Ayres Great Southern:

The Buenos Ayres Great Southern has tried both built-up and cast Manganese frogs obtained from Edgar Allen & Company, Limited, Imperial Steel Works, and Hadfield's Steel Foundry Company, Limited, both of Sheffield, England, and also Sandberg's Silicon steel, and finds they are affected considerably less by wear and tear than the ordinary ones of C. 0.40 to 0.50, P. not to exceed 0.06, Mn. 0.75 to 1.00, Si. not to exceed 0.06 and S. not to exceed 0.05. The test specimens of such rail are turned to ½-in. area, and of length to admit of 2 in. between gage points, and the material must stand not less than 92,960 nor more than 112,000 lbs. per sq. in. tensile strength, with a minimum elongation of 12½ per cent. The Manganese steel is of the following chemical composition:

Mn.	Carbon.	Phos.	Si.	Sulphur.
12.00	1.20	0.06	0.30	0.03

and the physical qualities are:

Tensile strength, 123,200 to 134,400 lbs. per sq. in.
Elastic limit, 44,800 to 56,000 lbs. per sq. in
Elongation, 40 to 45 in 4 in.

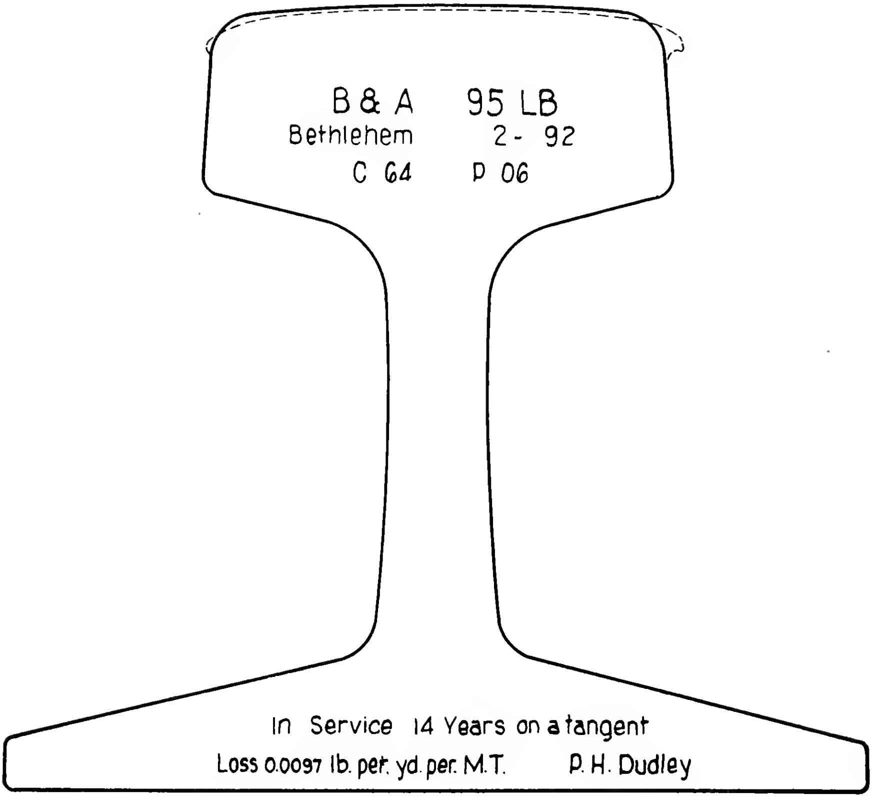

B & A 95 LB
Bethlehem 2- 92
C 64 P 06
In Service 14 Years on a tangent
Loss 0.0097 lb. per yd. per M.T. P. H. Dudley

Fig 26.

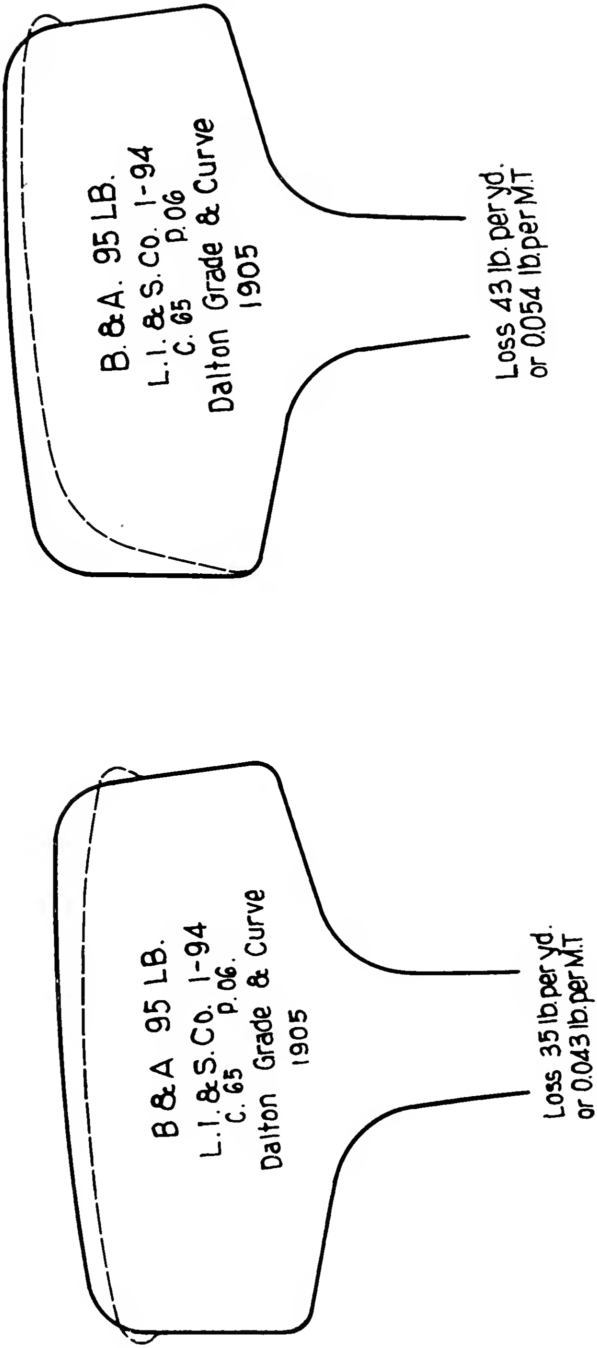
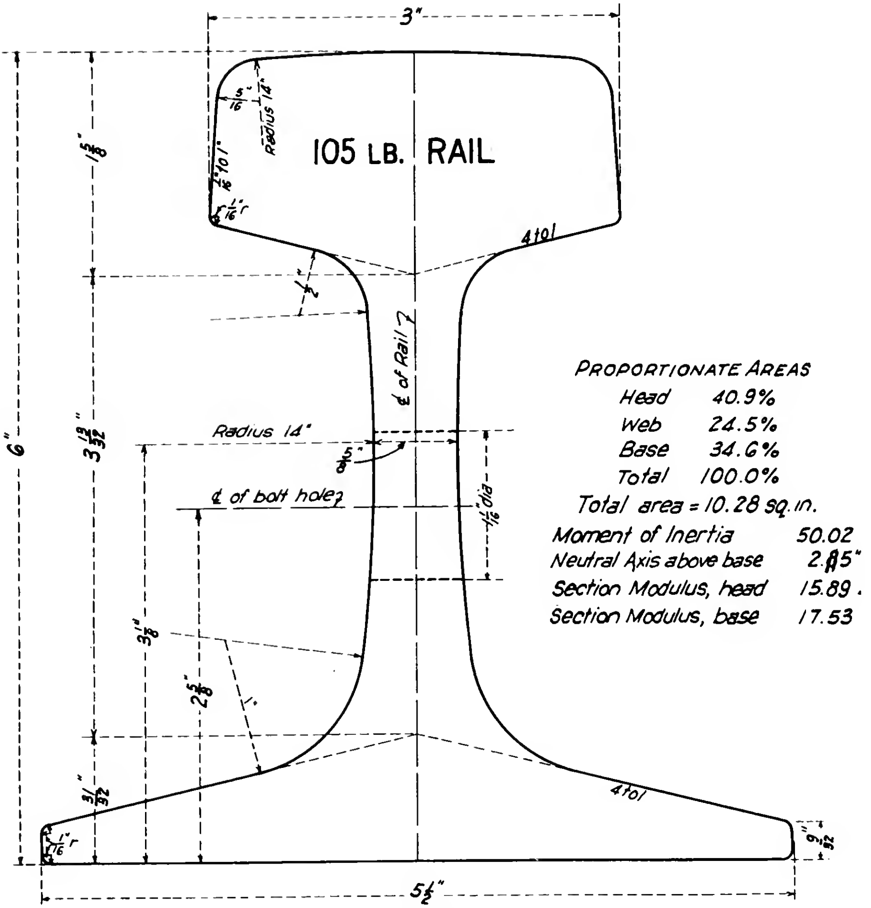

B. & A. 95 LB.
L. I. & S. Co. 1-94
C. 65 P. 06
Dalton Grade & Curve
1905
Loss 43 lb. per yd.
or 0.054 lb. per M.T
B & A 95 LB.
L. I. & S. Co. 1-94
C. 65 P. 06.
Dalton Grade & Curve
1905
Loss 35 lb. per yd.
or 0.043 lb. per M.T

Fig. 27

NEW YORK CENTRAL LINES
(DUDLEY RAIL SECTION)



PROPORTIONATE AREAS

Head	40.9%
Web	24.5%
Base	34.6%
Total	100.0%

Total area = 10.28 sq. in.

Moment of Inertia	50.02
Neutral Axis above base	2.85"
Section Modulus, head	15.89
Section Modulus, base	17.53

Fig. 28.

Edgar Allen & Co., Limited, has furnished this railway company with a very complicated* crossing of two double-track lines, 432 ft. long and 100 tons (2,240 lbs. per ton) in weight, built entirely of rolled Manganese steel rails, except the check rails.

Question 3-f:

In none of the cases reported are reduced dimensions attempted (Question 3-f, Appendix A). It is rather the opposite. The thickness of the walls of the castings are made greater because it is difficult to make thin castings of Manganese steel, and there must be no question of the strength of such costly material.

Switch-Points:

It was stated that the frogs and switches above mentioned, which were obtained from England by the Buenos Ayres Great Southern, were made entirely from rolled Manganese rail. Switches are also made in the United States entirely from rolled Manganese rail, and are being tried by several railroads, reports of such use, but with no data, having been made only by the Hocking Valley Railway and the Pennsylvania Railroad. They have not been generally used, owing to their high cost and the waste of Manganese steel when the point is sufficiently worn away to cause the discard of the whole switch.

For that reason the Manganese-tipped switch-points, illustrated in Figs. 29 to 32, are almost universally employed where Manganese steel is desired. They can be readily repaired with economy. Some companies have a preference for a longer Manganese tip in some locations, and so the longer one shown in Figs. 31 and 32 is also manufactured. The short points are about 3 ft. long for 18-ft. switches and 6 ft. long for 30-ft. switches, while the long ones are 6½ ft. long for 18-ft. switches, and correspondingly longer for the long ones, reaching about as far as the planing on the head of the switch-point.

A movable-point crossing, with the knuckle rails and points of Manganese steel, is illustrated in Figs. 33 and 34.

A record of the comparative trials of Manganese and Bessemer steel switch-points has been kept by the Pennsylvania Lines, and is exhibited in Appendix D. It shows that in no case has the monthly cost of the Bessemer been less than that of the Manganese. In a large number of the cases, the economy of the Manganese points is very great, the monthly cost of Bessemer points being as high as 13 times as large.

RÉSUMÉ.

The foregoing testimony abundantly proves that the use of Manganese steel for the manufacture of frogs and switch-points is satisfactory and economical for locations where the service is severe and trains numerous. What was regarded as experimental by the Congress of 1905

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*Fully illustrated in "Railway Gazette," January 23, 1914.

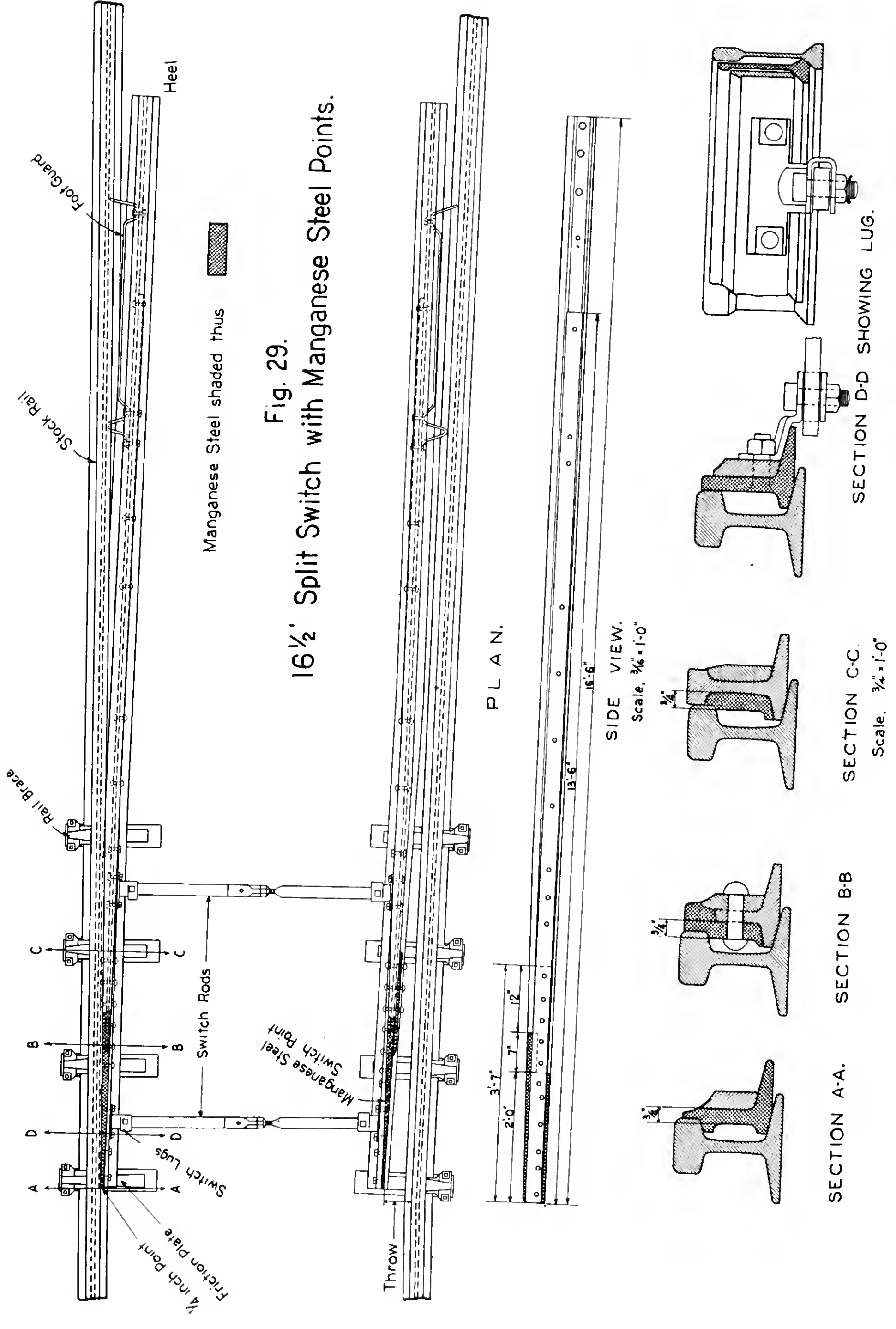


Fig. 29.
16½' Split Switch with Manganese Steel Points.

FIG. 30. MANGANESE-TIPPED SWITCH POINT.
(Short Tip.)

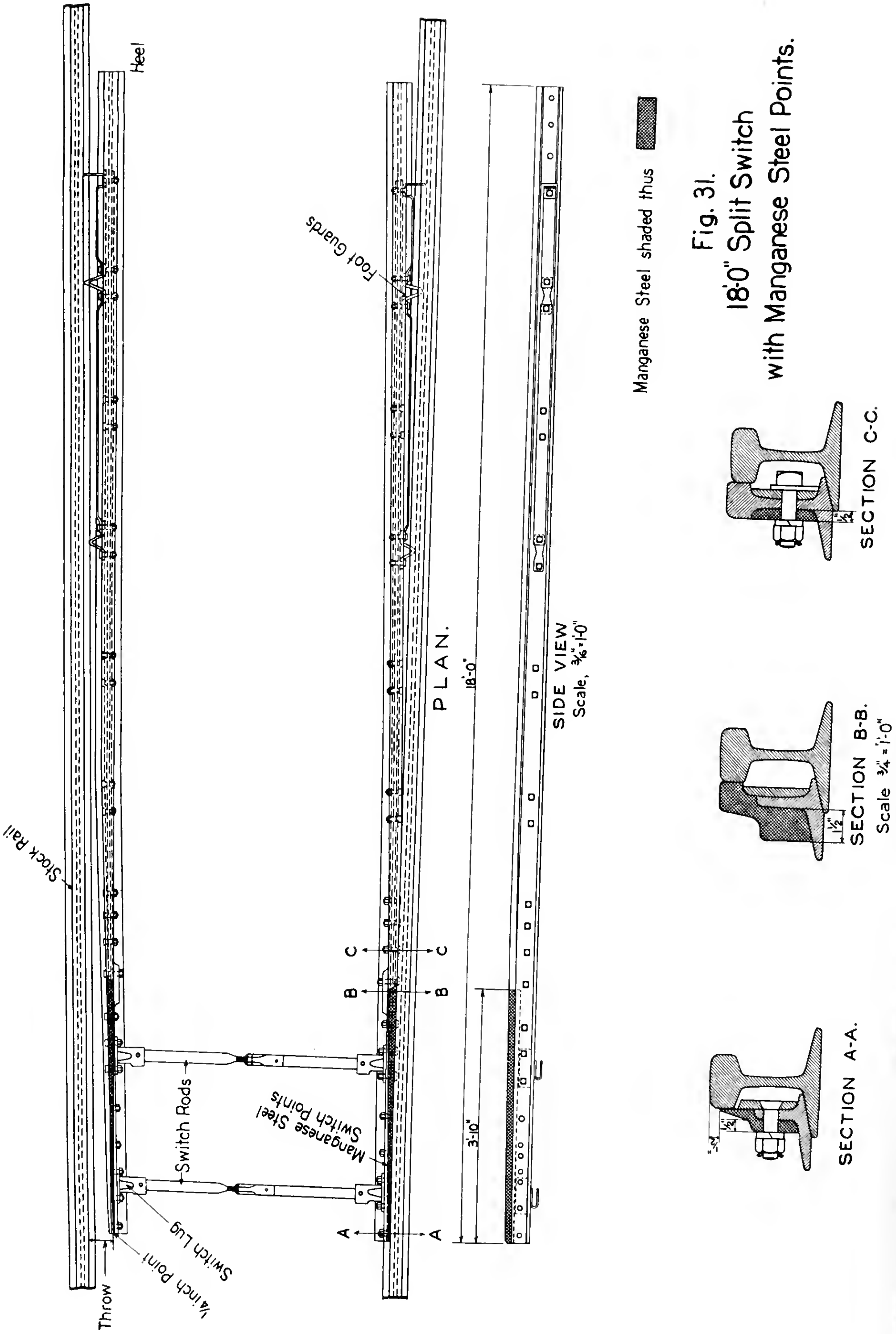


Fig. 31.
18'0" Split Switch
with Manganese Steel Points.

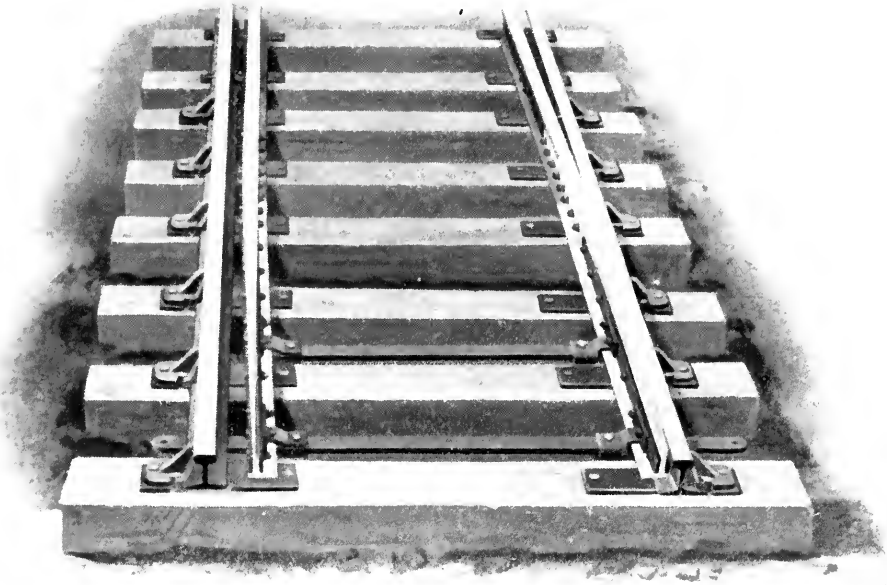


FIG. 32. MANGANESE STEEL POINT SPLIT SWITCH, WITH LONG POINTS—TWO RODS.

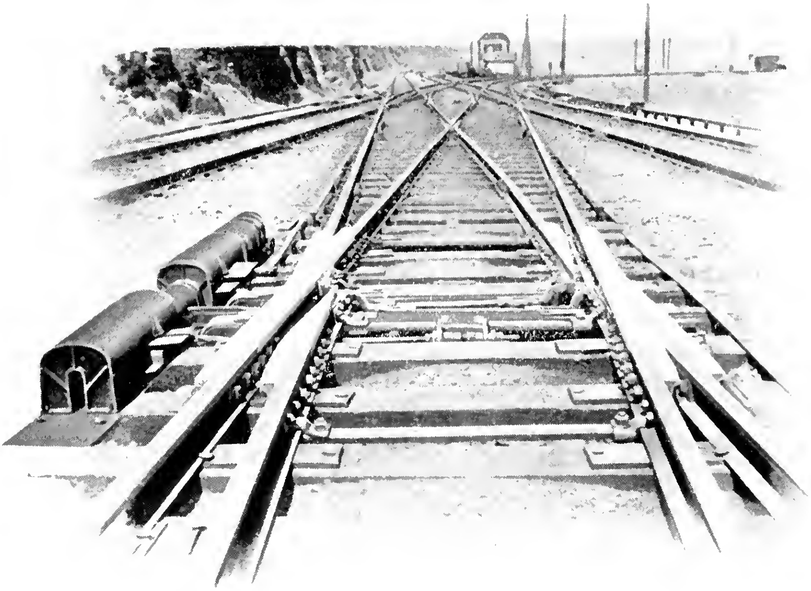
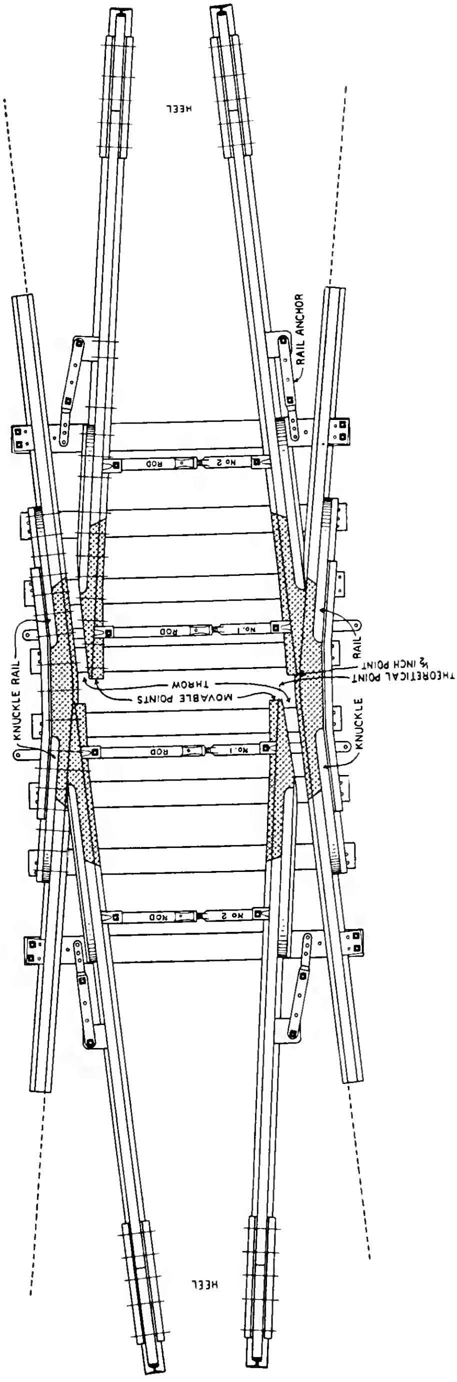


Fig. 33. Movable Point Crossing, with Manganese Steel Knuckle Rails and Points.



MANGANESE STEEL SHADED THUS ▨

MANGANESE STEEL MOVABLE POINT CROSSING.
Fig. 34

must be considered as an accomplished fact by the Congress of 1915. The experience has been long and widely extended. The report of the Pennsylvania Lines points out a method for forecasting the probable economy of their use at selected locations and illustrates a method for keeping the records of experiments.

(b) Manganese Steel for Rails.

RAIL STUDIES.

A plan quite generally in use in the United States for studying the relative efficiency of different kinds of rails is that which will now be described:

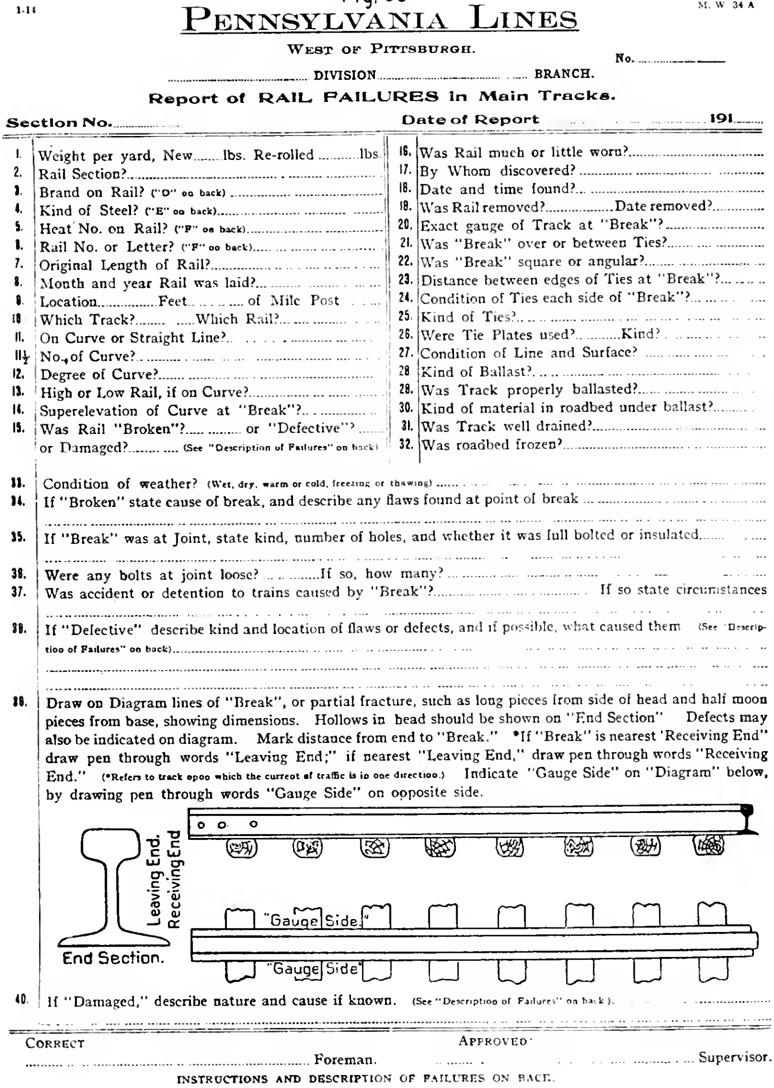
. It consists of separate studies, as follows:

(1) The study of the results of the inspection of the rails at the mills during the process of manufacture, rail inspectors being employed by the railway companies for the purpose of making such examinations and tests as will determine the compliance or non-compliance with the specifications under which they are purchased. The reports of the inspectors are tabulated on a blank form which enables a critical study to be made of the various causes for rejections, among which are failure to stand the drop (or falling weight) and ductility tests, and the chemical analyses of the ingot metal of each heat.

(2) The study of service tests, or results of the use of the rails in the tracks of the companies under traffic, which service studies are of three kinds, and are the ones directly connected with the work of the reporters:

(a) A quantitative or numerical study of the rail failures; and in order to obtain the data, a blank, shown in the accompanying Form M.W. 34-A, Fig. 35, is filled out by the Track Foreman for every rail which fails in the main tracks, and forwarded to the proper officer. On the back of the blank are descriptions of, and instructions for, classifying rail failures, and it will be observed that there are many types of failures separate and distinct from "Broken Rails," which latter are the ones which are most liable to be dangerous to train movement. Advance warning of the failure is usually given in the other cases. Each type of failure is illustrated by the photographs, Figs. 36 to 41. Some writers in mentioning the statistics of "Rail *Failures*" in the United States have often given an erroneous impression of the character of such failures, by calling them all indiscriminately "Broken Rails," and this opportunity is taken to explain the method of classification in use in the United States and Canada. It is understood by your reporter that query 4-(a) of the circular issued by the General Secretary deals with all kinds of failures, except those due to train disasters. The reports when received are sorted and tabulated so as to show clearly the position in the ingot from which the rail was rolled, and the character of the failure. These results, similarly prepared for each year, are compared the one with the other, in order to determine the effect of changes in the specifications, the rail section, or the methods, which are made from time to time. Besides the studies made by the separate railway administrations, these quantitative statistics are collected annually from all the railways by the American Railway Engineering Association and carefully studied.

Fig. 35



1-14

PENNSYLVANIA LINES

M. W. 34 A

WEST OF PITTSBURGH.

No. ....

.... DIVISION .... BRANCH.

Report of RAIL FAILURES in Main Tracks.

Section No. .... **Date of Report** .... 191......

1. Weight per yard, New......lbs. Re-rolled..........lbs.
2. Rail Section?..............................
3. Brand on Rail? ("D" on back) ....
4. Kind of Steel? ("E" on back) ....
5. Heat No. on Rail? ("F" on back) ....
6. Rail No. or Letter? ("F" on back) ....
7. Original Length of Rail? ....
8. Month and year Rail was laid? ....
9. Location..............Feet..........of Mile Post ......
10. Which Track?..........Which Rail?..............
11. On Curve or Straight Line?..............................
11½. No. of Curve?..............................
12. Degree of Curve?..............................
13. High or Low Rail, if on Curve?..............................
14. Superelevation of Curve at "Break"?..............
15. Was Rail "Broken"?..........or "Defective"?...... or Damaged?.......... (See "Description of Failures" on back)
16. Was Rail much or little worn?..............................
17. By Whom discovered? ....
18. Date and time found?..............................
19. Was Rail removed?..............Date removed?..........
20. Exact gauge of Track at "Break"?..............
21. Was "Break" over or between Ties?..............
22. Was "Break" square or angular?..............
23. Distance between edges of Ties at "Break"?..........
24. Condition of Ties each side of "Break"?..........
25. Kind of Ties?..............................
26. Were Tie Plates used?..........Kind?..........
27. Condition of Line and Surface? ....
28. Kind of Ballast?..............................
29. Was Track properly ballasted?..............
30. Kind of material in roadbed under ballast?..........
31. Was Track well drained?..............................
32. Was roadbed frozen?..............................

33. Condition of weather? (Wet, dry, warm or cold, freezing or thawing) ....

34. If "Broken" state cause of break, and describe any flaws found at point of break ....
....

35. If "Break" was at Joint, state kind, number of holes, and whether it was full bolted or insulated..........
....

36. Were any bolts at joint loose? ....If so, how many? ....

37. Was accident or detention to trains caused by "Break"?.............. If so state circumstances
....

38. If "Defective" describe kind and location of flaws or defects, and if possible, what caused them (See "Description of Failures" on back)..............................
....
....

39. Draw on Diagram lines of "Break", or partial fracture, such as long pieces from side of head and half moon pieces from base, showing dimensions. Hollows in head should be shown on "End Section" Defects may also be indicated on diagram. Mark distance from end to "Break." *If "Break" is nearest 'Receiving End" draw pen through words "Leaving End;" if nearest "Leaving End," draw pen through words "Receiving End." (*Refers to track upon which the current of traffic is in one direction.) Indicate "Gauge Side" on "Diagram" below, by drawing pen through words "Gauge Side" on opposite side.

40. If "Damaged," describe nature and cause if known. (See "Description of Failures" on back). ....
....

CORRECT APPROVED:

.... Foreman. .... Supervisor.

INSTRUCTIONS AND DESCRIPTION OF FAILURES ON BACK.

Back of Fig. 35

INSTRUCTIONS.

A. The Foreman will send this Report to the Supervisor the same day the break is discovered, and in the case of a damaged or defective rail, the day it is taken out of the track.

B. The Supervisor will forward this Report direct to the Division Engineer.

C. The Division Engineer will have copies of this Report made immediately upon receipt and send a copy to the Chief Engineer M. of W.

D. The answer to 3 is in raised characters on the web of the rail.

E. The answer to 4 is "Bessemer" (B); "Open Hearth", (O. H.); "Nickel" (N); "Ferro-titanium" (F. T.); "Chrome Nickel" (C. N.) or other method of manufacture or alloy.

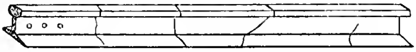
F. The answers to 5 and 6 are stamped into the metal on side of web;-figures for 5 and a letter for 6.

G. Mile Post Number from $\left\{\begin{matrix}\text{South}\\ \text{East}\end{matrix}\right\}$ end of Division to be used.

DESCRIPTION OF RAIL FAILURES.

When describing Failures of Rails, the following terms should be used.

1. **BROKEN RAIL.** This term is to be confined to a rail which is broken through, separating it into two or more parts. A crack which might result in a complete break will come under this head

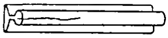


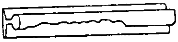
DEFECTIVE.

2. **FLOW OF METAL.** This term means a "Rolling Out" of the metal on top of the head towards its sides without there being any indication of a breaking down of the head structure; that is, the under side of the head is not distorted.

3. **CRUSHED HEAD.** This term is used to indicate a "Flattening" of the head, and is usually accompanied by a crushing down of the head as shown in the sketch.

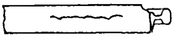
4. **SPLIT HEAD.** This term includes rails split through or near the center line of the head, or rails with pieces split off the side of the head. When this term is used it should be further defined by stating whether it is or is not accompanied by a seam or hollow head.



5. **SPLIT WEB.** This term is a longitudinal split along the axis of the web, generally starting from the end of rail through the bolt holes.

6. **BROKEN BASE.** This term covers all breaks in base of rail and should be described and illustrated on sketches on front page.



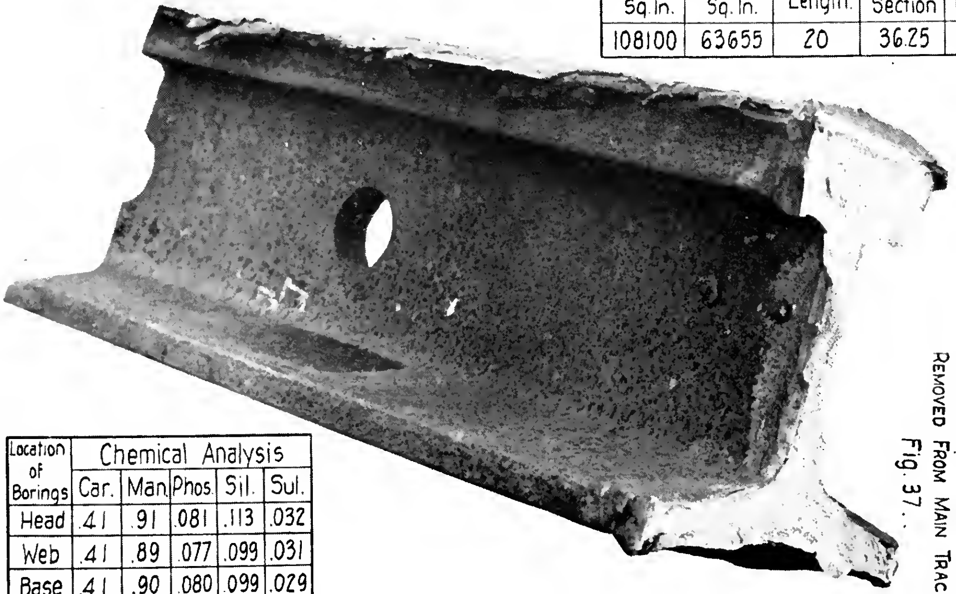

7. **DAMAGED.** Under this head will be included all rails broken or injured by wrecks, broken wheels or similar causes.

P.C.C. & St. L. Ry.
DEFECTIVE 85 LB A.S.C.E. RAIL.
REMOVED FROM MAIN TRACK.
Fig. 36

Location of Borings	Chemical Analysis				
	Car.	Man.	Phos.	Sil.	Sul.
Head	.63	1.4	.099	.075	.052
Web	.60	1.47	.084	.085	.054
Base	.63	1.47	.092	.075	.052
Average	.62	1.47	.091	.078	.052

Physical Tests				
Tensile Strength Lbs. per Sq. In.	Elastic Limit Lbs. per Sq. In.	Elongation % of Orig. Length	Reduction of Area-% of Orig. Section	Character of Fracture
95950	48320	14	17.1	Fine Grain

Physical Analysis.				
Tensile Strength Lbs. per Sq. In.	Elastic Limit Lbs. per Sq. In.	Elongation % of Orig Length.	Reduction of Area-% of Orig Section	Character of Fracture
108100	63655	20	36.25	S.&G



Location of Borings	Chemical Analysis				
	Car.	Man.	Phos.	Sil.	Sul.
Head	.41	.91	.081	.113	.032
Web	.41	.89	.077	.099	.031
Base	.41	.90	.080	.099	.029
Average	.41	.90	.079	.102	.031

P.C.C & St. L. Ry.
DEFECTIVE 85 LB. A.S.C.E. RAIL.
REMOVED FROM MAIN TRACK.
Fig. 37.

P.C.C & St.L.Ry.

DEFECTIVE 85 LB. A.S.C.E. RAIL.
REMOVED FROM MAIN TRACK.
Fig. 38.

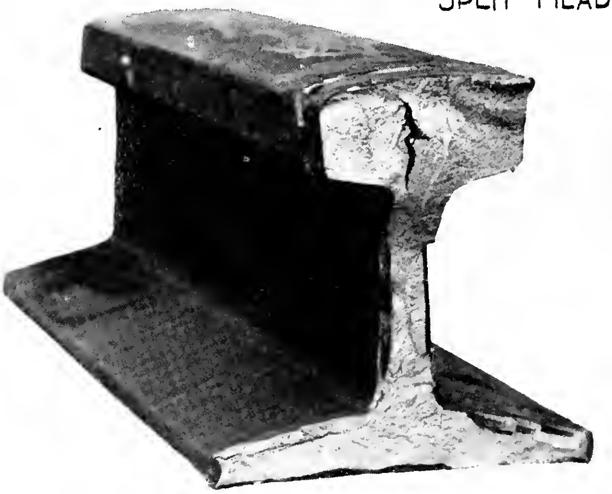
CRUSHED HEAD.

Location of Borings	Chemical Analysis.				
	Car.	Man.	Phos.	Sil.	Sul.
Head	.49	.89	.102	.163	.032
Web	.47	.88	.106	.167	.033
Base	.48	.89	.103	.167	.031
Average	.48	.89	.103	.166	.032

Physical Tests				
Tensile Strength Lbs. per Sq. In.	Elastic Limit Lbs. per Sq. In.	Elongation % of Orig. Length	Reduction of Area-% of Orig. Section	Character of Frature
111700	58290	20.75	36.04	G.

P.C.C & St. L.Ry.
DEFECTIVE 85LB. A.S.C.E. RAIL.
REMOVED FROM MAIN TRACK.
Fig. 39.

SPLIT HEAD.

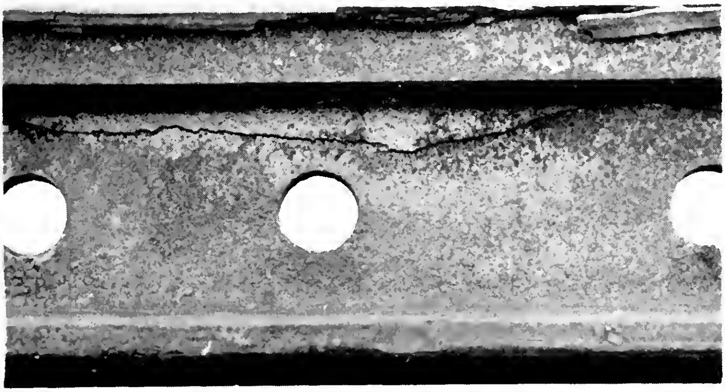


Location of Borings	Chemical Analysis				
	Car.	Man.	Phos.	Sil.	Sul.
Head	.46	.64	.098	.042	.043
Web.	.51	.63	.127	.038	.056
Base	.45	.64	.112	.042	.040
Average	.47	.64	.112	.041	.046

Physical Tests				
Tensile Strength. Lbs. per Sq. In	Elastic Limit Lbs. per Sq. In.	Elongation % of Orig. Length.	Reduction of Area. % of Orig. Section	Character of Fracture
92330	48880	19.5	25.8	Fg.& S.

P.C.C & St.L.Ry.
Defective 85 Lb. A.S.C.E. Rail
Removed From Main Track.
Fig. 40.

Split Web.



· P.C.C & St. L. Ry.
Defective 85Lb A.S.C.E. Rail.
Removed From Main Track.
Fig. 41.

Broken Base

Location of Borings	Chemical Analysis.				
	Car.	Man.	Phos	Sil.	Sul.
Head	.58	1.14	.098	.080	.031
Web.	.52	1.13	.089	.094	.027
Base	.55	1.14	.095	.078	.030
Average	.55	1.14	.094	.084	.029

Physical Tests.				
Tensile Strength Lbs. per Sq. In.	Elastic Limit Lbs. per Sq. In	Elongation % of Orig. Length.	Reduction of Area-% of Orig. Section	Chararter of Fracture
121650	75920	16	2404	S. & G

(b) By reason of the information contained in some of the reports received, certain individual rails are sent to the laboratory, where complete chemical, physical and microscopic studies are made, in order to determine the causes of failures and learn therefrom the changes, if any, which should be made in the specifications or rail section, in order to improve its service. Similar examinations for the purpose of comparison are made of rails which have given satisfactory service in the track.

(c) In addition to the failures, it is necessary to compare the relative economy of different kinds of steels by their resistance to the abrasive forces of wheels, especially on curves, commonly called the "wear." The method of making this study is well illustrated in the Baltimore & Ohio Railroad reports given further on.

Blank forms for tabulating and reporting all of the above studies have been adopted by the American Railway Engineering Association, and will be found, together with their description and instructions for use, in the "Manual of the American Railway Engineering Association," and in the Proceedings of that Association, Vol. 9, 1908, page 449, and Vol. 10, Part 1, page 339. They have been modified from time to time, as developed by experience, the "Manual" containing the latest editions.

*"The first attempt to apply Manganese steel to rails of curves was in 1895, in the shape of flat rails for street railways, by Wm. Wharton, Jr., & Co., Inc., and subsequently in November, 1898, 7-in. high girder guard rails were cast in about 12-ft. length for the Philadelphia Traction Company.

*"In the beginning of 1902, the Wharton Company had also been approached by the Boston Elevated Railway Company on the question of manufacturing Manganese Steel T rails for some of the curves of its system, where quite an unusual condition of rapid wear existed, and in April, 1902, the first Manganese Steel T rails cast in 20-ft. lengths and ground to section were furnished for a curve of 82 ft. radius near the Park Street Station of the Boston Subway. The rails were cast straight and afterwards curved. The section was quite heavy, i. e., while the contour of the head corresponded to the 85 lbs. per yard A.S.C.E. design, the web and base were made 1⅛ in., thinning down at the ends, which were ground to a splice bar fit, and the top and side of the head were also ground smooth and true."

Boston Elevated Railway:

†As about 40 per cent. of the entire length of the line is curved, the question of maintenance and the cost of rail renewals became a serious problem.

"The tracks were first laid with Bessemer rail having a low carbon content (about 0.45 per cent.), and the life of the outer rail on the sharp curves was very short, averaging about 60 days. This rail, preceding the placing of the Manganese rail, wore down 0.064 ft. in 44 days, as shown in Fig. 42. The figure also shows the wear of the Manganese rail after 2,409 days in the same location, the amount being 0.048 ft., which is remarkable, and illustrates its great resistance to rolling friction. The comparative wear of the ordinary Bessemer as against the Manganese steel is graphically shown in the figure.

"The traffic in 1902 was, of course, much less than in 1908, when these records were made, averaging probably 1,000 cars or 36,000 tons (2,000

---

*Letter from V. Angerer.

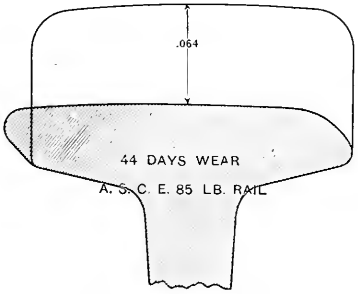
†From letter from H. M. Steward, Chief Engineer, Maintenace of Way, Boston Elevated Railway Company.

Record of Cast TISCO Manganese Steel "T" Rail Curve, Park St. Station, Boston Subway

The Manganese Steel Rails, cast in 20-foot lengths, were installed in this curve on April 26, 1902 Former curves of ordinary Bessemer Steel Rails were completely worn out in an average of 44 days. The diagrams below show the comparison of the wear of the TISCO Manganese Steel Rails up to November 29, 1908, to that of the former Bessemer Steel Rails when worn out

About three miles of similar cast TISCO Manganese Steel "T" Rails have since been furnished various elevated and subway railways in this country with every indication of similar results

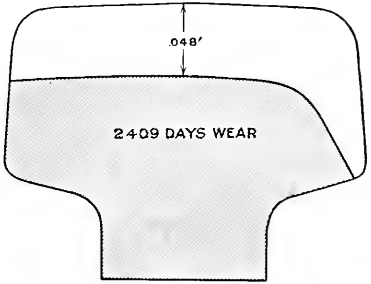
Fig. 42.



Bessemer Steel Rail
With Guard Rails in Use

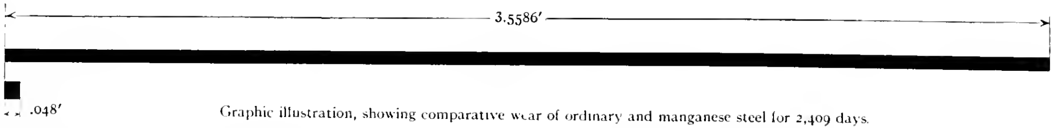
Ratio of Service November 29, 1908· 1 to 54.

TISCO Manganese Steel Rails have since had surface car traffic (about 2,100 days) with only slight additional wear



TISCO Manganese Steel Rail

The figures denote vertical wear in decimals of a foot



Graphic illustration, showing comparative wear of ordinary and manganese steel for 2,409 days.

Note.—The former Bessemer Steel Rail was protected from side wear by a guard rail The Manganese Steel Rail was allowed to take both the top and the side wear lbs. per ton) per diem, as against 1,700 cars, or 62,000 tons per diem in 1908. Consequently the Manganese rail, on account of the constant increase in traffic, has given even better service than the comparative results show.

"In 1902 and 1903 the railway company purchased about 700 linear feet of Manganese rail at an average price of $5.00 per linear foot, which is the price of the first lot, which turned out to be really below cost, due to the labor involved in making the patterns, casting, and especially in finishing the rails, which can only be done by grinding. The price of Bessemer rail averaged about 0.39 cent per linear foot.

"The Rapid Transit trains were removed from the subway in November, 1908, and the street surface cars have been operated there since. For the last two or three years a very heavy type of surface car has been in use, so that the traffic over this Manganese rail, which is still in service (December, 1913), is approximating the elevated train traffic at the time it was diverted in 1908.

"On account of these excellent results, the railway company purchased in 1906, 1907 and 1908 about 4,700 linear feet of cast Manganese rail at an average price of $6.70 per linear foot. The high cost lead to the attempt to reduce the thickness more nearly to the rolled section, with the result that the unequal distribution of metal between the head and the other portions of the rail created a tendency in the castings toward internal defects, which, after the rails had become worn to some extent, made their appearance in the shape of apparent small cracks. Some of the rails showing these defects had to be replaced, but otherwise they gave results similar to the first lot.

"As to the comparative cost of maintenance, the general maintenance of track, outside of rail renewals, should not vary appreciably whether the track be laid with Manganese rail or Bessemer rail. Taking the curve at Park Street as a basis, and assuming that the life of a Manganese rail at this point would be 8 years and that of Bessemer rail 2 months, the following figures would be a fair estimate of the comparative cost of maintenance per linear foot of single rail for a period of 8 years:

Cost of Manganese rail per foot	$ 6.70
Bonds, spikes, etc.	.09
Labor	.22
Total cost of maintenance	$ 7.01

Cost of Bessemer rail per foot (50 renewals)	$19.50
Spikes, bonds, etc.	3.25
Renewal of ties, account of "spike killing"	2.90
Labor	15.50
Total	$41.50

"This comparison is made from one specific case, in which the costs can be very closely estimated. The same proportions might or might not apply in other instances.

"From time to time this company, the Boston Elevated Railway, has made other experiments with special rollings of Bessemer, Nickel and Open-Hearth rails. In 1903 the Cambria Steel Company furnished some Bessemer rail with a carbon element of about 0.78, manganese 1.00 to 1.25, phosphorus .09 to .10 and sulphur .03 to .06, the wearing qualities of which were very satisfactory when compared with ordinary Bessemer rail, and were far better than the Nickel and Open-Hearth rail which we have obtained up to 1908. None of these rails, however, approached the Manganese rail in length of life.

"As it is of interest to compare the life of different brands of rails under the same conditions, five curves of short radii have been selected, and a tabulation of the comparative life of five different kinds of rail prepared. All of the rails have not been tested on each of the curves, but from the actual results obtained on curves of similar radii the life of the rails can be closely estimated. The comparisons are set forth in the table:"

TABLE VII.

COMPARATIVE LIFE OF SEVERAL KINDS OF STEEL RAILS ON TYPICAL SHARP CURVES.

Speed of Trains from 8 to 10 M.P.H.

Location of Curve	Radius	Ordinary Bessemer Rail.		High Carbon Bessemer Rail.		Nickel Rail.		Manganese Rail.		Open-Hearth Rail.	
		Mo.	Ds.	Mo	Ds.	Mo.	Ds.	Mo.	Ds.	Mo.	Ds.
Park St., S. B. (subway)...	82 ft.	2	3	8	18+	3	12+	76	4*	1	11
Adams Sq., N. B. (subway)	89 ft.	2	17	10	15	4	4+	80	10+	1	27
Park St., S. B. (subway)...	90 ft.	2	16	10	11+	4	3+	66	15*	1	20+
Haverhill St., N. B........	100 ft.	4	3	11	13	6	19	128	9+	2	21
Sullivan Sq. (loop).........	106 ft.	3	7	13	8	5	7+	101	5+	2	7

*Still in service. +Estimated life from actual results on curves of similar radii.

In commenting upon his experience with cast Manganese rail, Mr. Steward says further:

"The general use of Manganese steel on tangents does not seem to me to be advisable. Even under the severe traffic of the elevated division, ordinary rail has given fairly satisfactory service for over seven years. Our tangent rail does not, of course, receive such hard usage as that on steam roads, and the joints do not suffer from the pounding of heavy locomotives. Manganese steel, while offering great resistance to grinding friction, will not offer as great resistance to heavy blows on account of its ductility. . . . Its high cost also prohibits its use for this purpose.

"In our service we find that Manganese rail will not withstand side wear equally as well as top wear. The grinding friction from the flat of the tire does not seem to have the same effect on Manganese steel as the cutting action of the flanges, and we have found it advisable to protect the side of the head of Manganese rail, holding the flanges away from it by means of a check or guard rail fastened securely to the inner rail of the curve."

Between 1905 and 1908, the successful rolling of Manganese rail was accomplished by the Pennsylvania Steel Company of Steelton, Pa., and the Manganese Steel Rail Company of New York City, both of which rolled a quantity for the Boston Elevated Railway, and they were laid in the track November 4, 1908.

At the same time Open-Hearth steel rails were becoming more sought for, and a test of both was inaugurated on that date by the Chief Engineer Maintenance of Way. The rails of each kind in the test were laid alternately and measurements were taken periodically on each end of each rail a short distance away from the joint. It would have been better to have made them at the center, as a hard and tough rail would influence the end of its softer neighbor. The latest measurements, taken October 1, 1913, are given in Table VIII. It will be observed that the best record is being made by the cast Manganese rails, and the next by the Pennsylvania Steel Company's rolled "Manard" rails.

TABLE VIII.

TABULATION SHOWING COMPARATIVE WEAR OF VARIOUS KINDS OF RAIL TESTED ON CURVE AT BEACH STREET AND ATLANTIC AVENUE, NORTH-BOUND. CIRCULAR RADIUS 163', SPIRALED. SUPER-ELEVATION 4". RAIL INSTALLED NOVEMBER 4, 1908.

Kind of Rail	Measured So. end of rail	4/24/09 No. end of rail	Measured So. end of rail	9/23/09 No. end of rail	Measured So. end of rail	12/15/09 No. end of rail	Measured No. end of rail	6/15/10 No. end of rail	Measured So. end of rail	2/10/11 No. end of rail
Bethlehem Open-Hearth.........	.006	.006	.008	.0075	.012	.010	.015	.015	.021	.019(1)
Pennsylvania Steel Co. Manard..	.0085	.006	.0085	.007	.009	.007	.010	.009	.012	.011
Wharton Cast Manganese........	.003	.004	.003	.004	.003	.005	.004	.0065	.005	.008
Manganese Steel Rail Co.......	.006	.007	.008	.007	.009	.010	.012	.014	.015	.016
Pennsylvania Steel Co. Manard..	.008	.008	.008	.008	.008	.009	.009	.013	.012	.014
Wharton Cast Manganese........	.002	.000	.004	.000	.005	.000	.005	.000	.005	.003
Manganese Steel Rail-Co.......	.011	.011	.0125	.011	.015	.012	.017	.014	.020	.018
Bethlehem Open-Hearth.........	.005	.007	.007	.0085	.009	.009	.014	.018	.019	.027(2)
	Measured So. end of rail	9/21/11 No. end of rail	Measured So. end of rail	5/13/12 No. end of rail	Measured So. end of rail	11/20/12 No. end of rail	Measured So. end of rail	2/26/13 No. end of rail	Measured So. end of rail	9/29/13 No. end of rail
Bethlehem Open-Hearth.........	.025	.022	.028	.024	.030	.025	.032	.026	.036	.034(1)
Pennsylvania Steel Co. Manard..	.015	.013	.015	.013	.015	.0135	.017	.015	.017	.017
Wharton Cast Manganese........	.007	.009	.007	.009	.008	.010	.010	.012	.011	.012
Manganese Steel Rail Co.......	.018	.019	.019	.019	.021	.020	.022	.023	.025	.025
Pennsylvania Steel Co. Manard..	.015	.016	.015	.017	.016	.018	.017	.019	.018	.021
Wharton Cast Manganese........	.006	.005	.007	.006	.008	.007	.009	.008	.010	.008
Manganese Steel Rail Co.......	.023	.019	.024	.021	.026	.023	.027	.024	.028	.026
Bethlehem Open-Hearth.........	.024	.032	.027	.037	.030	.041	.033	.043(3)	.041(4)	.053(3)(4)

(1) = South end of curve. (2) = North end of curve.

(3) = Rail removed 2/26/13 account difference in wear.
(4) = Combined wear of rail removed and replacement rail.
(5) = The word "Manard" is the Pennsylvania Steel Company's trade name for "Manganese" rail, and is a corruption of the words "Manganese-hard."

Boston Elevated Railway Co.
Rapid Transit Lines,
Sullivan Square Terminal,
Charlestown, Mass.
October 1, 1913.

The price of the Open-Hearth rail was about $30.00 per ton, and of the rolled Manganese rail originally $180.00 per ton, but now about $90.co per ton.

Between the years 1903 and 1908 several other elevated railroad companies purchased Manganese steel rail for sharp curves with heavy traffic.

Description of Rolling Manganese Rails:

The following description of the process of rolling Manganese rail is taken from a report in 1909 by Mr. E. B. Ashby, Chief Engineer of the Lehigh Valley Railroad:

> "An average analysis of the rail would be about, manganese 12.50 to 12.75 per cent., carbon 0.92 to 0.95 per cent., phosphorus 0.03 to 0.037 and sulphur 0.03 to 0.035. To get this tmount of manganese, from 15 to 17 per cent. of ferro-manganese is added in the ladle when pouring, about one-half being put into the ladle when empty, the balance as the pouring progresses. The addition of the manganese greatly increases the heat of the molten metal, raising it about 500 degrees.
>
> "The ingots averaged 17 in. square, and from 57 to 58 in. long, the metal being poured to within about 6 in. of the top of the mold. After the metal is properly set, the ingots are put into the usual soaking pits, but are kept there from two to three times as long as is usual in the case of Bessemer steel, depending, of course, on the heat. The ingots are then given from 30 to 40 passes in the blooming mill, the time consumed being from 10 to 12 minutes, and the section being reduced to 8⅛ in. by 5¼ in. The average was 34 passes in 14 minutes to obtain this reduction, the bloom being worked until quite stiff. There seemed to be considerable delay in the working of the machinery. The bloom was then carried to the shears, where the discard, about 20 per cent., although it may be anywhere from 10 to 25 per cent., was made, and the bloom cut into short lengths, each sufficient to make one rail. The blooms were then carried to the heating furnaces, where they were held from 5 to 9 hours, according to the temperature when received. The blooms were then given ten passes, five in each in the shaping and finishing rolls, taking about 2½ minutes. The temperature at the start was about 1,200 degrees C., and about 400 degrees were lost in passing through the rolls. A rolled shape is finished at a higher temperature than would be the case if carbon steel were similarly heated and worked, because the specific heat of Manganese steel, ranging from 0.145 at ordinary temperatures to about 0.20 at 1,200 degrees C., is considerably higher than that of carbon steel, and its coefficient of conduction is very much lower.
>
> "The rails were then given a water bath for about 2½ minutes, after which they were thrown on the cooling racks. The camber after cooling is most extreme, but is taken out by camber rolls instead of the usual gagging press, generally two passes on the side and one on the head being sufficient to straighten them.
>
> "The bolt holes are punched, without developing any ill effects at the edges of the holes, and the rails cold-sawed to exact lengths."

The steam railroads have been much slower than the elevated railroads in adopting Manganese steel rails because of the high cost, while at the same time their curves are not so sharp. Nevertheless, trials have been made by some of them, and will be described by the reporter.

Atchison, Topeka & Santa Fe Railway System:

In 1909 the Atchison, Topeka & Santa Fe Railway Company purchased enough rolled Manganese rail to lay about a mile of track, and placed it on sharp curves. The details of the experiment are given in Appendix E. After 3 years and 2 months' service on 10-degree curves (radius 574 ft.), the abrasion amounted to 0.11 sq. in. and 0.15 sq. in. for the low rails, and 0.17 sq. in. and 0.18 sq. in. for the high rails per 10,000,000 tons of traffic. No information has been given about the life of the ordinary rail used at these places. The failures of these Manganese rails were in the ratio of 1 in 64 in the year 1911, and 1 in 111 in 1912. The total number of failures has been 7, due to unknown causes.

Norfolk & Western Railway:

The Norfolk & Western Railway Company has had two small lots of rolled Manganese rail in experimental use. The chemical analysis is 9.93 per cent. manganese, 0.77 per cent. carbon and 0.06 phosphorus. It was of 85-lb. A.S.C.E. section and was compared with Bessemer rail from the Carnegie Steel Company and with Open-Hearth rail from the Bethlehem Steel Company, of the same weight and pattern. The first trial was begun on April 1, 1909, in comparison with the Carnegie rail, which, after 18½ months was removed, and replaced by the Bethlehem rail, which was in service at the end of 1912.

The areas of metal abraded were as follows:

Carnegie Bessemer rail, 18½ months' service, 0.825 sq. in.
Bethlehem Open-Hearth rail, 27½ months' service, 0.270 sq. in.
Manganese rail, 46 months' service, 0.350 sq. in.

The second trial was started January 30, 1912, with the following results for areas abraded in 12 months:

Bethlehem Open-Hearth rail, 0.19 sq. in.
Manganese rail, 0.08 sq. in.

The conditions of service are the same for the rails compared together, and the Bessemer and Open-Hearth rails are of the ordinary composition already quoted. Three of the Manganese rails of the first trial broke, without any definite or satisfactory cause being assigned, although it was thought it might be on account of faulty heat treatment.

Great Northern Railway:

On the Great Northern Railway, an equal number of rails, as follows, were laid on a 5-degree curve (radius 1,146 ft.), one mile east of Hudson, Minn.:

Manganese rail of the Pennsylvania Steel Company.
Open-Hearth rail of the Pennsylvania Steel Company.
Open-Hearth rail of the Illinois Steel Company.
Open-Hearth rail of the Algoma Steel Company.
Open-Hearth rail of the Bethlehem Steel Company.
Bessemer rail of the Illinois Steel Company.
Bessemer rail of the Algoma Steel Company.
Bessemer rail of the Lackawanna Steel Company.
Ferro-Titanium rail of the Lackawanna Steel Company.

The Ferro-Titanium rail was removed in 23 months, on account of being damaged by a wreck.

The Manganese rail was in the track at the end of 1911, and showed the least wear.

All the other rails were removed at the end of 26 months.

Trials of Manganese rail have been made also by the following administrations, but no data in regard to them have been supplied:

Delaware, Lackawanna & Western Railroad.
Central Railroad Company of New Jersey.
Northern Pacific Railway.
Chicago Junction Railway.
Delaware & Hudson Company.
Erie Railroad.
Chicago & North Western Railway.
Lake Shore & Michigan Southern Railway (New York Central Lines).

RÉSUMÉ.

The use of Manganese steel rail is not well established like that of Manganese steel frogs and switches, but it is still being tried in especially difficult locations, and will in all probability meet with greater favor among railway Engineers when some of the objections have been removed. The principal faults found with it at the present time are:

(1) A number of breakages has been recorded, which is disquieting. The ordinary rolled carbon steel shapes are difficult to reproduce in Manganese steel, on account of the trouble in quenching the metal without the formation of minute cracks, which may subsequently cause fracture.

(2) It is strong and tough, but the hardness is not superior to that of Bessemer steel, and consequently the resistance to battering at the ends of the rails is not altogether satisfactory. Measurements to show this have been made by the Atchison, Topeka & Santa Fe Railway System Engineers, as pictured in Appendix E, Fig. 68. The maximum joint depression or "set" recorded by them up to the present time seems to be 0.10 in., after 3 years and 2 months' service.

(3) The present primary cost, about $90.00 per ton of 2,240 lbs., is so high that, although the resistance to wheel flange abrasion on curves is very great, greater than any other metal tried, the resulting economy is not sufficiently great to be attractive to the railway administrations. It is hoped that additional knowledge and skill in manufacture will overcome this, because the price has already been reduced from $180.00 per ton. This high price was, of course, partly due to the very small quantities produced, and the lack of suitable manufacturing facilities.

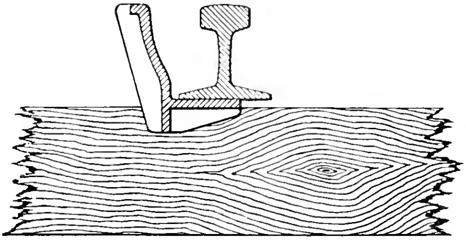
(4) It is impossible to drill or cut it in the field, on account of its great toughness. It is beyond the reach of present tools.

(c) *Manganese Steel for Guard Rails.*

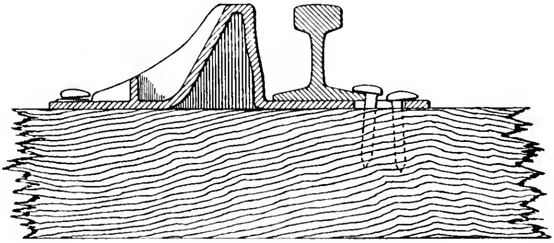
The use of Manganese steel for guard rails has been introduced within the last four or five years, because of the increasing severity of the service which must be performed by a guard rail in guiding the wheels of the modern extremely heavy equipment safely past the frog

Fig. 43. Manganese Steel One-Piece Guard Rail.

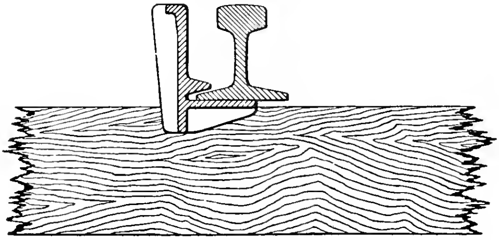
Fig. 44. Manganese Steel One-Piece Guard Rail.



Between Ties Near Ends



On Ties Near Ends



Between Ties at Center

FIG. 45. SECTIONS OF MANGANESE STEEL ONE-PIECE GUARD RAIL.

point. The wearing away of a guard rail made of Bessemer or Open-Hearth rail, the common practice, is very rapid, which causes a frequent adjustment or resetting in order to make it perform its work effectively. A more resistant material will reduce the number of resettings and save labor. The relative economy of the Manganese steel one-piece guard rail is now fairly well determined, but additional trials are being made, and its use is already quite large. The pioneer design is illustrated in Figs. 43, 44 and 45.

II. NICKEL STEEL RAIL.

Between the years 1900 and 1902, some small lots of Bessemer rail with a percentage of nickel were rolled for trial by different administrations, some of which were the Pennsylvania Lines, Baltimore & Ohio Railroad, Bessemer & Lake Erie Railroad, Lehigh Valley Railroad, New York Central Lines and Pennsylvania Railroad.

Pennsylvania Lines:

The Pennsylvania Lines (North West and South West Systems) between March and June, 1903, laid 3,248 tons (2,240 lbs. per ton) or 22 miles of Nickel rail, weighing 85 lbs. per yard, in comparison with Bessemer rail in curved track, some of the curves of which were as sharp as 7 degrees (radius 819 ft.). The two kinds were laid in alternate stretches, the change from Nickel to Bessemer being made at the center of the curve so that one-half of the curve was laid with each kind, in order to have them under the same conditions of traffic, as illustrated in Fig. 46, which is a typical situation plan of a test for the comparison of service, as shown by the relative abrasion or wear of the two kinds of rail.

The average chemical composition of the two kinds of rail was as follows:

TABLE IX.

Pennsylvania Lines	Kind of Steel	Carbon	Phosphorus	Manganese	Silicon	Sulphur	Nickel
North West System..	Nickel....	0.443	0.090	0.833	0.059	0.030	3.46
	Bessemer..	0.498	0.093	0.850	0.105	0.039	
South West System...	Nickel....	0.433	0.090	0.800	0.090	0.030	3.44
	Bessemer..	0.430	0.095	0.910	0.106	0.037	

The price paid per ton for Nickel rail was $54.50 and for Bessemer rail was $28.00, and the scrap Nickel rail was to be received back at $19.60 per ton for the nickel plus whatever might be the market price for old steel rails at the time of return (all 2,240 lbs. per ton).

The outline or profile of the rail section was measured with a Sommer & Rauge (Berlin) instrument, illustrated in Figs. 47 and 48, twice a year, at set places, numbered as illustrated in Fig. 46, in order to determine the rate of abrasion, and ultimately the comparative wear or life. Figs. 49 to 52 show the measurements of the sections having the maximum and

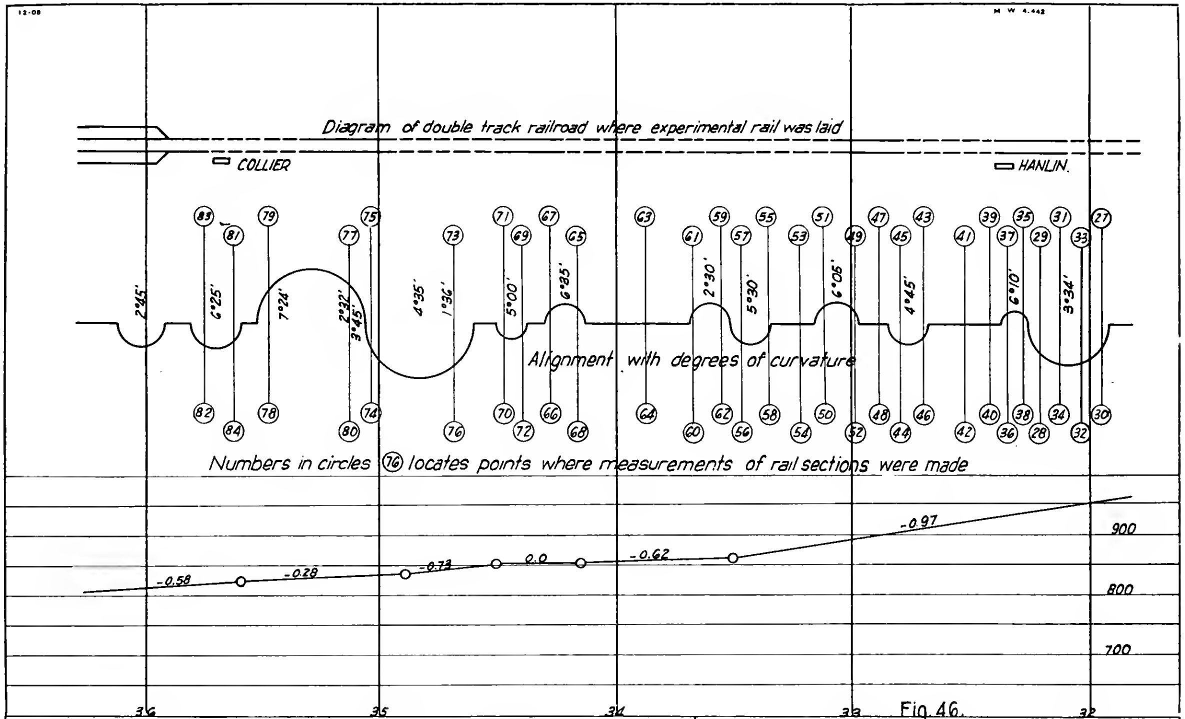


Fig. 46.

Profile showing grades

A...*Bessemer* shown ▬ B. *Nickel* ... Shown ▬

Summary

Month and Year	*March 1905*		*Nov. 1905*		*March 1906*		*June July 1906*		*March 1907*			
Kind of Rail	A	B	A	B	A	B.	A	B.	A	B.	A	B.
Total sq. in abraded	*16.46*	*18.22*	*23.30*	*24.59*	*23.94*	*26.14*	*20.00*	*21.43*	*11.59*	*11.64*		
Aver. sq. in abraded per Section	*0.32*	*0.29*	*0.45*	*0.39*	*0.46*	*0.41*	*0.49*	*0.41*	*0.58*	*0.43*		
Percentage of Area abraded to total Area of Head.	*9.2*	*8.1*	*12.8*	*11.1*	*13.1*	*11.7*	*14.0*	*11.7*	*16.6*	*12.3*		

PENNSYLVANIA LINES
WEST OF PITTSBURGH.
Pittsburgh Div
Location Diagram
of
85 lb. A.S.C.E. Carnegie Bessemer & Nickel Rails
LAID IN 19*03* REMOVED IN 19*06 & 1907*
Between *Hanlin* and *Collier*
Office of Chief Engineer M of W *S.W.* System
Scale 1 in. = 1 m Date *April 1909*

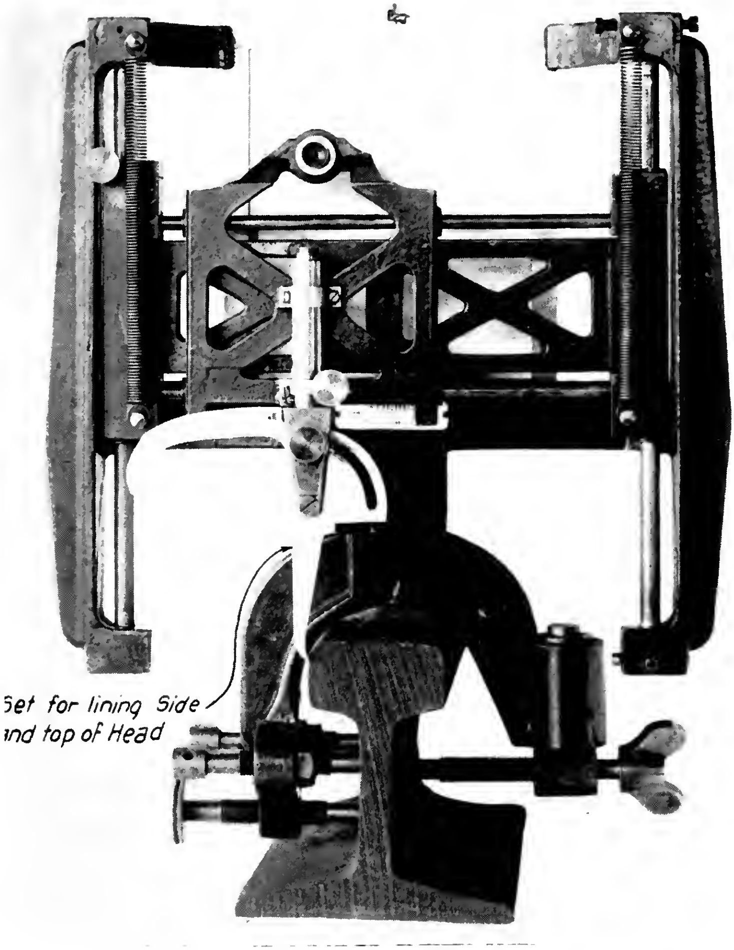
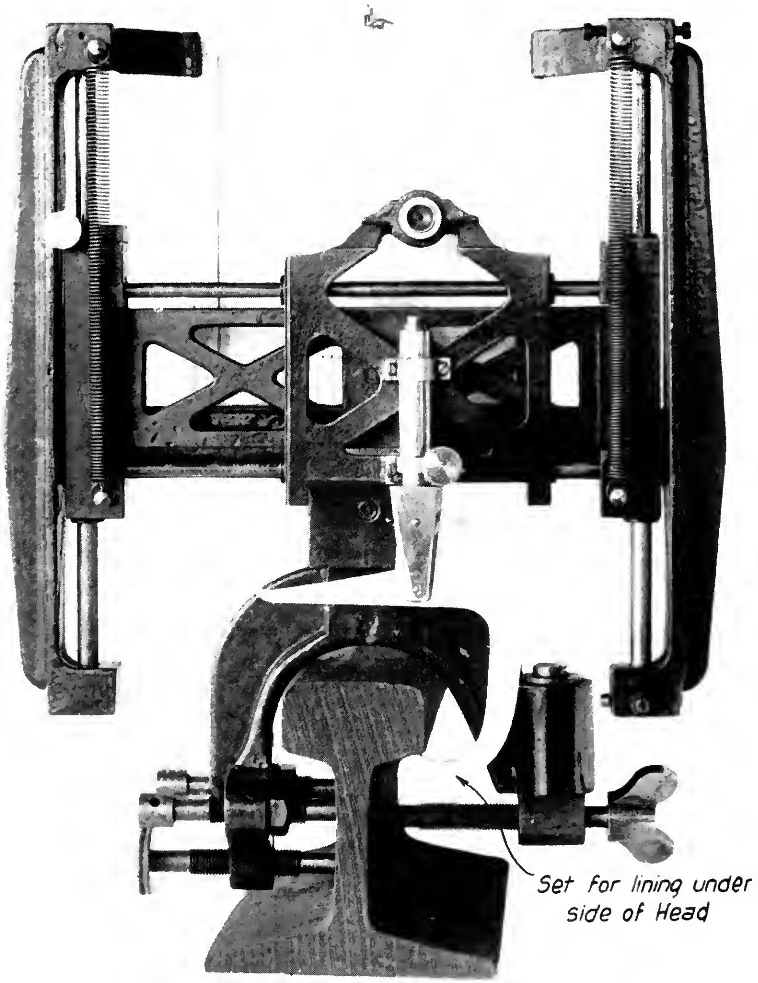


FIG. 47. INSTRUMENT FOR MEASURING "PROFILE" OR "SECTION" OF RAIL WHILE IN TRACK.

(Manufactured by Sommer & Range, Berlin.)



Set for lining under side of Head

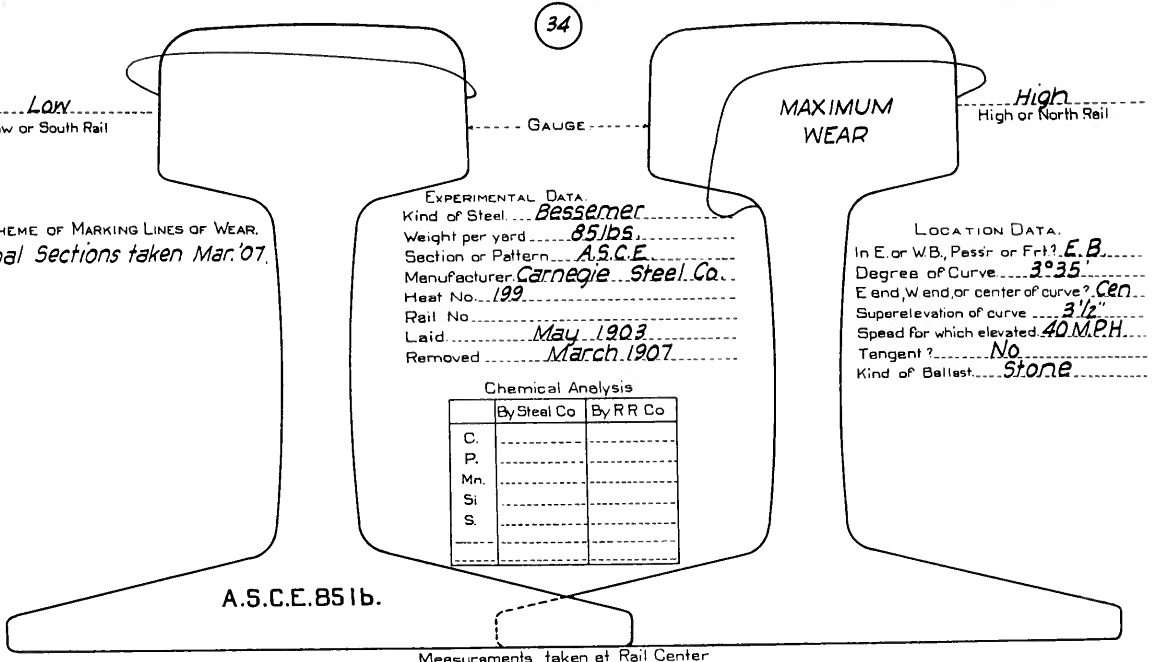
FIG. 48. INSTRUMENT FOR MEASURING "PROFILE" OR "SECTION" OF RAIL WHILE IN TRACK.

(Manufactured by Sommer & Runge, Berlin.)

12·08

MW 4.445

No showing Location in Track.



Scheme of Marking Lines of Wear.
—— Final Sections taken Mar.'07.

Experimental Data.
Kind of Steel ... Bessemer
Weight per yard ... 85 lbs.
Section or Pattern ... A.S.C.E.
Manufacturer Carnegie Steel Co.
Heat No. 199
Rail No ...
Laid ... May 1903
Removed ... March 1907

Chemical Analysis

	By Steel Co	By R R Co
C.		
P.		
Mn.		
Si		
S.		

Location Data.
In E. or W.B., Pess'r or Frt.? E.B.
Degree of Curve ... 3°35'
E end, W end, or center of curve? Cen.
Superelevation of curve ... 3½"
Speed for which elevated 40 M.P.H.
Tangent? ... No
Kind of Ballast ... Stone

Measurements of Area Abraded

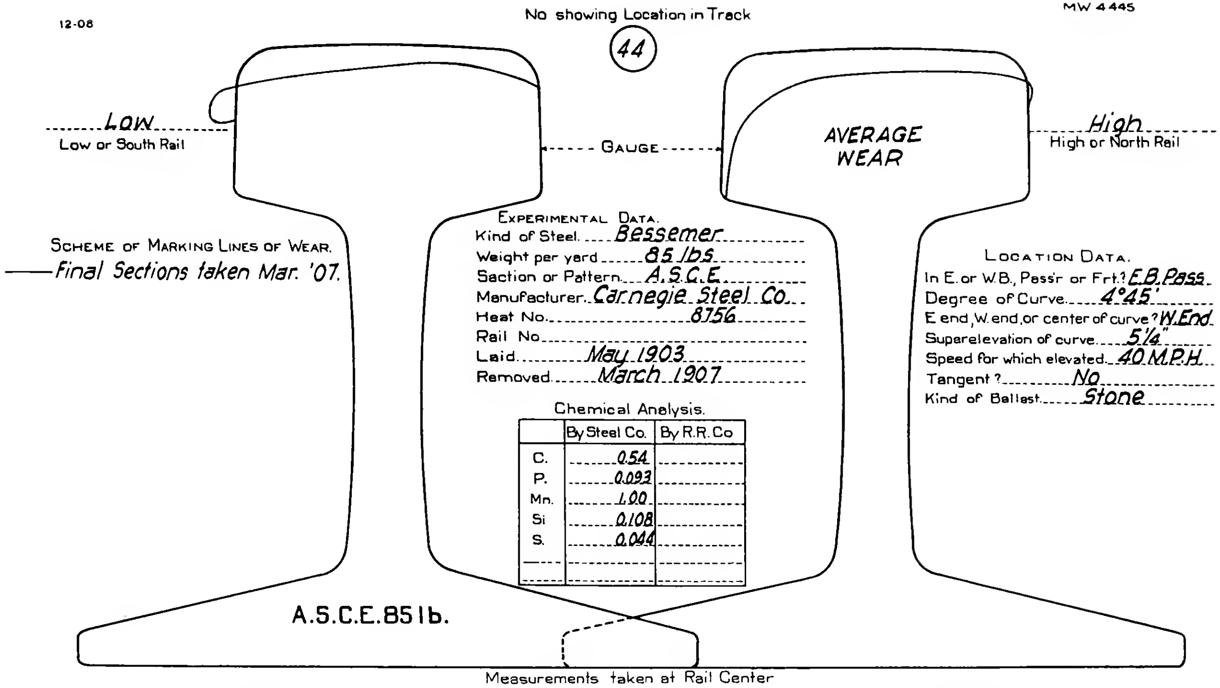
Date of Measurement	Sq. in. Abraded			
	Low Rail		High Rail	
	Area Abraded	Diff.	Area Abraded	Diff.
Mar. '05	.27		.52	
Nov. "	.39	.12	.99	.47
Mar. '06	.48	.09	.99	.00
July "	.49	.01	1.02	.03
Mar. '07	.64	.15	1.26	.24

Fig. 49.

PENNSYLVANIA LINES
WEST OF PITTSBURGH.
Pittsburgh Div.
Diagram Showing Lines of Wear
of
85 lb. A.S.C.E. Carnegie Bess. Rail
Laid in 1903 ... Removed in 1907
Between ... Hanlin ... and Collier
Office of Chief Engineer M. of W. S.W. System.
Scale Full Size. Date April 1909.

12-08

MW 4445



Experimental Data.

Kind of Steel. Bessemer

Weight per yard 85 lbs

Saction or Pattern A.S.C.E.

Manufacturer. Carnegie Steel Co.

Heat No. 8756

Rail No.

Laid May 1903

Removed March 1907

Chemical Analysis.

	By Steel Co.	By R.R. Co
C.	0.54	
P.	0.093	
Mn.	1.00	
Si	0.108	
S.	0.044	

Location Data.

In E. or W.B., Pass'r or Frt.? E.B. Pass.

Degree of Curve 4°45'

E end, W. end, or center of curve? W. End

Superelevation of curve 5¼"

Speed for which elevated 40 M.P.H.

Tangent? No

Kind of Ballast Stone

Measurements of Area Abraded

Date of Measurement.	Sq in Abraded.			
	Low Rail		High Rail	
	Area Abraded	Diff.	Area Abraded	Diff.
Mar. '05.	.21		.39	
Nov. " .	.38	.17	.53	.14
Mar. '06.	.40	.02	.54	.01
July "	.41	.01	.55	.01
Mar. '07.	.51	.10	.61	.06

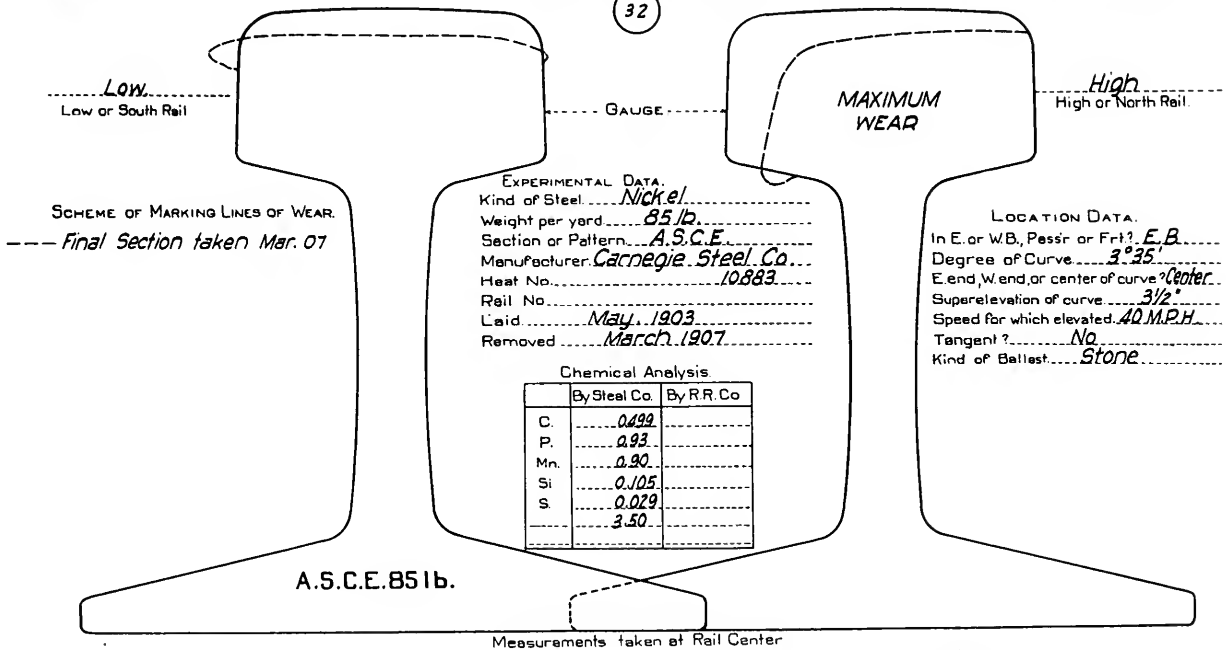
Fig. 50.

Pennsylvania Lines
West of Pittsburgh.
Pittsburgh Div.
Diagram Showing Lines of Wear
of
85 lb. A.S.C.E. Carnegie Bess. Rail
Laid in 19 03 Removed in 19 07
Between Hanlin and Collier
Office of Chief Engineer M. of W. S.W. System.
Scale Full Size. Date April 1909

12-08

MW 4.445

No showing Location in Track. ㉜



Scheme of Marking Lines of Wear.
--- Final Section taken Mar. 07

Experimental Data.
Kind of Steel Nickel
Weight per yard 85 lb.
Section or Pattern A.S.C.E.
Manufacturer Carnegie Steel Co.
Heat No. 10883
Rail No.
Laid May. 1903
Removed March 1907

Chemical Analysis.

	By Steel Co.	By R.R. Co
C.	0.499	
P.	0.93	
Mn.	0.90	
Si	0.105	
S.	0.029	
	3.50	

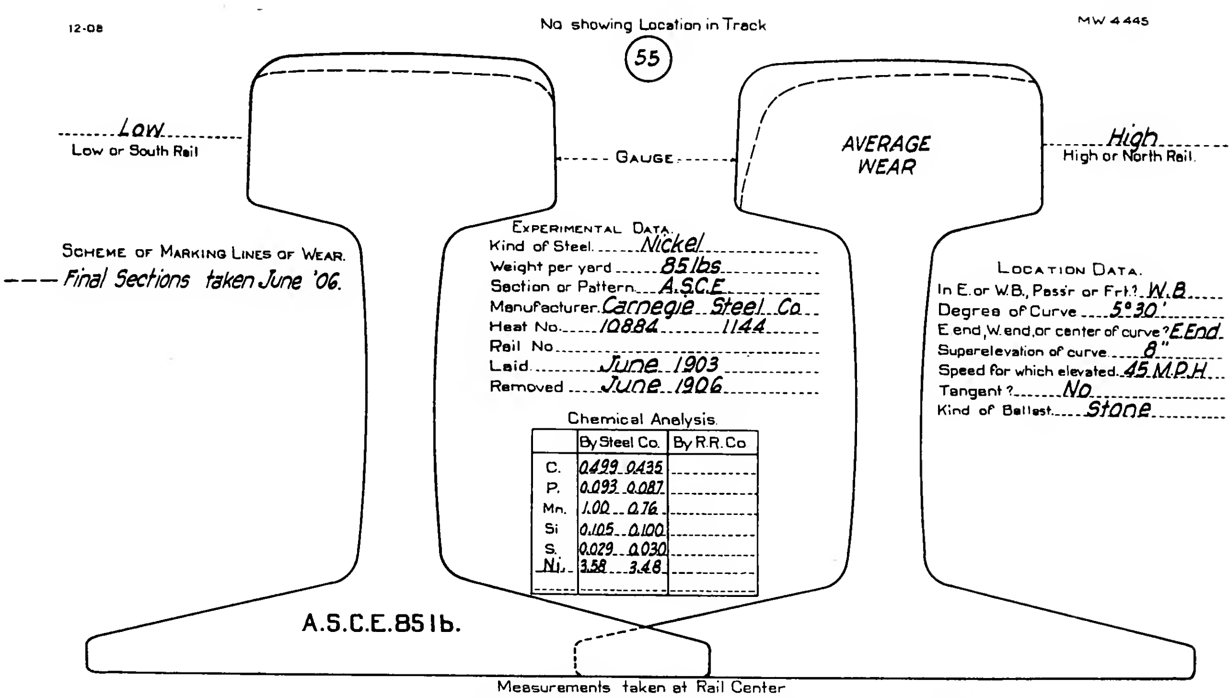
Location Data.
In E. or W.B., Pass'r or Frt.? E.B.
Degree of Curve 3°35'
E. end, W. end, or center of curve? Center
Superelevation of curve 3½"
Speed for which elevated 40 M.P.H.
Tangent? No
Kind of Ballast Stone

Measurements of Area Abraded

Date of Measurement	Sq in Abraded			
	Low Rail		High Rail	
	Area Abraded	Diff.	Area Abraded	Diff.
March '05	.20		.42	
Nov. '05	.38	.18	.84	.42
Mar. '06	.41	.03	.85	.01
July '06	.41	.00	.85	.00
Mar. '07	.53	.12	.95	.10

Fig. 51

PENNSYLVANIA LINES
WEST OF PITTSBURGH.
Pittsburgh Div.
Diagram Showing Lines of Wear
of
85 lb. A.S.C.E. Carnegie Nickel Rail
Laid in 1903 Removed in 1907
Between Hanlin and Collier
Office of Chief Engineer M. of W. S.W. System.
Scale Full Size. Date April 1909



Experimental Data.
Kind of Steel *Nickel*
Weight per yard *85 lbs*
Section or Pattern *A.S.C.E.*
Manufacturer *Carnegie Steel Co.*
Heat No. *10884 1144*
Rail No.
Laid *June 1903*
Removed *June 1906*

Chemical Analysis.

	By Steel Co.	By R.R. Co.
C.	0.499 0.435	
P.	0.093 0.087	
Mn.	1.00 0.76	
Si	0.105 0.100	
S.	0.029 0.030	
Ni.	3.58 3.48	

Location Data.
In E. or W.B., Pass'r or Frt.? *W.B.*
Degree of Curve *5° 30'*
E end, W. end, or center of curve? *E End.*
Superelevation of curve *8"*
Speed for which elevated *45 M.P.H.*
Tangent? *No*
Kind of Ballast *Stone*

Measurements of Area Abraded

Date of Measurement.	Sq. in. Abraded. Low Rail Area Abraded	Sq. in. Abraded. Low Rail Diff.	Sq. in. Abraded. High Rail Area Abraded	Sq. in. Abraded. High Rail Diff.
Mar. '05.	.22		.42	
Nov. '05.	.33	.11	.44	.02
Mar. '06.	.34	.01	.46	.02
June '06	.34	.00	.46	.00

Fig. 52.

PENNSYLVANIA LINES
WEST OF PITTSBURGH.
Pittsburgh Div.
Diagram Showing Lines of Wear
of
85 lb. A.S.C.E. Carnegie Nickel Rail
Laid in 19*03* Removed in 19*06*
Between *Hanlin* and *Collier*
Office of Chief Engineer M. of W. *S.W.* System.
Scale Full Size. Date *April 1909*

TABLE X.

TABLE OF NICKEL AND BESSEMER STEEL RAIL FAILURES

Kind of Rail	System	Failures								Broken	Split Heads	Crushed Heads	Other Defects	Total Fail-ures	Ratio of Rails laid to 1 Failure
		1903	1904	1905	1906	1907	1908	1909	1910						
Nickel	North West	22	46	53	51	54	90	28	29	29	95	133	116	373	9
Bessemer	" "	16	34	32	40	30	22	14	2	29	53	37	71	190	18
Nickel	South West		6	19	16	1				4	19	19		42	86

average abrasion for the test selected for illustration. At some points the Nickel rail showed some slight superiority in life, but the average of all the tests pointed to the fact that the life of each, and hence resistance to abrasion, was practically the same.

The removals began in 1906, and were continued until 1911 when the last was removed, these differences being due to the differences in degree of curvature and amount of traffic.

It is also necessary to compare the relative safety by keeping a record of the failures, and these are given in Table X.

To test the strength and ductility of the Nickel steel, 48 pieces struck by a weight of 2,240 lbs., falling from a height of 17 ft. 10 in., the supports for the test pieces being spaced 3 ft. apart, gave a deflection of 1½ to 2¾ in., the average being 1 15/16 in. Only one piece broke.

This series of tests shows that the Nickel rail cost almost twice as much as the Bessemer, lasted only about the same length of time under similar conditions, and was less strong and safe, having a very small ratio of rails laid to one failure.

Bessemer & Lake Erie Railroad:

The Bessemer & Lake Erie Railroad reported that the Nickel steel rails tried by that company did not give satisfactory results. The chemical constituents were carbon 0.35 to 0.45, phosphorus 0.04, manganese 0.65 to 0.80, silicon 0.05 to 0.15, nickel 3.00 to 5.00 per cent. The physical properties were as follows:

TABLE XI.

Kind of Steel	Ultimate Strength pounds per square inch	Elastic Limit pounds per square inch	Elongation per cent in 2 inches	Reduction of area, per cent	Brinell Hardness
Nickel Rails...........	135,000	80,000	15	25	220
Bessemer Rails.........	115,000	75,000	15	18	220
Open-Hearth Rails.....	115,000	75,000	16	20	220

New York Central Lines:

On the New York Central & Hudson River Railroad, 200 tons of Nickel rail, 80 lbs. per yard, were laid in 1903, and 100 tons of 100 lbs. per yard in 1905. Both lots were Bessemer steel with 0.40 to 0.50 carbon and 3½ per cent. nickel. The 80-lb. rails after a short time of service commenced to flow laterally on the curves, and large flakes were detached from the heads, though the loss of metal did not take place quite so rapidly as in the case of the plain Bessemer rails laid with them for comparison. The flow from the heads of the 100-lb. rails was rapid, great slivers being detached on the curves after a few months' service.

Baltimore & Ohio Railroad:

One of the administrations which has been most assidious and painstaking in making trials of Special Steels is the Baltimore & Ohio Railroad Company, and several of its records of comparative tests of Nickel,

Nickel-Chromium and Titanium-treated rail with Bessemer and Open-Hearth rail are given in Appendix F, together with a description of the methods adopted.

Test No. 11 is a comparison between Nickel steel and Bessemer steel rails, the tables in Appendix F showing the chemical composition of both. The amount of nickel is 3.32 per cent. The diagram shows that for the first 28 months the Nickel rail wore away faster than the Bessemer, but after that Bessemer wore away faster in increasing ratio, and at the end of the trial this abrasion or wear had amounted to 21 per cent. greater. The test-rails were laid on the outside of the curve only, as shown in the location diagram at the top.

The result of this test seems to be more favorable to Nickel rail than those previously described.

III. NICKEL-CHROMIUM STEEL RAIL.

Baltimore & Ohio Railroad:

The next step was to add Chromium, a hardener, to the Nickel steel rail, and Tests Nos. 911, 913, 914, 915 and 916 (Appendix F) are of that alloy (only Nos. 911 and 915 illustrated).

The Nickel-Chromium rail was of the usual Open-Hearth steel with 2½ per cent. Nickel and 0.50 to 0.90 per cent. Chromium, and the comparisons were made with ordinary Open-Hearth rail, and with Bessemer steel rails in addition in Tests Nos. 915 and 916.

The hardening effect of the Chromium is clearly exhibited in the diagrams of all the tests, and the inferiority of the Bessemer rail to either of the others is plainly evident. In the case of the "outside" or "high" rails the abrasion of the Open-Hearth rail was 10, 13, 35, 38 and 55 per cent. greater in the different tests than the Nickel-Chromium alloy; and in the case of the "inside" or "low" rails the abrasion of the Open-Hearth rails was 14, 22, 37, 58 and 62 per cent. greater.

It will be noticed in the location diagram of Test No. 911 that there were 20 rails of each kind in the test, on a 9-degree 20-minute curve (radius 615 ft.), and that 5 Nickel-Chromium and no Open-Hearth rails broke, while 1 Nickel-Chromium and 4 Open-Hearth rails had crushed heads. This shows that the greater resistance to abrasion of the Nickel-Chromium rail is at the expense of greater brittleness.

In Test No. 913, with 16 rails of each kind in the test, on a 7-degree 32-minute curve (radius 761 ft.), 5 of the Nickel-Chromium rails broke and one had a split head, while none of the Open-Hearth rails failed.

In Test No. 914, with 19 Nickel-Chromium rails and 15 Open-Hearth rails, on a 4-degree 30-minute curve (radius 1,274 ft.), 3 of the former broke and two had split heads, while 2 of the latter broke and one had a split head.

In Test No. 915, with 18 Nickel-Chromium rails and 23 Open-Hearth rails, on an 8-degree curve (radius 717 ft.), 5 of the former broke and 1 of the latter had a split head.

In Test No. 916, with 19 Nickel-Chromium and 21 Open-Hearth rails, on a 6-degree curve (radius 955 ft.), there is no record of any failures.

All of the tests show that for greater resistance to the forces of the abrasive action of wheels the addition of Nickel and Chromium to Open-Hearth steel rails in the quantities and in the manner used is very desirable, but is undesirable on the score of safety.

Central Railroad Company of New Jersey, and Erie Railroad:

Similar unsatisfactory service has been given by Nickel-Chromium rail on the Central Railroad of New Jersey, where the breakages were 1 in 20 rails laid, and on the Erie, where they were 1 in 78 rails laid.

Lehigh Valley Railroad:

On the Lehigh Valley Railroad the results of trials were the same in regard to failures, but the rate of abrasion was slower than for ordinary steel under the same conditions, the difference being as high as 70 per cent. in some cases. The composition of the rails was carbon 0.50 to 0.60, phosphorus not over 0.04, manganese 0.60 to 0.90, nickel 2.0, chromium 0.4 to 0.75 per cent.

RÉSUMÉ.

It is evident, therefore, from these trials that Nickel and Chromium introduced into the rail steel in the quantities and proportions used, and in the manner adopted by the manufacturers, gave quite unsatisfactory results, but there is a natural ore containing Nickel and Chromium in different proportions from those cited from which rail steel is being made, which is much more satisfactory.

IV. HIGH CARBON STEEL RAIL.

Pennsylvania Lines:

The only administration which has sent in any information about high-carbon steel rails is the Pennsylvania Lines, and the experiments carried on by that company have been described in Appendix G. They have given excellent service from the standpoint of resistance to the abrasive action of wheels, lasting more than twice as long as ordinary Bessemer and Open-Hearth rail, under similar conditions of traffic, but have developed serious fault from the standpoint of safety, as the breakages have been numerous, 1 in 14 rails laid, and, most alarming of all, the silvery oval spot, called the "transverse fissure," has been found in the head. The carbon was very high for rail weighing 85 lbs. per yard, from 0.80 to 0.88 per cent., and in addition Nickel and Chromium were present, making a very hard and brittle material, and it is not known what the effect might be in the case of rails of heavier section. It is customary to increase the percentage of carbon in the heavier rails. It is evident that the proportions used in the 85-lb. section were too high.

B. SPECIAL PROCESS STEELS.

TITANIUM, ALUMINUM, VANADIUM AND SILICON IN STEEL RAILS.

Silicon belongs strictly under the head of "A. Special Steels," but is discussed in connection with Titanium, Aluminum and Vanadium because its effects are similar.

It has come to be fully recognized by American railway Engineers that sound ingots are essential for the production of sound rails, and, although nearly all railways are opposed to interference in the processes of manufacture, believing instead in the principle of specifications for rails which set forth clearly and concisely the physical qualities which they must have, and the methods of conducting tests which will prove that the product offered for sale does or does not possess those qualities, nevertheless, it is the universal practice in the United States and Canada to specify the chemical constituents as well, and a few introduce other clauses relating to mill practice, such as holding in the ladle for a specified time, size of teeming nozzle, length of ingots, etc., as described in Appendix H, which gives the results of practice and experiments on the New York Central Lines.

While such requirements have generally been excluded from specifications, yet the subject of mill practice has been and is being widely studied by the railway Engineers, and many of their studies will be found in the annual Proceedings of the American Railway Engineering Association and of other technical societies.

The subject of sound ingots has been dealt with in the above Proceedings, Vol. 14, year 1913, page 449 et seq., and in "Transactions of the American Institute of Mining Engineers" for the meeting of February, 1913, but the principal papers on which these discussions were based were from the "Journal of the Iron and Steel Institute," No. II, for 1912, and for May, 1913.

Mr. Bradley Stoughton has admirably summed up our available information on ingot defects, and what follows is largely taken from his article.*

These defects are phosphorus, which has been mastered in the Open-Hearth steel process, slag inclusions (sub-divided into solid oxidized enclosures and entrained sulphides), blowholes, combined gases, pipes and segregation.

The purpose of the addition of aluminum, silicon, ferro-titanium, vanadium and other "physics" or "cleansers," is to remove as many of the defects enumerated as possible. In doing this, aluminum and titanium pass off with the impurities and leave no trace behind in the finished rail.

SLAG ENCLOSURES.

The oxides of iron, silicon, manganese, aluminum, phosphorus and calcium originate directly or indirectly from the oxidation of iron and its

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*Railway Age Gazette, Feb. 7, 1913, p. 245.

constituents during the process of conversion into steel, and are probably in the liquid bath in the form of emulsified particles which will be held in suspension for a long time unless coagulated and removed by gravity, and when this occurs it is for the most part during the recarburizing of the steel. Perhaps the oxide of iron at least may be soluble, and the other oxides which originate chiefly because silicon, manganese, aluminum, etc., are added to decompose iron oxide, are themselves entangled before they have a chance to escape.

"Acid steel seems to be less liable to the defect than basic steel, but slag inclusion is an impurity which must be reckoned with in all steel which has been purified by oxidation, and especially in all steel which has been recarburized.

"These foreign bodies are dangerous in their influence not only in causing steel to be frequently brittle and unreliable, but more especially in creating microscopic fissures and flaws (generally in the interior of the steel), which continuously develop under the strains of service and often cause the sudden rupture of steel which withstood a severe test for acceptance. This ill effect of the foreign oxides is dependent not so much on their size or amount as on their mode of occurrence between the pearlite crystals of the steel, where they lessen the toughness of hypo-eutectic steel by interfering with the intercrystalline ferrite upon which this toughness so largely depends, and where they increase the fragility of hypo-eutectic steel due to the intercrystalline cementite. This mode of occurrence is probably the reason why slag enclosures are more dangerous to high carbon steels."

A very important property of these oxide enclosures is their melting-point in relation to the melting-point of steel, because if the enclosures become solid before the steel is frozen, their escape from the bath is rendered more difficult. Silica and some of the silicates, especially if made less fusible by the presence of aluminum, have a higher melting-point than mild steel, and often become entangled therein. The fluxing property of titanium oxide on silicates and other oxides is therefore the cause of its well-known effect in eliminating slag enclosures from steel ingots. It assists them to coalesce and this removes them, but the bath should be left for at least 3 minutes in Bessemer steel and 8 to 10 minutes in Open-Hearth steel, after the titanium addition, in order that this washing out of the enclosures may be completed. Manganese oxide, manganese silicate and manganese sulphide are the commonest of the solid enclosures.

Mr. Stoughton agrees with Dr. Dudley in condemning the use of aluminum, which is excluded from the New York Central Lines rail specifications, in the following words:

"The addition of aluminum for recarburizing is seen to be dangerous practice, because aluminum not only forms a deleterious enclosure by itself, but it increases the viscosity of other solid enclosures and this hinders or prevents their coalescence and removal. . . . To add aluminum in the ladle is worse than adding it in the furnace, and its addition in the ingot may be followed by grave consequences. Deoxidation by aluminum in ingots is a practice which can only be required when the previous manufacture of the steel was improperly or neglectfully performed; such addition is wrong and is now forbidden by specifications of several large consumers."

SULPHIDE ENCLOSURES.

Sulphides entrained in steel ingots produce an effect like that discussed in the case of oxide enclosures. Manganese sulphide is much less injurious to the properties of steel than iron sulphide, so that the addition of manganese to liquid steel, forming manganese sulphide, MnS, will lessen the evil, and will also, to a limited degree, bodily remove some of the entrained sulphide if the bath is left in a quiescent state for a short time. Having a much higher freezing temperature than the iron-sulphur eutectic, the manganese addition also moderates segregation, but it is still an evil, making steel somewhat red-short, initiating fissures and cracks, and causing the corrosion of steel by producing local differences of electric potential. The basic processes of steel manufacture have been the greatest remedy for sulphide evils by removing sulphur almost to harmless traces, provided the resulting basic steel be thoroughly deoxidized and quieted, in order to limit segregation, and not interefere with the perfect welding of blowholes.

BLOWHOLE PREVENTION.

The gases ordinarily found in blowholes are: Carbon dioxide, carbon monoxide, hydrogen, nitrogen and hydro-carbons. To prevent them they must either be eliminated entirely from the steel, together with the agents which form them anew, or else they must be partially eliminated, and partially caused to dissolve by increasing the solvent power of the steel for them. Iron oxide is the agent which chiefly forms blowhole gases anew, because it reacts with carbon when the temperature falls, and particularly when the metal is so viscous that the gas bubbles cannot escape from it. The complete elimination of iron oxide is therefore the secret of blowhole prevention. The best deoxiders are aluminum and titanium, but vanadium and silicon are likewise effective, and manganese and carbon, by deoxidizing the metal, greatly lessen the tendency to form blowholes. Silicon has the disadvantage, when used in connection with a basic process, that the first ingots may be quite free from blowholes, while the latter ones may be porous on account of the absorption of the silicon in the interval by the basic slag. "If steel is so thoroughly deoxidized that no blowholes form, the volume of the pipe will be correspondingly increased, and, conversely, if a sufficient number of blowholes is allowed to form, the pipe may be almost entirely avoided."

GASES IN STEEL.

"The same gases found in blowholes are also found occluded in the steel, or combined with it, where they reduce both the strength and ductility. This is especially true of hydrogen and nitrogen, as well as oxygen. Hydrogen is still an unconquered impurity, except that silicon, aluminum and titanium cause it to remain dissolved in the steel instead of forming a blowhole. Nitrogen is removed in large part by titanium, which has a greater affinity for this inert element than any other known substance, whose effect on the steel is embrittling and harmful. Vanadium, too, perhaps, causes a partial elimination of this gas, and both titanium and vanadium seem able to get rid of oxygen in both of its gaseous forms, and the same result is obtained by a super-refining in an electric furnace."

PIPES.

"Titanium, vanadium, aluminum, silicon, and any other element which decreases blowholes, will increase the volume and depth of pipe, that is, the purer the steel the larger will be the pipe. Aluminum and silicon have a special influence in increasing the depth of piping on account of their causing the steel to pass quickly from the liquid to the solid state, while titanium and vanadium tend to lengthen the period of solidification and thus decrease the depth of the pipe in relation to its volume. Aluminum has a further ill effect on the depth of the pipe in that, if added in too large proportions, it segregates and may produce a pipe extending even from top to bottom of the ingot." It would appear, therefore, that these deoxidizers would be most valuable in connection with some method for removing the deep pipe from the top of the ingots, such as the Hadfield method of heating the top of the ingot, the Talbot method of semi-liquid compression in a rolling mill, or the Goldschmidt method of heating and stirring by thermit.

SEGREGATION.

"The most beneficial remedy for segregation is to deoxidize and quiet the steel, and researches have proved that aluminum and titanium are especially effective in this respect. Manganese and silicon themselves segregate and therefore are more of a detriment than a remedy. Vanadium is quieting to steel, and, for this reason, is probably a preventive of segregation."

The comparative influence of different "corrective agents" on ingot defects is given by Mr. Stoughton in the following table:

TABLE XII.

INFLUENCE OF CERTAIN "CORRECTIVE AGENTS" ON DEFECTS IN STEEL INGOTS, IN THE RELATIVE ORDER OF THEIR EFFECTIVENESS.

Prevents Blowholes	Removes Oxides of Iron and Manganese	Removes all Oxides and Slag Enclosures	Removes Nitrogen	Breaks up and removes Sulphide of Iron	*Causes a Pipe*	Hinders Segregation
1.Aluminum	1.Titanium	1.Titanium	1.Titanium	1.Manganese	1.*Aluminum*	Aluminum
2.Titanium	2.Silicon (weakly)	*Hinders removal of all these enclosures*	2.Vanadium (?)	2.Titanium (?)	2.*Silicon*	Titanium
3.Silicon	*Hinders this removal*	1.*Aluminum*			3.*Titanium*	Vanadium
4.Vanadium	1.*Aluminum*				4.*Vanadium*	*Promotes segregation*
5.Manganese	2.*Manganese*				5.*Manganese*	1.*Manganese* 2.*Silicon (sometimes)*

Note.-- Words printed in italics indicate a detriment to the steel.

Having set forth at some length in the foregoing the various reactions and effects of the deoxidizers, titanium, aluminum and silicon, in the bath of molten steel and in the ingots, some attention will now be given to the results of the practical trial of rails manufactured from steel in which they were introduced.

I. TITANIUM.

New York Central Lines:

The administration which first began the use of ferro-titanium in steel from which rails were made is the New York Central Lines, and the history of this use and the results of the trials have been set forth in Appendix H from information obtained from P. H. Dudley, C.E., Ph.D. That administration is well satisfied with the titanium treatment, principally by reason of the more homogeneous and more ductile metal, because the difference in abrasive resistance between plain Open-Hearth steel rails and Titanium-treated Open-Hearth steel rails is very small.

Delaware & Hudson Company:

Other administrations have made experimental use of Titanium-treated steel rails, one of which is the Delaware & Hudson Company, which obtained 250 tons of 90-lb. A.S.C.E. Open-Hearth rail treated with 0.1 per cent. metallic titanium, and compared it with the standard Open-Hearth steel rails on curves with the same traffic. The carbon appeared to be somewhat higher in the Titanium-treated rails, but the latter were on 4-degree (radius 1,433 ft.) and 4-degree 8-minute (radius 1,387 ft.) curves, as compared with a 3-degree 31-minute (radius 1,630 ft.) curve for the former. With these differences the Titanium-treated rails showed considerably increased resistance to abrasion, 51 per cent., as given in detail in Fig. 53, which shows the sections most closely representing the average abrasion, the measurements for which were made October 20, 1913.

Lehigh Valley Railroad:

The results of trials on the Lehigh Valley Railroad are indicated by Fig. 54, which shows the nearest representations of the average wear for all sections. The carbon is higher in the Titanium-treated rail, but the latter is laid on a little sharper curve. Under these circumstances the superiority in resistance to abrasion is 54 per cent. for the Titanium-treated rail. That company has used more than 57,000 tons of such rail.

Northern Pacific Railway:

The Northern Pacific Railway has purchased 13,133 tons of Bessemer rail, treated with 0.1 per cent. of metallic titanium, having the following chemical composition compared with Open-Hearth rail:

TABLE XIII.

Chemical Elements	Titanium-treated Steel	Open-Hearth Steel
Carbon	0.45 to 0.55	0.62 to 0.75
Phosphorus, not to exceed	0.10	0.04
Manganese	0.70 to 1.00	0.80
Silicon	0.05 to 0.20	0.05 to 0.20

Explanation of Figs. 53 and 54.

Fig 53. Nos. 101 and 102 TITANIUM-TREATED OPEN-HEARTH
0.1% Metallic-Titanium used
Location, First Curve South of Howes Cave Station, North Bound Trk
Curvature 4°, Grade 22% Down
Laid in Track July 1911.
Measured November 2, 1911, May 1, November 4, 1912, October 20, 1913.
Wear in Square Inches in 27 Months
High 30 Low .17 Average .235

Numbers 202 and 203
STANDARD OPEN-HEARTH
Location Second Curve North of Mile Post 41.
Curvature 3°30', Grade 22% Down.
Laid in Track June 1911
Measured November 2, 1911, May 1, November 4, 1912, October 20, 1913
Wear In Square Inches in 28 Months
High .40 Low .17 Average .285

Number 3 and 4, TITANIUM-TREATED OPEN-HEARTH
0.1% Metalic-Titanium used
Location, in Curve at Howes Cave Station, North Bound Track.
Curvature 4°8', Grade 27% Down
Laid in Track July 1911.
Measured November 2, 1911, May 1, November 4, 1912, October 20, 1913
Wear in Square Inches, in 27 Months
High ·25 Low .13 Average .19

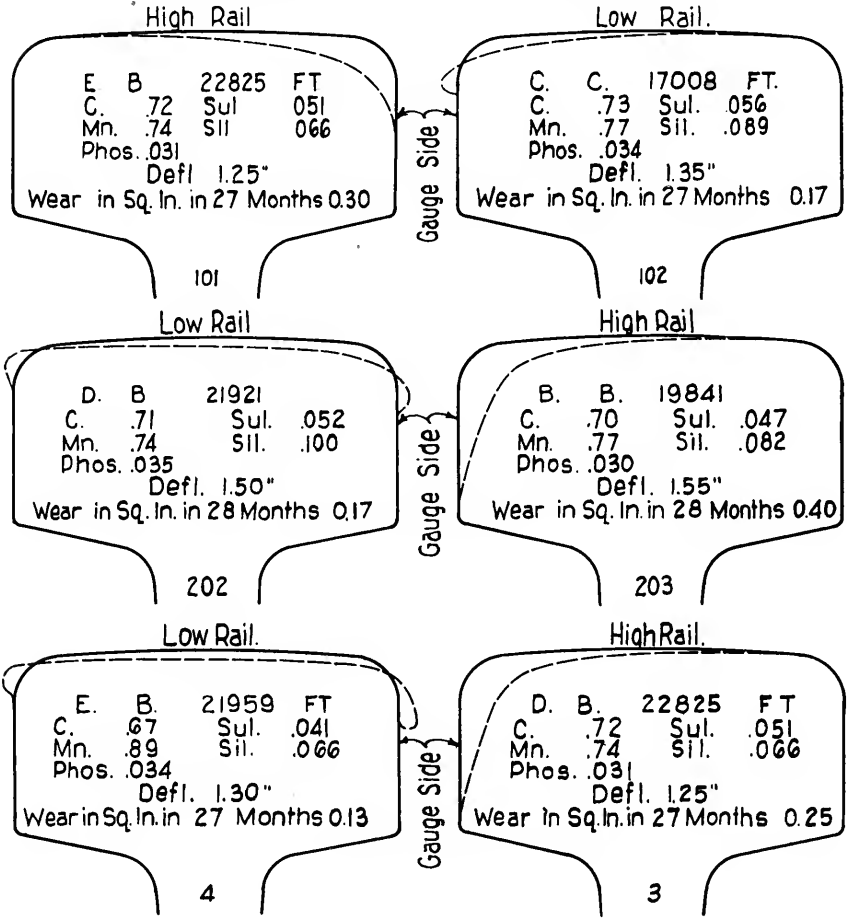
Fig 54 Number 4, TITANIUM-TREATED OPEN-HEARTH.
Located, near Moosehead Pa
High Rail, East Bound Track, Gauge 4'-8¼" Super elevation 4"
Curvature 6° 16', Grade 1.3% Down.
Rail marked Bethlehem OH 90 A. FT VI 1910
ASCE 90 lbs. per Yard.
Laid August, 1910, Measured April 10, 1912
In Service 20 Months

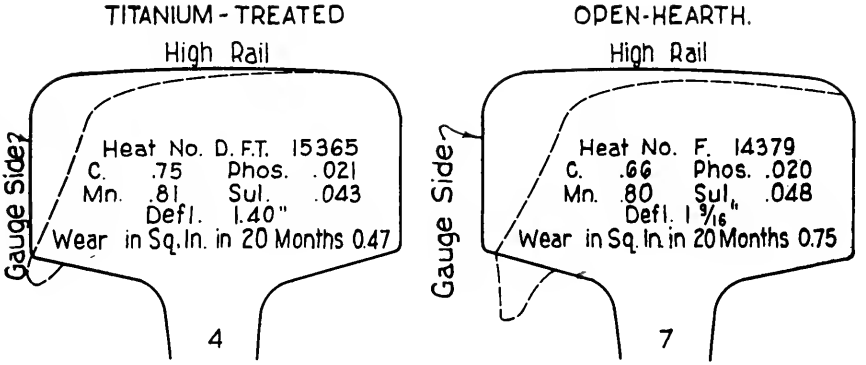
Number 7, STANDARD OPEN-HEARTH
Located near Braders
High Rail, East Bound Track, Gauge 4'-8¾" Superelevation 3¾"
Curvature 5° 55', Grade 1.3% Down
Rail marked Bethlehem O.H. 90 A V 1908.
ASCE. 90 lbs. per Yard
Laid August 1910 Measured April 10, 1910.
In Service 20 Months

ABBREVIATIONS

C. Means Carbon Sul Means Sulphur.
Mn. " Manganese. Sil. " Silicon.
Phos " Phosphorus. Defl. " Deflection.
First Lines
1st Letter indicates Position in Ingot
2nd " " Furnace from which Heat was taken
Figures " Heat Number F.T. means Ferro-Titanium

DELAWARE & HUDSON CO.
COMPARATIVE ABRASION
OF TITANIUM TREATED
AND OPEN-HEARTH RAILS
FIG. 53.





ABBREVIATIONS

C.	Means	Carbon.
Mn.	"	Manganese.
Phos.	"	Phosphorus
Sul.	"	Sulphur.
Sil.	"	Silicon
Defl.	"	Deflection
F.T.	"	Ferro - Titanium
The letter in the Heat No	"	Position in Ingot
T.T.O.H.	"	Titanium-Treated Open-Hearth
O.H.	"	Open - Hearth

LEHIGH VALLEY R.R.
Comparative Abrasion of
Titanium-Treated & Open - Hearth Rails.
Figure 54

Although the resistance to abrasion in the track has been found to be slightly better than Open-Hearth, this administration reports that the results have not been good on account of a much higher percentage of piped rails in the nick test than in the ordinary Open-Hearth rails. This simply adds proof to the well-known fact that titanium increases the size of the pipe, rendering additional discard from the bloom necessary, or else the employment of a method for reducing the size of the pipe.

Rock Island Lines:

The Rock Island Lines have, in experimental use, 480 tons of 100-lb. A.R.A. Type A rail (Fig. 61), made from Bessemer steel treated with ferro-titanium, the chemical composition of which is as follows, compared with Open-Hearth and Electric-Process rails:

TABLE XIV.

Chemical Elements	Titanium-treated	Open-Hearth	Electric-Process
Carbon	0.45 to 0.55	0.63 to 0.76	0.50 to 0.65
Phosphorus, not over	0.10	0.04	0.07
Manganese	0.84 to 1.14	0.60 to 0.90	0.50 to 0.80
Silicon	Not over 0.20	Not over 0.20	0.10 to 0.18

At the beginning of 1913, there had been no failures of Ferro-Titanium or Electric-Process rails, while for the Open-Hearth there was 1 failure in 1,008 rails laid.

At the same time the comparative abrasion for 17 months' service was as given in the table below:

TABLE XV.

Kind of Steel	Average square inches of Head Wear	Average per cent of area of head abraded
Titanium-treated	0.016	0.44
Open-Hearth	0.080	2.21
Electric-Process	0.038	1.04

Atlantic Coast Line Railroad:

The Atlantic Coast Line Railroad tried Bessemer rail treated with ferro-titanium, and the failures were 1 in 700 rails laid.

Maine Central Railroad:

The Maine Central Railroad obtained 800 tons of Bessemer rail treated with 0.2 per cent. titanium in 1910, but did not find any difference between it and Bessemer rail in chemical composition, in wear or in breakage.

Terminal Railroad Association of St. Louis:

The Terminal Railroad Association of St. Louis used Bessemer 100-lb. A.S.C.E. rails, treated with titanium, Fig. 55, on sharp curves laid alternately with ordinary Bessemer rails, but found no appreciable difference in resistance to abrasion.

Chicago Great Western Railroad:

On the Chicago Great Western Railroad a comparative test of Bessemer-Titanium, Bessemer and Open-Hearth rails of 85-lb. A.S.C.E. section has been conducted for 26 months, with the result that the average area of head metal abraded is Titanium, 0.079 sq. in.; Bessemer, 0.056 sq. in., and Open-Hearth, 0.075 sq. in., the poorest record being made with the Titanium-treated.

Delaware, Lackawanna & Western Railroad:

Some of the trials conducted by the Delaware, Lackawanna & Western Railroad between Titanium-treated Open-Hearth, Open-Hearth and "Special Premium" Open-Hearth (presumably requiring more than the usual discard) show superiority in abrasive resistance to be with the ordinary Open-Hearth in one case, and with the Titanium-treated in the others.

Lake Shore & Michigan Southern Railway:

The Lake Shore & Michigan Southern Railway (subsidiary of the New York Central Lines) found 100-lb. A.S.C.E. Titanium-treated Bessemer rail to show more abrasion than the same section of ordinary Bessemer rail.

Boston & Maine Railroad:

The Boston & Maine Railroad is conducting a service test at Athol with 85-lb. A.S.C.E. rails of different kinds, laid in September and October, 1910. The results up to the end of 1912 are given in the following table, and are favorable to the Titanium-treated:

TABLE XVI.

The following test is in progress at Athol. The rail is all 85-lb. A.S.C.E., laid in September and October, 1910.

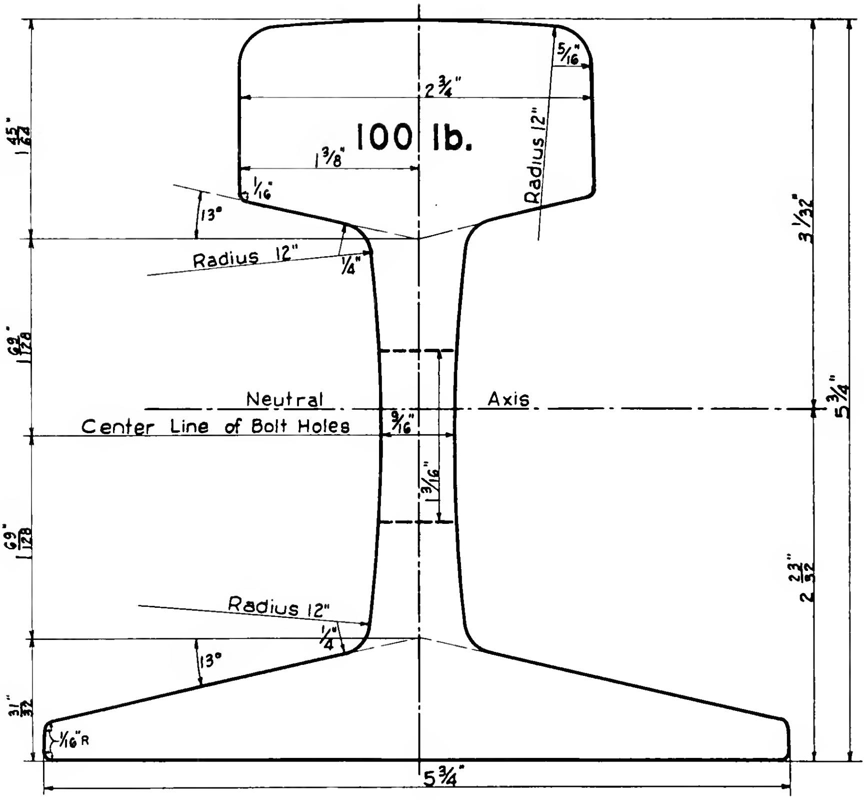
Kind of Rail	Length of Service	Chemical Composition							% of Head Abraded
		C.	P.	Mn.	Si.	F. T.	Chro.	Ni.	
Bethlehem Open-Hearth....	27 mo.	.67	.025	.87	.175				6.46
Maryland Open-Hearth.....	27 mo.	.68	.016	.75-.80	.067		.51	.51	4.99
Lackawanna Open-Hearth...	27 mo.	.68	.017	.90	.144	.15			2.83
Lackawanna Open-Hearth...	27 mo.	.85	.021	.90	.144	.20			3.26
Lackawanna Open-Hearth...	27 mo.	.71	.019	.85	.118				4.19
Maryland Bessemer........	26 mo.	.53	.059	1.02	.075		.19	.19	5.39
Lackawanna Bessemer F. T.	26 mo.	.53	.059	1.02	.075				4.33

Baltimore & Ohio Railroad:

The results of the Baltimore & Ohio Railroad trials of Titanium-treated Bessemer rails are shown in Appendix F, Figs. 75 to 78.

Test No. 902 in Fig. 75, on a 9-degree (radius 637 ft.) curve, is a comparison between Titanium-treated Bessemer rail and ordinary Besse-

Fig. 55
AMERICAN SOCIETY OF CIVIL ENGINEERS.
STANDARD A.S.C.E. RAIL SECTION



Area of Head = 4.13 sq. in. = 42%
" " Web = 2.06 " " = 21%
" " Base = 3.63 " " = 37%
" Total = 9.82 " " = 100%

Ratio Periphery of Head to Area of Head = 1.656
" " " Web " " " Web = 3.433
" " " Base " " " Base = 3.057
Total Periphery to Total Area = 2.549

Moment of Inertia = 43.80
Section Modulus Head = 14.44
" " Base = 16.11

mer rail, the chemical composition being given in Tables XXI and XXII. The diagram, Fig. 75, shows considerable superiority in average resistance to abrasion of the Titanium-treated over the plain Bessemer, while the chemical constituents appear to be about the same. Apparently the amount of ferro-titanium was 1 per cent. of a 10 per cent. ferro-titanium alloy. No rails of either kind are reported broken.

Test No. 920, Fig. 78, between Titanium-treated Bessemer steel and ordinary Open-Hearth steel, shows some superiority in resistance to abrasion for the former on the low side or inside of Kessler's curve, 9-degree (radius 637 ft.), while for the outside or high rail, the superiority is on the side of the Open-Hearth rail. This appears to be due to the additional hardness of the Open-Hearth rail on account of the higher carbon content, 0.63 to 0.76 per cent., as against 0.45 to 0.55 for the Titanium-treated Bessemer rail. Rails with several different percentages, varying from 0.3 to 1.5 per cent., of the 10 per cent. ferro-titanium alloy have been used in this test, but the abrasion or wear has been averaged in the above results. Examining the differences between these in the bottom table, we find that the 1.5 per cent. quantity of the alloy shows the least wear and the 0.5 per cent. quantity the next lowest wear on the outside rail, while in the case of the low or inside rail these relations are just reversed. The poorest results are shown by the 1 per cent. quantity in both cases. Further tests would be necessary to enable one to draw any definite conclusions in regard to the superiority of one percentage over the other. Test No. 919, Figs. 76 and 77, on Snow Creek 8-degree 42-minute curve (radius 659 ft.), seem to have been made to attempt to bring out the differences more conclusively. In the case of the high rail, looking at the table, the 1 per cent. quantity shows the least wear, although the 1.5 per cent. quantity is not far in excess, while in the case of the low rail the 0.3 per cent. quantity is the superior in abrasive resistance. The averages of both rails, looking at the diagram, Fig. 77, change the relations. The poorest results in both cases are given by the 0.5 per cent. quantity. Thus the additional tests have made the results still more discordant. Other elements or conditions must be working in these cases, perhaps differences in manufacture (the name of the mill where each was rolled is not given), or chemical elements. These inferences are more pointed when it is observed that there are no broken rails recorded in Test No. 920, while in Test No. 919 there are several. The greater number, 5, is in the 1 per cent. quantity, while there is 1 each in the 1.5 per cent. and 0.5 per cent. quantities, with the addition of a split head in the latter, and no failures at all in the 0.3 per cent. quantity. Thus it is evident that additional information is necessary to determine the relative values of different percentages of titanium introduced during the manufacture of rails.

Miscellaneous:

Some of the other railroad companies which have tried rails of Titanium-treated steel are the following, but no data have been sent to the reporter:

Chicago, Milwaukee & St. Paul Railway.
Chicago, Burlington & Quincy Railroad.
Philadelphia & Reading Railway.
Atchison, Topeka & Santa Fe Railway.
Buffalo, Rochester & Pittsburgh Railway.
Pere Marquette Railroad.
Chicago Junction Railway.
Erie Railroad.
Pennsylvania Railroad.
Michigan Central Railroad.
Great Northern Railway.
Wheeling & Lake Erie Railroad.
Central Railroad Company of New Jersey.

RÉSUMÉ.

The results of the trials of Titanium-treated steel rails have up to the present time been conflicting, due, perhaps, to the fact that the variables in the tests have been too numerous. In order to obtain accurate information, there should be but one variable, the treatment with ferrotitanium. This has already been brought to notice in the description of the trials of the New York Central Lines in Appendix H. The conditions in the cases of the Delaware & Hudson Company and of the Lehigh Valley Railroad were not the same, and it is impossible to say to what extent the sharper curvature for the Titanium-treated rail offsets the greater power of resistance to abrasion due to the higher carbon content in it.

In the case of the Northern Pacific, the results are reported not good on account of the higher percentage of piped rails, which shows the necessity for an improved method of making sound ingots or an additional discard. This additional discard is aimed at by the progressive method of testing in the Carbon Steel Rail Specifications of the American Railway Engineering Association. The trials of the two kinds of rails are not exactly comparable, with reference to the titanium treatment, because Titanium-treated Bessemer steel, with its lower carbon and high phosphorus, is compared with Open-Hearth steel with its higher carbon and low phosphorus.

In the Rock Island trials, the advantage seems to lie with the Titanium-treated Bessemer rail over Open-Hearth and Electric-Process rail during 17 months' service.

Neither the Maine Central, the Terminal Railroad Association of St. Louis, the Chicago Great Western nor the Delaware, Lackawanna & Western found any appreciable difference in resistance to abrasion by the use of ferro-titanium, but the results on the Boston & Maine were quite favorable to it.

The Baltimore & Ohio tests exhibit superiority in resistance against the abrasive action of wheels of Titanium-treated Bessemer rail over ordinary Bessemer rail of practically the same composition, but in the case of Open-Hearth rail, with its higher carbon, the superiority is lost. Of course, the comparison would be fairer if Open-Hearth steel of the same composition had been treated with titanium.

The Baltimore & Ohio tests to determine the varying effect of different percentages of the 10 per cent. ferro-titanium alloy are not conclusive, because other elements or conditions seem to interfere with reasonable deductions.

The principal value of ferro-titanium, as already pointed out by Mr. Stoughton in the preliminary discussion, is in helping to produce solid ingot metal, and that is, of course, a splendid quality. Its tendency to produce a deeper pipe must be counteracted by a greater discard (as provided for in the specifications above quoted), or an improved method for making the top of the ingot sound. It leaves no trace of itself in the resulting metal, and therefore does not make an alloy steel with any greater resistance to abrasion, or with any greater strength, than is brought about by its less spongy condition and greater compactness.

II. ALUMINUM.

*Aluminum is used in their daily practice by many of the rail manufacturers at their mills, but its use has not been specifically requested by any railroad administrations for special tests, but, on the contrary, is entirely prohibited in the specifications of some railroad administrations.

III. HIGH SILICON.

Although trials have been made in limited quantities of steel rails high in silicon, that is, over 0.30 per cent., but little information has been furnished to the reporter.

On an 8-degree curve (radius 717 ft.) at Hoblitzell, on the Baltimore & Ohio Railroad, some rail with carbon 0.596, phosphorus 0.10, manganese 1.11 and silicon 0.69 was tried, but it was too brittle, as 7 out of 8 rails failed.

Other tests are now being conducted by other administrations.

IV. ELECTRIC-PROCESS.

A few railways are trying small quantities of rail manufactured by this process at the Heroult furnace of the Illinois Steel Company at South Chicago. Some of them are the Terminal Railroad Association of St. Louis, Chicago & North Western Railway, Lake Shore & Michigan Southern Railway, Rock Island Lines and Pennsylvania Lines.

Terminal Railroad Association of St. Louis:

The Terminal Railroad Association of St. Louis reports that limited experience indicates that it has better resistance to abrasion than ordinary

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*Proceedings, American Railway Engineering Association, Vol. XV, 1914, "Influence of Aluminum and Silicon on Bessemer Ingots and Rails," by M. H. Wickhorst, Engineer of Tests, Rail Committee.

Bessemer steel, and the Lake Shore & Michigan Southern Railway reports that the Electric-Process shows less abrasion than the Bessemer.

Rock Island Lines:

The Rock Island Lines put 287 tons of 100-lb. rail in service and state that after 17 months' service the number of square inches worn off the head compared with other kinds was as already shown in Table XV.

The amount is less for the Electric-Process than for the Open-Hearth, but greater than for the Titanium-treated rail.

There were no failures of the Titanium-treated or of the Electric-Process, while there was 1 failure in 1008 rails laid of the Open-Hearth.

The chemical composition of the several kinds is as stated in Table XIV.

Pennsylvania Lines:

The Pennsylvania Lines purchased 1555 tons of 100-lb. rail in 1912, and the first of it was laid in the track in August. Measurements to determine resistance to abrasion are being made every six months, but the time of service is too short to derive any information on that question as yet. Nevertheless, some facts in connection with the inspection during rolling at the mill may be of interest.

The average chemical composition was as follows: Carbon 0.63 per cent., phosphorus 0.028 per cent., manganese 0.64 per cent., silicon 0.207 per cent. and sulphur 0.024 per cent. The carbon ranged from 0.57 to 0.70 per cent., the phosphorus from 0.012 to 0.04 per cent., the manganese from 0.50 to 0.80 and the silicon from 0.15 to 0.25.

The total amount rejected was 4.3 per cent. of the total rolled, being 148 rails out of 3285 (3137 accepted). Of the rejections, 108 rails or 73 per cent. were rejected for showing interior defect, and 37 rails or 25 per cent. for surface imperfections, while only three rails broke under the drop test, which is a weight of 2000 lbs. falling in guides from a height of 15 ft. Under this drop test, the permanent set for a span of 3 ft. center to center of supports under one blow was 1.1 in. as an average, with 1.4 in. maximum and 0.7 in. minimum. The total per cent. elongation for 1 in. in one or more blows of the tup was 11 per cent. highest maximum, 4 per cent. lowest maximum and 6 per cent. average of the maxima.

The size of the ingots from which the rails were rolled was 18 in. by 19 in.

One rail failed March 8, 1913, from a visible split 20 in. long in the head, which extended from the top of the head through to the web of the rail.

V. HEAT-TREATED RAILS.

Carnegie Steel Company:

The Carnegie Steel Company is conducting an investigation into the performance of oil-quenched rails, and is making service tests on the Union Railroad, belonging to it, as explained in the following letter from Mr. C. F. W. Rys, Metallurgical Engineer of the company:

> "After some preliminary work early in 1912 we developed that oil quenching of a 33-ft. rail from the rolling heat could be accomplished without serious difficulty if the proper precautions were taken.
>
> "No serious difficulties resulted from shrinkage, scaling, cracking, warping, distortion, straightening or drilling of the oil-quenched rails.
>
> "An average improvement of 20 to 25 per cent. was obtained in the treated over the untreated rail, as shown by the various mechanical tests. A final experiment was made, therefore, in order to determine whether a corresponding improvement would be found in track service. With that object in view, a number of Open-Hearth rails of 100-lb. A.R.A. Type B (Fig. 14) section were rolled and treated in April, 1912, and were placed in track June 10 and 11, 1912.
>
> "The oil-quenched, together with untreated rails of the same heats, were laid in the southbound track of the Union Railroad on the high and low sides of Northern Pike Curve, near Hall Station, about 3½ miles from East Pittsburgh. The track at this point has a curvature of 5 degrees and is on a down grade of 1.24 per cent. A careful record is being kept of all tonnage passing over these rails. The tonnage from June 11, 1912, to July 1, 1913, or approximately one year, amounted to 17,794,060 tons.
>
> "As far as our profiles and inspections show up to July 1, 1913, the oil-quenched rails show an average improvement of 41 per cent. over the untreated rails on the high side of curve, and about 37 per cent. improvement on the low side of curve, or an average of 39 per cent. for the oil-quenched rails over the untreated rails under exactly the same conditions of service."

Pennsylvania Steel Company:

Other steel companies are also making experiments with heat-treated rails in order to raise the elastic limit without sacrificing ductility, and the Pennsylvania Steel Company has recently rolled 16 rails of special section approximating 121 lbs. per yard, which are to be laid for service test in the tracks of the Pennsylvania Railroad, where the curvature is sharp and the traffic heavy.

The Pennsylvania Steel Company manufactures rail from Cuban iron ore, known as Mayari ore, which naturally contains a small amount of nickel and chromium, and it has been found that this steel when heat-treated possesses the qualities of extreme hardness unaccompanied by brittleness, but it is difficult to heat-treat an unbalanced section like a rail without distorting it, and at a reasonable cost. The test to be described points to the successful solution of the problem.

The rails in question were rolled November 21, 1913, and some are being manufactured into frogs and switches. The chemical constituents compared with the Pennsylvania Railroad and Philadelphia & Reading Railway specifications are as follows:

TABLE XVII.

Chemical Constituents.

Chemical Elements	Mayari Heat-treated	Pennsylvania R. R. Specifications	Phila. & Reading Ry. Specifications
Carbon	0.33	0.62 to 0.75	0.67 to 0.80
Phosphorus	0.015	Not over 0.04	Not over 0.04
Manganese	0.33	Not over 0.80	0.60 to 0.90
Silicon		0.05 to 0.20	
Nickel	1.28		
Chromium	.49		

The results of the physical tests are as follows:

TABLE XVIII.

Physical Qualities.

Test	Mayari Heat-treated	Pennsylvania R. R. Rail Steel	Phila. & Reading Ry. Rail Steel
Tensile Strength, lbs. per sq. in.	145,000	145,000	147,000
Elastic Limit, lbs. per sq. in.	115,000	65,000	69,000
Elongation, per cent	7½	10	10
Reduction of Area, per cent	15	15	14

Under blows from a weight of 2,000 lbs. falling from a height of 25 ft. on pieces of rail laid on supports 36 in. from center to center, the pieces stood the punishment given in detail in Figs. 56, 57 and 58. The "A" rail is the one at the top end of the ingot, the "B" rail the second one, and so on.

Inasmuch as there was no regular machinery for making such rails, the methods of manufacture were rather crude. The rail section is shown in Fig. 59, and was developed by using a set of rolls which was available for the experiment. It is therefore not such a section as would necessarily be recommended. It was not possible to finish the rails at as low a temperature, nor to put as much work on them in the finishing pass as was desirable.

The material near the surface and penetrating to ⅜-in. to ½-in. is of very fine silky texture and the Brinell hardness higher than in the case of 0.70 carbon rails, so that it should resist abrasion from the wheels very satisfactorily.

Miscellaneous:

Heat treatment and quenching in oil are being applied quite extensively for several of the railway administrations in the manufacture of splice bars and bolts for rails.

FIG. 56.

"A" Rail No. 12.
Twelve blows—25-ft. drop.
Elongation in 6 in. = 2.09 in. after each blow.
Tensile strength, 147,000 lbs.
Elastic limit, 121,000 lbs.
Elongation in 2 in., 8.0 per cent.
Reduction of area, 17.5 per cent.

Fig. 57.

"B" Rail No. 32.
Six blows—25-ft. drop.
Elongation in 6 in. = 1.16 in. after 5th blow.
Tensile strength, 136,000 lbs.
Elastic limit, 117,000 lbs.
Elongation in 2 in., 10.50 per cent.
Reduction of area, 20.5 per cent.

Fig. 58.

"C" Rail No. 4.
Eight blows—25-ft. drop.
Elongation in 6 in. = 1.36 in. after 7th blow.
Tensile strength, 141,500 lbs.
Elastic limit, 119,000 lbs.
Elongation in 2 in., 8.50 per cent.
Reduction of area, 24.5 per cent.

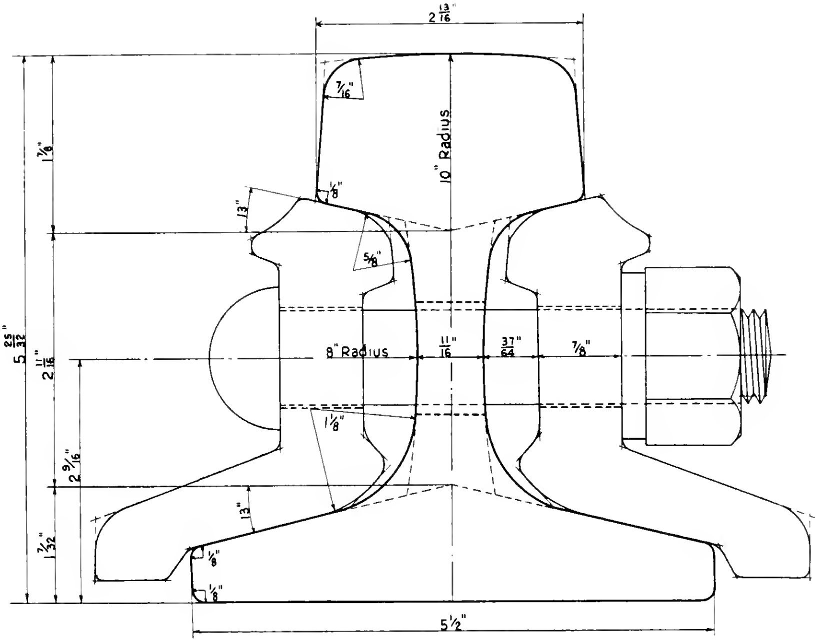


Fig. 59
PENNSYLVANIA STEEL CO.
RAIL SECTION No. 96-B. FOR HEAT TREATMENT.
WEIGHT 121 POUNDS PER YARD.
JAN. 6, 1914

VI. CRUCIBLE OR TOOL STEEL.

A special hard crucible or tool steel is used by several railways for rail locks for drawbridges, a general type of which is illustrated in Fig. 60.

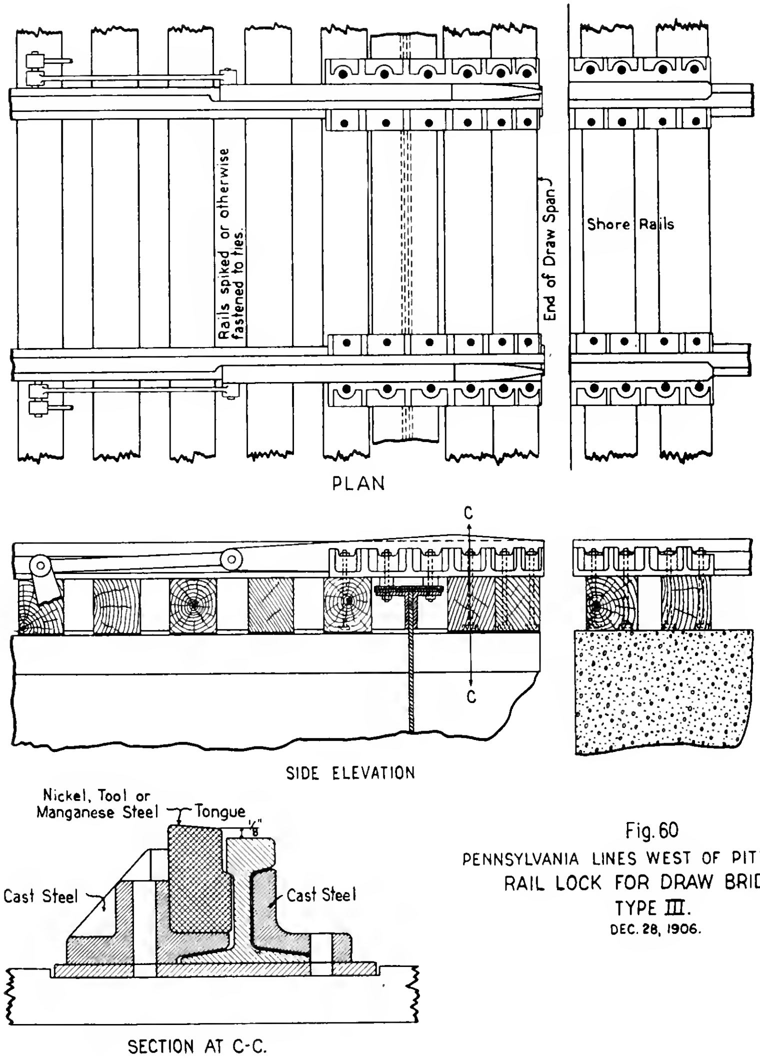


Fig. 60
PENNSYLVANIA LINES WEST OF PITTSBURGH
RAIL LOCK FOR DRAW BRIDGES.
TYPE III.
DEC. 28, 1906.

McMANAMA NARROW-HEAD RAIL.

A trial is now being made of curved track, constructed with rails of different widths of head on the outside and inside of the curve, in order to reduce the pressure of wheels against the outer rail, and thus diminish the flange friction and consequently the flange abrasion of the rail head. These rails are not of "Special Steel," but as two of the objects, that of increasing the safety and the life of the rail on curves, are the same, it seems fitting to call attention to the progress of the experiment.

It is impossible to superelevate the outer rail on curves carrying both freight and passenger trains so as to be exactly right to counteract the centrifugal force in both cases, and as the adjustment is usually made for the passenger trains, the inside or low rail often carries a much greater proportion of the load than the outside or high rail. This, together with the slipping action of the wheels, has a tendency to cause the low rail to overturn by cutting into the ties at the outside edge of the rail-base, especially before the use of tie plates became general. This progressive overturning of the rail caused the head to become unevenly worn, aggravated also by the coned tread of the wheels, and after a certain point had been reached, it was the common practice to adze the ties and thus restore the rail to its original position perpendicular to the tie. The wheels then had a new and narrower surface on which to roll, and Mr. J. W. McManama, a Roadmaster of the Fitchburg Railroad, now part of the Boston & Maine Railroad, noticed that, until the head became again worn down so as to offer a wider bearing surface once more, the cars seemed to ride around the curves more smoothly, and he then followed up the idea with additional experiments. They resulted in the belief that the relief was due to the increased facility for slipping given to the inner wheel by the narrower bearing surface. He therefore designed the narrow-head rail for use as the inside rail on curves as a companion to the standard outside rail, and one of the types is illustrated in Fig. 61. In this particular case, the narrow rail has been made higher than the outside rail so that the standard splice bars could be used for both.

It seems hardly necessary to state that in rounding a curve the outside wheel travels much farther than the inside one, while at the same time making the same number of revolutions, and, as they are rigid on the axle, one of them must slip while rolling. It is also well known that the axles of the truck are at an angle with the radius of the curve, and the outside wheel flange is always pushing strongly against the rail flange at an angle and grinding off the metal of the rail head and of the wheel. During this action it is also necessary for one wheel to slip. Mr. McManama's idea therefore is to make it easier for the inside wheel to slip backwards during these two operations 'by affording it a smaller bearing area than that for the outside wheel. This is done by narrowing the inside rail head.

Objections to this plan immediately crowd to the front, as follows:

(1) As the present contact area between the wheel and rail is so small, and as the wheel loads are very heavy (Table I), there is evidence

of a flow of metal on the surface of rail heads under the severe action of the wheels, which on curves is towards the outside of each rail. Will not this condition be aggravated by making the rail head narrower?

(2) The bearing area for the splice bars on the under side of the head of the rail is diminished, while that area is already too small to be satisfactory.

(3) The moment of inertia and section modulus of the rail are reduced.

The answer is, go and see the rails in service, and several prominent railway Engineers have come away convinced that further trials are worth while.

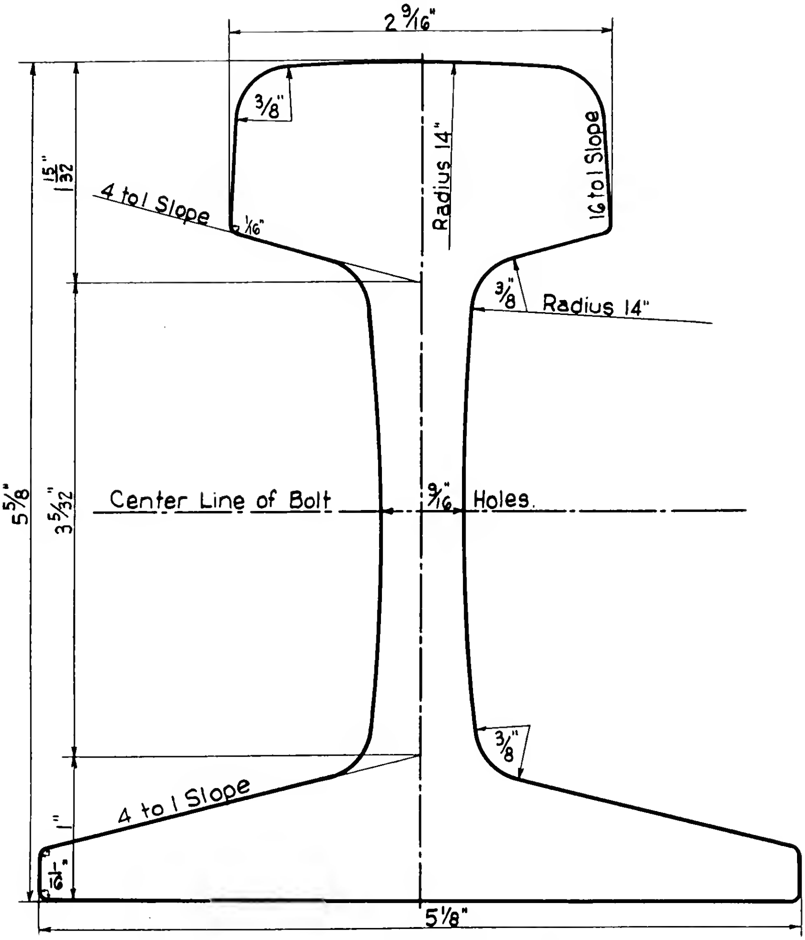
A 7-degree curve (radius 819 ft.) near Waterville, Me., on the Maine Central Railroad, had been laid with new A.S.C.E. rail, weighing 85 lbs. per yard, in February, 1911. By December, 1911, a period of 10 months, the outside rail was considerably flange worn, about ¼-in., and the inside rails were replaced by the narrow-head rails previously described, and illustrated in the photograph, Fig. 62. The wear or abrasion of the head of the outside rail was at once diminished, and since then the amount of abrasion has been much smaller. The last measurements taken, October, 1913, after 22 months' service, are shown in Fig. 63, and bear out this observation. Some flow of metal on the top of the low rail is observed, but it is not considered extreme by those who have seen it. The superelevation of the outer rail is only 4½ in., as the speed is moderate on account of the proximity of the bridge. The traffic is about 12 million tons per annum.

The noticeable improvement in the hauling capacity of the locomotives, as well as the increased life of the rail, led the railway administration to purchase 200 more tons of the rail in October, 1912, for use on about 27 sharp curves, ranging from 4 to 8 degrees in the White Mountain region, and the reports are even more favorable than in the first trial, because new rail was laid on the outside, as well as the inside, and in that case the action seems to be better because, presumably, of the greater width of bearing area over that of flange-worn rail. The traffic is about 3½ million tons per annum, and but little wear on either rail is noticeable.

At Bemis, where some of these rails were laid on a steep grade, freight trains formerly stalled and had to back to get a fresh start with full head of steam and perfect fires, but since the narrow-head rail was laid they make the ascent with perfect ease. This diminution of frictional resistance has led Mr. McManama or Mr. Barbey to give it the inappropriate trade name of "Frictionless Rail."

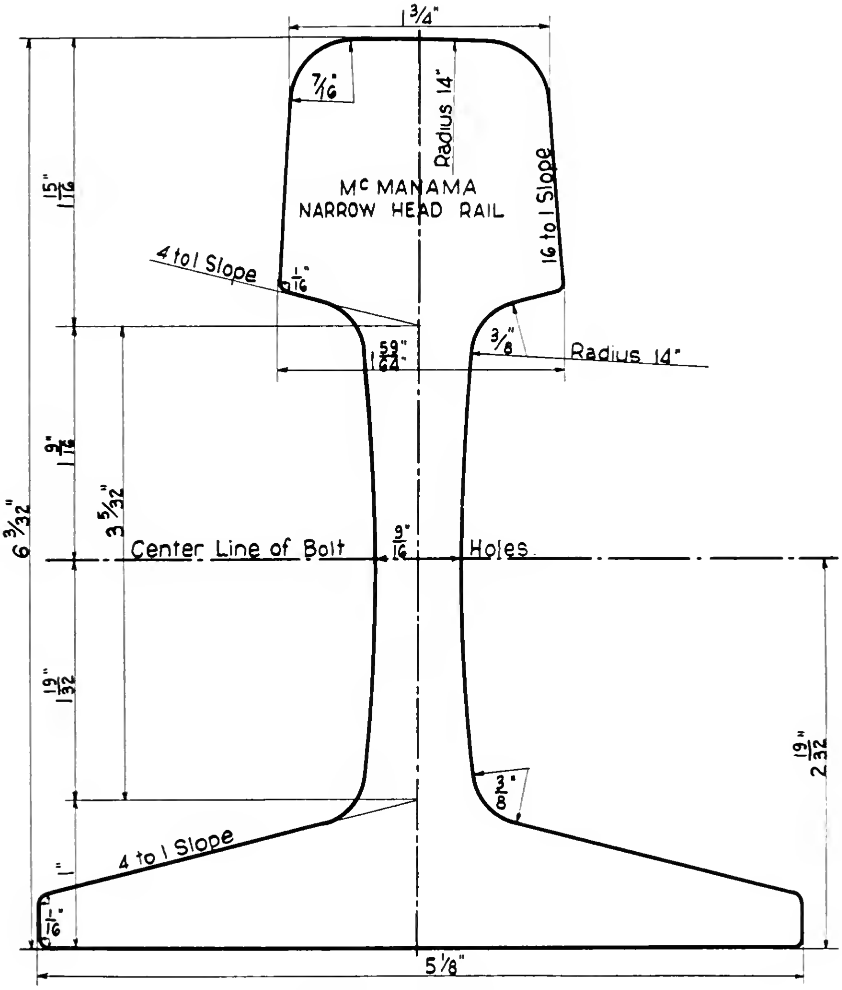
Some of these rails are being tried by the Boston & Maine Railroad, the Boston Elevated Railway and the Southern Pacific Railway, while others are now considering the question.

A.R.A. SECTION–SERIES A.
90 LB. STEEL RAIL



OUTSIDE OR HIGH RAIL.

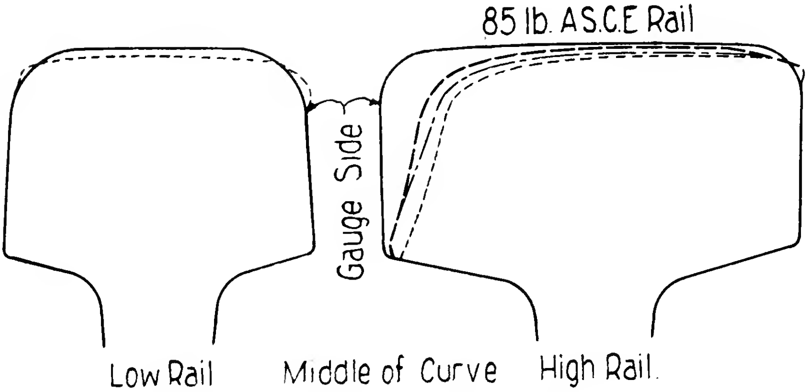
Fig 61
COMBINATION OF WIDE-AND
NARROW-HEAD RAILS TO REDUCE
FRICTIONAL RESISTANCE
PATENTED, OCT 24, 1911 AND SEPT 24, 1912



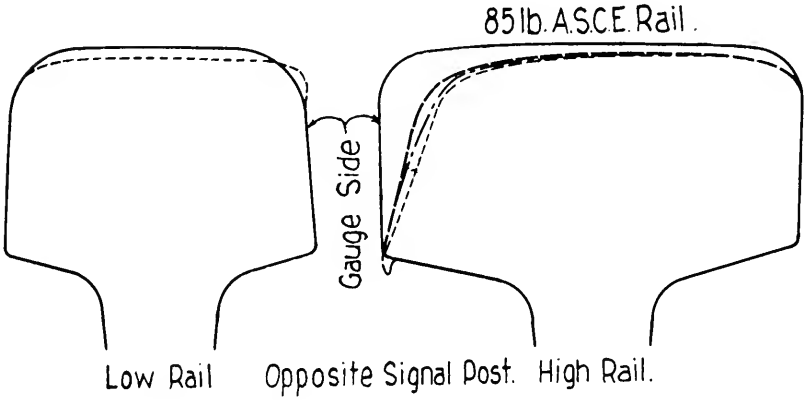
INSIDE OR LOW RAIL

FIG. 62. MAINE CENTRAL RAILROAD. SEVEN-DEGREE CURVE NEAR WATERVILLE, ME. FRICTIONLESS, OR NARROW HEAD RAIL, ON THE INSIDE OF CURVE.

MAINE CENTRAL RAILROAD.
7° Curve near Waterville Maine,
laid with Narrow-Head rail on
inside of curve after outside
rail had been in service 10 months.
Fig. 63.



Sections taken Dec 1911 shown ——
" " " 1912 " —-—
" " Oct. 1913 " ------



QUESTION 7. HARDENING OR TEMPERING RAILS.

In answer to Question 7 (Appendix A), which is—"From the point of view of the safety of the traffic, do you approve of the hardening or tempering of rails?"—some administrations reply that it is desirable if it can be done without sacrificing safety by causing brittleness, but the general trend of the information received is against such a course. The objections are well expressed by Dr. P. H. Dudley: "I do not, as hardening and tempering rails are not at present understood and practiced at the mills. Great care is required not to chill portions of the red-hot rails quickly, either in oil or water, as transverse cracks are liable to develop in the web from the sudden shrinkage. This has occurred in several instances where water was used as the medium to harden the rails."

Nevertheless, it will be noticed from the tests of the Carnegie and Pennsylvania Steel companies, previously described, that progress in the heat treatment of rail steel is being made, and the preliminary results are encouraging.

QUESTION 8. ADDITIONAL INVESTIGATION.

Question 8 (Appendix A), is—"In your opinion, what properties of the material have as yet not been sufficiently elucidated and require careful investigation and further improvement in order to enable railways to use given special steel, with advantage, for given purposes?" This is answered by Dr. Dudley for the New York Central Lines, as follows:

"1. Special manganese steel: This should be investigated to see whether or not it is possible to raise its present low elastic limits and retain its toughness, as constructions from it lose shape from deformations of the section faster than from loss of metal from wear and abrasion.

"2. The chemical composition for rail steels should be studied and adapted to the sections, temperatures of the lines, conditions of service, as wheel loads, and spacing, speed, ballast and character of the subgrade.

"3. The purification of the bath, and time for the escape of the deoxidation products after the recarburizer is added, to insure practically all the ductility in the product due to the chemical composition of the basic Open-Hearth grades of metal, either for plain carbon or alloy steel.

"4. The investigation of segregation and its causes.

"5. The provision of proper and sufficient deoxidizers in connection with the making of the steel to check segregation and cause it to set quiet and solid in the molds without exterior or interior blowholes in the ingots.

"6. The form of the ingots in relation to size of base to their length, volume and the freezing from hot to set metal.

"7. The clean and proper teeming of the ingots with limited segregation.

"8. The time factors to strip and then to charge the hot-setting ingots into the reheating furnaces to avoid decided interior shrinkage before the ingots are bloomed under their own initial equalized heat.

"9. The relation of the draft and speed of the blooming passes to compress and elongate the ingot into a bloom without checking the exterior skin.

"10. The relations of hardness for wear and brittleness of the section as a girder, compared to purity of metal and toughness for wear, with ductility of the section as a girder."

In elaboration of No. 2 above, the Central Railroad Company of New Jersey calls attention to the present uncertainty with respect to the correct amount of carbon to be used under various conditions to gain certain definite results, and to the desirability of investigation in regard to the introduction of nickel in steel rails. The first trials have not been considered successful, as indicated by the results already given in detail.

The Pennsylvania Lines call attention to the lack of homogeneity in Manganese steel, and the Cleveland, Cincinnati, Chicago & St. Louis Railway (New York Central Lines) to the failures of that steel through progressive cracks, starting either from defects of the casting, or unequal contraction, and gradually increasing until they produce failures. These faults may possibly be overcome, that administration thinks, by correct design so as to balance the distribution of metal in order to prevent too great inequality of cooling after casting.

The Northern Pacific Railway believes that the action of various kinds of steel under low temperatures, especially from —20 degrees to —40 degrees Fahrenheit (—28.9 to —40 degrees C.), should be studied. Laboratory experiments along these lines have already been made, and are the subject of present consideration, but are not yet ready to be given to the Congress. Such experiments were also made in France, as long ago as 1880, by La Compagnie du Chemin de Fer du Nord.

The Bessemer & Lake Erie Railroad thinks that a study should be made of the shape, size and design of the rail, tie plate, splice and fastenings, and of the test treatment the steel should receive to give the best service, while the Missouri Pacific Railway questions "the sufficient determination of the action of the various alloys, that is, will a given amount of alloy added to a given amount of steel, under the same conditions, always produce a product which will have the same physical properties and furnish the same physical tests?"

CONCLUSIONS.

1. Cast Manganese steel has been proved by long experience, under exacting conditions, to be a satisfactory and safe metal for the manufacture of frogs and switch-points.

2. The trials of rolled Manganese steel for rails, and for the manufacture of frogs and switches have not been so extensive as with the cast product, but have been continued to a sufficient degree to enable us to conclude that it will ultimately be entirely suitable for those uses at locations where great strength, toughness and a maximum abrasive resistance are desirable.

3. The experiments with nickel, and nickel and chromium in certain proportions, in rail steel have not, up to the present time, been entirely satisfactory; but the accepted employment of Nickel steel in bridge construction, and the trials of nickel and chromium in other proportions in rail steel, especially when incorporated as two of the natural elements of the iron ore, justify continued use.

4. The use of high carbon (over 0.80 per cent.) in rails weighing 85 lbs. per yard, in combination with 0.92 to 1.00 per cent. of nickel, and 0.24 to 0.29 per cent. of chromium, has not been satisfactory. The conditions with rail sections of greater weight might be entirely different.

5. Further study of the qualities possessed by High Silicon rails, that is, steel with over 0.30 per cent. of silicon, is advisable.

6. The value of the use of ferro-titanium in rail steel manufacture as a "physic" for improving the condition of solidity of the metal is conceded, but at the same time steps should be taken to overcome its injurious effect in deepening the "pipe" in the ingot.

7. Heat-treated rails, and those manufactured with the assistance of the Electric-Process, are at present in experimental use only, but the possibility of future value is promising, and the study should be continued.

APPENDICES

Appendix A.

INTERNATIONAL RAILWAY CONGRESS.

NINTH SESSION—BERLIN, 1915.

Detailed list of questions relating to Question III (Section 1).

SPECIAL STEELS.

"Use of special steels, both for the track generally, and in particular for the track appliances (points, crossings, etc.)."

Reporter: Mr. Cushing (W. C.), Chief Engineer, Maintenance of Way, Pennsylvania Lines West of Pittsburgh; Pennsylvania Station, Pittsburgh (Pa.).

Name of the Administration..

LIST OF QUESTIONS.

1. What kinds of special steel have you hitherto used for your tracks, in particular for your rails, switches, single and double crossings, expansion devices at the ends of bridges, and other parts of the track not enumerated here?
2. (a) What has been your special purpose in using these special steels, and what advantages have you obtained by using them?
   (b) Besides manganese, nickel, chrome-nickel, silicon, titanium and carbon steel (that is to say, steel containing at least 0.75 per cent. of carbon, that is, more carbon than is in ordinary rail steel), have you also used other kinds of special steel, not mentioned here?
3. (a) What elements of the track have you made *wholly* of special steel, or for only what *parts of such elements* have you used special steel? Please give an accurate list (stating number and weight) based on the list given in Question 1.
   (b) Please give the chemical analysis of the special steels used for the more important elements of the track, or for parts of such elements.
   (c) Please give the chemical analysis of similar elements or parts of elements made of ordinary or generally-used material and used under the same conditions of service.
   (d) Please give results of tests of special steel used for elements of the track, or for parts of such elements: ultimate tensile strength, limit of elasticity, elongation (if possible, measured on a length of 200 millimetres (8 in.)), appearance of fractured surface, Brinell hardness test, or other tests not mentioned here.
   (e) Please give results of tests of similar elements, or of parts of such elements, used under the same conditions of service, but made of ordinary material.
   (f) Please mention any abnormal phenomena observed during these tests. When special steels are used, especially in the case of castings, have you made provision for reduced dimensions (thickness of web)? What minimum dimensions were attained and with what results?
   (g) Please add photographs, if these seem necessary to show the results of the tests.

4. As regards rails, please state how they are manufactured: whether by rolling, by pressing or by casting. Please give, for purposes of comparison, the same information about rails made of ordinary steel, if these are used under the same conditions of service:
   (a) The coefficient of quality, that is, the ratio of defective rails[1] to the number of rails laid (1:....);
   (b) Wear of the rail heads (rolling surface and side), per unit of surface, and
   (c) In percentage of the surface of the rail head.
5. In the case of frogs, please state whether these are cast or are built up of pieces of rail; also whether special steel is only used for the rolling surface and for the knuckles of the wing rails.
6. In the case of point rails, are these wholly made of special steel, or only over part of the length, starting from the point?
7. From the point of view of the safety of the traffic, do you approve of the hardening or tempering of rails?
8. In your opinion, what properties of the material have as yet not been sufficiently elucidated, and require careful investigation, and further improvement, in order to enable railways to use given special steel, with advantage, for given purposes?

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(1) A rail is considered defective if it has to be taken out of the track in consequence of fracture or of defects in the metal used; provided that the fracture is not caused by any defect in the rolling stock.

Appendix B.

Liste
des
Administrations Exploitant des Chemins de Fer
Appartenant

A L'ASSOCIATION INTERNATIONALE DU CONGRÈS DES CHEMINS DE FER

(Juillet, 1912)

Replies received from those with "R" prefixed.

	Kilomètres	Designation des Administrations	Addresses
		ARGENTINE (REPUBLIQUE).	
1	4,016	Chemins de fer de l'Etat	Buenos-Aires, Peru, 672.
2R	5,446	Buenos Aires Great Southern Railway	London, E. C., Finsbury Circus, 7.
3R	2,670	Buenos Aires Western Railway	London, E. C., River Plate House, Finsbury Circus.
4R	4,636	Central Argentine Railway	London, E. C., Coleman St., 3a.
5	1,107	Entre Rios Railways	London, E. C., River Plate House, Finsbury Circus.
6	800	Rosario à Puerto-Belgrano	Paris, rue Louis-le-Grand, 11.
		BRÉSIL.	
7	2,169	Compagnie auxiliare de chemins de fer au Brésil	Bruxelles, rue de l'Industrie, 33.
8	1,778	Chemin de fer Central du Brésil	Rio de Janeiro.
9	195	Great Southern of Brazil Railway	London, E. C., Queen Victoria st., 14.
10	1,503	Great Western of Brazil Railway	London, E. C., River Plate House, Finsbury Circus.
		CHILI.	
11	1,238	Antofagasta (Chili) & Bolivia Railway	London, E. C., Broad street place, 1 Finsbury Circus.
12	608	Nitrate Railways	London, E. C., Cannon St., 110.
		COSTA-RICA.	
13	357	Costa-Rica Railway	London, E. C., Dashwood house, New Broad street, 9.
		CUBA.	
14	410	Cuban Central Railways	London, E. C., Coleman street, 2.
		ÉTATS-UNIS D'AMÉRIQUE. (UNITED STATES OF AMERICA.)	
15	476	Alabama Great Southern Railroad	Cincinnati (O).
16R	4,086	Atchison, Topeka & Santa Fe Railway	Chicago (Ill.).
17R	352	Atlanta & West Point Railroad and the Western Railway of Alabama	Atlanta (Ga.).
18R	3,190	Atlantic Coast Line Railroad	Wilmington (N. C.).
19R	7,136	Baltimore & Ohio Railroad	Baltimore (Md.).
20R	314	Bessemer & Lake Erie Railroad	Pittsburgh (Pa.), Carnegie Building.
21R	631	Boston & Albany Railroad	Boston (Mass.).
22R	3,083	Central of Georgia Railway	Savannah (Ga.).
23R	956	Central Railroad of New Jersey	New York, Liberty street, 143.
24R	863	Central Vermont Railway	St. Albans (Vt.).
25	2,148	Chesapeake & Ohio Railway	Richmond (Va.).
26R	1,606	Chicago & Alton Railway	Chicago (Ill.), Railway Exchange Building, Michigan avenue and Jackson boulevard.
27	5,145	Chicago, Burlington & Quincy Railroad	Chicago (Ill.), West Adams street, 226.
28	930	Chicago, Indianapolis & Louisville Railway.	Chicago (Ill.), Republic Building.
29	378	Chicago, Peoria & St. Louis Railway of Illinois	Springfield (Ill.).
30R	6,720	Chicago, Rock Island & Pacific Railway	Chicago (Ill.), La Salle Street Station.

	Kilomètres	Designation des Administrations	Addresses
31R	544	Cincinnati, New Orleans & Texas Pacific Railway (Queen & Crescent)	Cincinnati (O.).
32R	2,288	Cleveland, Cincinnati, Chicago & St. Louis Railway	Cincinnati (O.).
33	85	Cumberland & Pennsylvania Railroad	Cumberland (Md.).
34	262	Cumberland Valley Railroad	Chambersburg (Pa.).
35R	1,258	Delaware & Hudson Company	New York, Nassau street, 32.
36	1,585	Delaware, Lackawanna & Western Railroad	Scranton (Pa.).
37R	4,189	Denver & Rio Grande Railroad	New York, Broadway, 165.
38	309	Elgin, Joliet & Eastern Railway	Chicago (Ill.), Commercial National Bank Building.
39R	1,357	El Paso & Southwestern System	New York, John street, 99.
40R	3,645	Erie Railroad	New York, Fulton Building, Hudson Terminal, Church street, 50, corner Fulton.
41R	945	Grand Rapids & Indiana Railway	Grand Rapids (Mich.).
42R	546	Hocking Valley Railway	Columbus (O.), East Broad street 50.
43	1,223	Kansas City, Mexico & Orient Railway	Kansas City, Tenth street and Baltimore avenue.
44	217	Lehigh & New England Railroad	Philadelphia (Pa.), Chestnut street, 437.
45R	2,222	Lehigh Valley Railroad	Philadelphia (Pa.), South Third street, 228.
46R	636	Long Island Railroad	New York City (N. Y.), Pennsylvania Station.
47R	1,938	Maine Central Railroad	Portland (Me.).
48	116	Manistee & Grand Rapids Railroad	Manistee (Mich.).
49R	3,003	Missouri, Kansas & Texas Railway	St. Louis (Mo.).
50R	3,822	Missouri Pacific Railway	St. Louis (Mo.).
51R	1,490	Mobile & Ohio Railroad	Mobile (Ala.).
52	1,979	Nashville, Chattanooga & St. Louis Railway	Nashville (Tenn.), Broadway, 1000.
53	650	New Orleans, Mobile & Chicago Railroad	Mobile (Ala.).
54R	1,297	New York Central & Hudson River Railroad	New York, Grand Central Station.
55	842	New York, Chicago & St. Louis Railroad	Cleveland (O.).
56R	3,202	Norfolk & Western Railway	Roanoke (Va.).
57R	3,304	Northern Pacific Railway	St. Paul (Minn.).
58R	4,974	Pennsylvania Lines West of Pittsburgh	Pittsburgh (Pa.), Pennsylvania Station.
59R	8,572	Pennsylvania Railroad	Philadelphia (Pa.), Broad Street Station.
60	344	Pittsburgh, Shawmut & Northern Railroad	New York, Wall street, 60.
61	230	Alabama & Vicksburg Railway	New Orleans (La.).
62	315	New Orleans & Northeastern Railroad	New Orleans (La.).
63	277	Vicksburg, Shreveport & Pacific Railway	New Orleans (La.).
64	132	Richmond, Fredericksburg & Potomac Railroad	Richmond (Va.).
65	3,003	St. Louis & San Francisco Railroad	St. Louis (Mo.), Frisco Building.
66R	2,538	St. Louis Southwestern Railway	St. Louis (Mo.).
67R	10,644	Southern Railway	Washington (D. C.), Pennsylvania avenue, 1300.
68	55	Staten Island Rapid Transit Railway	New York, State street, 17.
69R	....	Terminal Railroad Association of St. Louis	....
70	399	Toledo, Peoria & Western Railway	Peoria (Ill.).
71	148	Toronto, Hamilton & Buffalo Railway	Rochester (N. Y.).
72	208	Ulster & Delaware Railroad	Kingston (N. Y.).
73R	1,331	Vandalia Railroad	St. Louis (Mo.), Century Building.
74	**871**	Western Maryland Railroad	Baltimore (Md.).
		CANADA.	
75R	3,003	Grand Trunk Railway	Montreal.
76	407	Quebec Central Railway	London, E. C., Great Winchester street, 5.
		PÉROU.	
77	32	Lima Railways	London, E. C., College Hill, 23.

	Kilomètres	Designation des Administrations	Address
		SALVADOR.	
78	161	Salvador Railway...........................	London, E. C., Idol Lane, 7-8.
		URUGUAY.	
79R	1,569	Central Uruguay Railway of Montevideo.....	London, E. C., River Plate House, Finsbury Circus.
80	150	Uruguay Western & Port Company..........	Montevideo, Casilla de Correo, 49.

NOTES:

The Pennsylvania Railroad, No. 59, is the parent company of the **Pennsylvania Railroad System,** which embraces the following companies operated under their own management, supervised by the parent company:

No. 58—Pennsylvania Lines West of Pittsburgh, subdivided into:
- (a) North West System.
- (b) Central System.
- (c) South West System.

No. 73—Vandalia Railroad.
No. 34—Cumberland Valley Railroad.
No. 41—Grand Rapids & Indiana Railway.
No. 46—Long Island Railroad.
No. 56—Norfolk & Western Railway.
No. 70—Toledo, Peoria & Western Railway.

The New York Central & Hudson River Railroad, No. 54, is the parent company of the **New York Central Lines,** which embrace the following companies operated under their own management, supervised by the parent company:

No. 21—Boston & Albany Railroad.
No. 32—Cleveland, Cincinnati, Chicago & St. Louis Railway (Big 4).
No. 55—New York, Chicago & St. Louis Railroad (Nickel Plate).
No. 74—Western Maryland Railroad.

The **Southern Railway,** No. 69, controls the following companies, operated under their own management:

No. 15—Alabama Great Southern Railroad.
No. 31—Cincinnati, New Orleans & Texas Pacific Railway (Queen & Crescent Route), joint control with C. H. & D. Ry., and Alabama, New Orleans, Texas & Pacific Junction Rys.
No. 51—Mobile & Ohio Railroad.

Appendix C.

LIST OF THE FROG AND SWITCH MANUFACTURERS IN THE UNITED STATES AND THEIR ADDRESSES.

Ajax Forge Co.	Chicago, Ill.
American Frog & Switch Co.	Hamilton, O.
Barbour-Stockwell Co.	Cambridge, Mass.
Buda Co., The	Chicago, Ill.
Cincinnati Frog & Switch Co., The	Cincinnati, O.
Cleveland Frog & Crossing Co.	Cleveland, O.
Columbia Steel Co.	San Francisco, Cal.
Conley Frog & Switch Co.	Memphis, Tenn.
Continuous Frog & Crossing Co.	St. Louis, Mo.
Curtis & Co. Mfg. Co.	St. Louis, Mo.
Elliot Frog & Switch Co.	East St. Louis, Ill.
Falk Co.	Milwaukee, Wis.
Frog, Switch & Mfg. Co.	Carlisle, Pa.
Guerber Engineering Co.	Bethlehem, Pa.
Indianapolis Switch & Frog Co., The	Springfield, O.
Judson Mfg. Co.	San Francisco, Cal.
Kilby Frog & Switch Co.	Birmingham, Ala.
Lorain Steel Co.	Johnstown, Pa.
Maryland Steel Co.	Baltimore, Md.
M-C-B Co., The	Chicago, Ill.
Morden Frog & Crossing Works	Chicago, Ill.
Newhall, Geo. M., Engineering Co.	Philadelphia, Pa.
New York Switch & Crossing Co.	Hoboken, N. J.
Pennsylvania Steel Co.	Steelton, Pa.
Pettibone, Mulliken & Co.	Chicago, Ill.
Ramapo Iron Works	Hillburn, N. Y.
Richardson & Co. (Inc.)	Pittsburgh, Pa.
Robinson & Orr	Pittsburgh, Pa.
St. Louis Frog & Switch Co.	St. Louis, Mo.
Seattle Frog & Switch Co.	Seattle, Wash.
Weir Frog Co.	Cincinnati, O.
Wharton, Wm., Jr., & Co., Inc.	Philadelphia, Pa.

Appendix D.

REPORT OF PENNSYLVANIA LINES ON THE COMPARATIVE RESULTS OF THE USE OF ORDINARY BESSEMER STEEL AND MANGANESE STEEL FROGS AND SWITCH POINTS.

Frogs:

We have now had the Manganese steel frogs and crossings in service on our lines a sufficient length of time to form some conclusion regarding their economy, as compared with frogs and crossings of ordinary construction.

From the data obtained the annual charge or cost of a frog of each type may be computed by the method shown below, which requires the use of compound interest and annuities. A fixed sum of money paid annually is called an annuity and is expressed by the formula:

$$\text{Annuity} = \frac{\text{rate}}{(1 + \text{rate})\ n-1} \quad \text{where “n”} = \text{number of years.}$$

Example—Take the case of two No. 8 spring frogs on the Pittsburgh Division, replaced with Hard Point Manard Frogs.

Ordinary Construction:

Average Net Cost (is the sum of first cost, cost to install and cost of repairs, less scrap value)..$ 40.00			
Annuity on $1.00 at 4 per cent. for average life of frogs (1.13 years), derived from above formula	0.883		
Annual charge, $40.00 × 0.883 =		$35.32	
Interest on $40.co for 1 year at 4 per cent.........		1.60	
Total Annual Average Charge, ordinary frog.			$36.92

Hardened Steel Construction:

Average Net Cost (obtained as above)...........$111.00			
Annuity on $1.co at 4 per cent. for average life of frogs (3.95 years), derived from above formula	0.238		
Annual charge, $111.co × 0.238 =		$26.42	
Interest on $111.00 for 1 year at 4 per cent........		4.44	
Total Annual Average Charge, hardened steel frog			$30.86
Average Annual Saving, per frog, by using hardened steel			$ 6.06

By transposing the above formula to:

$$n = \frac{\text{Log}\dfrac{(cr + (A-1)}{(A - I)}}{\text{Log } I + r}$$

Where c = Net cost.
I = Interest on net cost.
A = Annual charge.
r = Rate per cent.
n = Number of years.

We may form some idea of the economy of a hardened steel frog by estimating its probable life, for instance:

An ordinary frog costing \$56.00 will last 1.5 years in a given location, the annual charge for it being \$38.98. How long must a hardened steel frog costing \$114.00 last in the same location to effect the same annual charge?

Here c = \$114.00.
A = \$ 38.98.
I = \$114 × .04 = \$4.56.
r = .04.

Substituting these values in the formula, and solving for "n":

$$n = \frac{\text{Log}\dfrac{(4.56 + (38.98 - 4.56)}{(38.98 - 4.56)}}{\text{Log } 1.04} = \frac{\text{Log}\dfrac{(38.98)}{(34.42)}}{\text{Log } 1.04} = \frac{.0541532}{.0170333}$$

$$n = 3.17 \text{ years.}$$

From the reports received, the average annual saving or deficit due to the use of hardened steel frogs has been tabulated in Table XIX. In this tabulation the frogs have been grouped by numbers and types.

A study of the Table XIX will show:

1. Among the frogs considered the hardened steel frogs give a greater average life than those of ordinary steel, the average being about 4 to 1 for stiff rail and 3¼ to 1 for spring rail.

2. There are a number of instances where the records indicate that the average annual cost for the hardened steel frogs is greater than for frogs of ordinary construction.

It should be borne in mind, however, that in many cases the life of the hardened steel frogs has been estimated, inasmuch as these frogs are still in service and that when they are worn out the results as now noted may become somewhat different.

3. In general, the hardened steel frogs show a greater annual saving when compared with ordinary stiff-rail frogs than when compared with ordinary spring-rail frogs.

4. Of the twenty-six single-track crossings considered, there are but six where the average annual cost is greater for the hardened steel construction than for the ordinary construction, viz., the six crossings on the

Western Division of Manard steel construction. These were of early design, which has since been changed.

Too much stress should not be placed on relative comparisons at different points, since these comparisons are made without regard to location of crossings, angle, or other local conditions; for instance, it is felt that crossings approximating right angles are the most difficult and costly to maintain on account of the more severe wheel blows they receive, and no consideration has been given to the crossing angle in these tables.

Another point to be remembered is that this method of comparison of average annual costs does not take into consideration the comparative traffic over the frogs and crossings, but it is felt that even with the omission of this consideration the results obtained from the use of the formula are dependable enough for all practical purposes, and that, unless the traffic over the different frogs and crossings during their life has varied to a marked degree, it can be ignored without leading to false conclusions.

From the information tabulated, the data necessary to show graphically on Fig. 64 the average relative cost, life and annual charges of stiff-rail frogs of ordinary construction compared with those of hardened steel construction, and on Fig. 65 a similar comparison with the ordinary spring-rail frogs, have been deduced.

The ratio of the average life of hardened steel frogs to frogs of other construction in same location was found to be:

1 to 3.95 for ordinary stiff-rail frogs.
1 to 3.25 for ordinary spring-rail frogs.

For simplicity the ratio 1 to 4 has been used in preparing the data for Fig. 64, but the exact ratio 1 to 3.25 has been retained in the case of Fig. 65.

On these two figures are platted curves of annual charges for frogs, the first and net cost of which are shown along the upper margin. The annual charges include the average cost of installing the frogs, repairs during life and credit taken for scrap value.

These figures are intended to show where it may or may not be economical to substitute a frog of hardened steel construction for one of ordinary construction, for instance:

In a certain location we have a stiff-rail frog of ordinary construction, its first cost being $33.00 and its life 2 years. How much can we afford to pay for a hardened steel frog with the expectation of it giving a life four times that of the ordinary frog? By referring to Fig. 64 we find that the curve of annual charges for the ordinary frog crosses that of a hardened steel frog costing $105.00 on the "two-eight" year line and if we can buy the hardened steel frog for less than $105.00 we can reduce our annual charge to less than that required for an ordinary frog costing $33.00.

Again we have in a certain location an ordinary stiff-rail frog, which originally cost $57.00 and gave 3 years' service. We have a quotation of $170.00 for a hardened steel frog. Will this pay? Fig. 64 shows that the annual charge for the $57.00 frog at the end of its life was about $17.00 and for a life 4 times greater, or 12 years, the annual charge for the $170.00 frog will be about $17.80; therefore, it would not be economical to make the substitution unless we secured a better quotation than $170.00.

Again we have a spring-rail frog which cost $47.00 and gave a life of 2½ years. A hardened steel frog can be substituted which will cost $115.00. Will this pay?

The annual charges for the two frogs are approximately equal, viz., $16.00 after a life of 2½ and 8⅛ years for the ordinary and hardened steel frogs, respectively; therefore, a determination of the frog to be used can be based on traffic or other conditions which would warrant the selection of one or the other type of frog.

Figs. 64 and 65 also bring out the following interesting points:

(1) An ordinary stiff-rail frog costing $27.00 and giving six months or more service is more economical than the cheapest hardened steel frog at $90.00, while if we have to pay $33.00 for the ordinary frog it is not economical unless it gives more than four years and nine months' service.

(2) An ordinary spring-rail frog costing $38.00 and giving 1 year and nine months or more service is more economical than the cheapest hardened steel frog at $90.00; while, if we have to pay $47.00 for the spring frog, it is not economical unless it gives more than six years and ten months' service.

(3) Hardened steel frogs costing $255.00 are not economical to substitute for highest price ordinary stiff-rail frogs at $62.00 if the ordinary frog gives six months or more service.

(4) Hardened steel frogs costing $210.00 or more are not economical to substitute for the highest price spring-rail frog at $71.00 if the spring frog gives six months or more service.

When Manganese frogs were first introduced, some manufacturers only made the wheel tread supports of the wings of Manganese steel, and left the point of ordinary carbon steel. Those frogs are called "Manard S. P." in column 4 of the table, which means "Manard Soft Point," and are no longer manufactured, as it is now well recognized that the "point" also should be made of Manganese steel.

A hardened steel frog generally shows the first wear on the point which becomes low; it then wears on top of treads, forming a ridge where wheels strike it. In the case of some frogs, these worn places can be repaired.

Manganese steel offers a safe, durable and economical material for the stiff-rail frogs, especially the higher numbered frogs, where better material is needed in the frog point.

From a trackman's point of view, the hardened steel frogs are much superior to the ordinary common rail frogs. They do not become loose so easily, stand up better under traffic and require less maintenance. They are especially favored now over the spring-rail frogs on heavy traffic divisions.

One disadvantage of the built-up hardened steel frog lies in the impossibility of drilling it or working it in any way in the field, owing to the extreme hardness of the Manganese steel, this disadvantage being common to all makes.

The percentage of defects in hardened steel is greater than in ordinary rail steel and for this reason good specifications and rigid shop inspection are highly essential for good results. This applies especially to the solid casting types of hardened steel frogs, which are now made by various frog and switch manufacturers. While this type of frog as made by the different manufacturers may vary but little in general design, yet a material difference may be noted in the location and thickness of metal for the reinforcing ribs and other essential details of a substantial design. This design of frog has not yet been demonstrated as safe for use at high-speed points, on account of the absence of any reinforcing bars or other means of tieing the frog together in case of fracture.

C. E. Rowe,
Assistant Engineer.

Switches:

The accompanying table contains the record of the relative service of Bessemer and Manganese steel switch-points on the Pennsylvania Lines, similar to the table for frogs, but in this case the average number of trains per diem at the place of observation is given. Owing to the fact that it has been necessary to estimate the probable total life of the most of the Manganese steel switch-points, although it has been performed in each case by skilled observers, it does not yet seem to be possible to forecast the relative economy by the number of trains per diem. Nevertheless, it is very plain that the use of the Manganese steel switch-points is economical in every case. It must not be forgotten, however, that they have only been selected for locations known to be severe on the Bessemer steel points.

The primary cost of the Manganese switch-points is 1½ to 3 times greater than of those made of Bessemer steel, but the monthly cost of the latter is sometimes 13 times as great.

EXPLANATION OF TABLE XIX.

Column 1. Abbreviations for names of Divisions:
Pgh.means Pittsburgh Division.
East.means Eastern Division.
West.means Western Division.
C.& P.means Cleveland and Pittsburgh Division.
E.& A.means Erie and Ashtabula Division.
Rich.means Richmond Division.
Logan.means Logansport Division.
C.T.means Chicago Terminal Division.

Column 2. Figures indicate frog number.
"Stiff" means a rigid frog. "Spring" means a spring rail frog.

Column 3. Shows the number of frogs considered in the comparison.

Column 4. "Manard" is the Pennsylvania Steel Co.'s trade name for "Manganese," and is a corruption of the words "Manganese-hard."
"H.P." means Hard Point. "S.P." means Soft Point.
Design No.160 is illustrated in Fig.17.

Column 5. "Penna.Steel Co." means Pennsylvania Steel Co.
"Wharton" means William Wharton Junior Co.
"Cleveland F.& S.Co." means Cleveland Frog and Switch Co.
"Indianapolis S.& F.Co." means Indianapolis Switch and Frog Co.
"Morden F.& C.Wks." means Morden Frog and Crossing Works.
"F.& S.Co." means The Frog and Switch Co.of Carlisle,Pa.

TABLE XIX.

ORDINARY VERSUS HARDENED STEEL FROGS.
ANNUAL SAVING OR DEFICIT BY USE OF HARDENED STEEL CONSTRUCTION.

Div.	Frog Number	No. of Frogs.	Hardened Steel Frogs		Average Life in Years		Average Net Cost		Average Annual Charge		Average Annual Saving
			Type	Maker	Ord.	Hard.	Ord.	Hard.	Ord.	Hard.	
1	2	3	4	5	6	7	8	9	10	11	12
Pgh.	7 Stiff	2	Manard H.P.	Penna.Steel Co.	0.25	2.00	$20.50	$95.50	$82.82	$50.62	$32.20
"	7 "	9	Manganese	Wharton	0.75	6.00	28.50	133.50	39.18	25.50	13.68
"	7 "	22	Manard S.P.	Penna.Steel Co.	5.34	12.64	20.50	88.90	4.33	9.07	4.74
"	7 Spr.	1	" Solid	" " "	0.25	2.83	30.50	93.40	123.22	35.68	87.54
"	7 "	1	Mang. "	Wharton	0.25	3.00	30.50	85.50	123.22	30.78	92.44
"	8 Stiff	1	Manard H.P.	Penna.Steel Co.	0.75	1.83	26.00	101.00	35.71	58.28	-22.57
"	8 "	2	Manganese	Wharton	0.75	4.00	26.50	120.50	36.39	33.14	3.25
"	8 "	1	Manard 160	Penna.Steel Co.	1.50	6.00	26.00	78.40	18.10	14.98	3.12
"	8 Spr.	3	" S.P.	" " "	1.67	4.53	40.00	103.00	25.12	25.34	- 0.22
"	8 "	2	" H.P.	" " "	1.13	3.95	40.00	111.00	36.92	30.86	6.06
"	8 "	5	Manganese	Wharton	0.75	3.42	38.20	121.20	52.46	38.54	13.92
"	8 "	1	"	Cleveland F.& S.Co.	2.50	5.08	35.50	127.50	15.19	28.08	-12.89
"	8 "	1	Manard 160	Penna.Steel Co.	1.50	6.00	31.00	78.40	21.58	14.98	6.60
"	8 "	1	" Solid	" " "	1.00	8.00	31.00	100.85	32.24	14.92	17.32
"	10 Stiff	6	" S.P.	" " "	1.17	2.79	25.50	98.50	22.72	38.02	-15.30
"	10 "	3	" H.P.	" " "	0.75	2.08	27.83	108.50	38.29	55.43	-17.14
"	10 "	14	Manganese	Wharton	1.67	4.59	26.50	129.43	16.76	31.45	-14.69
"	10 "	1	" Solid	Indianapolis S.& F.Co.	0.67	4.00	25.50	87.50	38.37	24.06	14.31
"	10 Spr.	7	Manard S.P.	Penna.Steel Co.	1.64	4.63	38.30	101.80	24.59	24.53	0.06
"	10 "	1	" H.P.	" " "	1.00	2.50	30.50	102.50	31.72	43.87	-12.15
"	10 "	11	Manganese	Wharton	1.48	4.79	38.05	138.60	33.01	32.43	0.58
"	10 "	2	"	Cleveland F.& S.Co.	1.75	3.70	37.50	127.00	22.58	37.59	15.01
"	10 "	13	Manard 160	Penna.Steel Co.	1.49	5.23	39.50	143.10	27.81	30.91	- 3.10
"	15 Stiff	7	" S.P.	" " "	1.50	4.09	48.43	134.71	33.71	35.23	- 1.52
"	15 "	7	" H.P.	" " "	0.79	2.49	48.43	144.71	63.40	62.08	1.32
"	15 "	9	Manganese	Wharton	1.17	5.13	50.55	192.11	45.04	42.07	2.97
"	15 "	2	Manard 160	Penna.Steel Co.	1.00	4.08	51.00	152.00	53.04	41.17	11.87
"	15 "	1	" Solid	" " "	1.00	5.00	51.00	179.80	53.04	40.27	12.77
"	15 Spr.	5	" S.P.	" " "	1.50	2.55	54.40	131.00	37.87	55.15	-17.28
"	15 "	1	" H.P.	" " "	1.50	3.50	60.00	152.00	41.76	47.42	- 5.66
"	15 "	14	Manganese	Wharton	1.74	5.70	55.14	172.74	33.47	39.59	- 6.12
"	15 "	6	"	Cleveland F.& S.Co.	2.00	5.00	60.00	134.00	31.80	30.02	1.78
"	15 "	19	Manard 160	Penna.Steel Co.	1.31	5.57	60.00	121.00	47.94	24.68	23.24
"	15 "	2	" Solid	" " "	1.17	7.00	56.50	172.50	50.34	28.59	21.75
"	15 "	2	Manganese	Wharton	0.50	2.50	53.00	129.00	109.18	55.21	54.97
"	15 "	1	"	"	2.00	5.00	60.00	199.00	31.81	44.58	-12.78
"	15 "	1	Manard H.P.	Penna.Steel Co.	1.50	6.00	60.00	152.00	41.76	29.03	12.73

Rich	8 Stiff	5	Manard, S.P.	Penna.Steel Co.	3.90	7.00	$38.00	$71.00	$10.72	$11.79	$-1.07
"	10 "	12	" S.P.	" " "	1.40	3.45	38.08	77.25	28.52	24.41	4.11
"	10 "	3	" H.P.	" " "	0.92	3.45	38.00	120.00	42.94	37.92	5.02
"	10 Spr.	3	" S.P.	" " "	2.00	2.97	38.00	100.00	25.04	36.40	-11.36
"	15 Stiff	5	" S.P.	" " "	3.40	8.83	38.00	132.00	16.05	17.95	- 1.90
Logan	8 Stiff	1	Manard	Penna.Steel Co.	1.00	4.00	41.00	113.00	42.64	31.08	11.56
"	8 "	2	Manganese	Wharton	0.75	4.50	46.00	115.00	60.02	28.41	31.61
"	10 "	2	"	"	0.75	4.00	51.50	133.00	70.56	36.58	33.98
"	15 "	1	"	"	0.50	4.00	60.00	126.00	123.60	34.65	88.95
"	15 "	3	"	Penna.Steel Co.	1.00	4.00	51.00	141.00	53.04	38.78	14.26
"	15 "	1	Manard	" " "	1.00	4.00	46.00	126.00	47.84	34.65	13.19
"	15 Spr.	1	Manganese	" " "	5.00	6.00	90.00	166.00	20.16	31.71	-11.55
C.T.	7 Stiff	2	"	Wharton	1.00	10.40	38.25	142.00	39.78	16.90	22.88
"	8 "	2	"	"	1.25	5.04	37.16	111.17	31.11	24.79	6.32
"	8 "	1	"	F.& S.Co.(Carlisle)	1.00	5.00	36.66	149.86	38.13	33.56	4.57
"	8 "	1	Manard	Penna.Steel Co.	1.50	6.00	36.66	109.21	21.52	20.86	0.62
"	8 "	1	Manganese	Indianapolis S.& F.Co.	1.00	4.75	36.66	106.16	38.13	24.95	17.18
"	10 "	5	"	Wharton	1.00	4.59	34.98	91.67	36.38	22.28	14.10
"	10 "	1	Manard	Penna.Steel Co.	1.00	4.59	44.98	123.53	46.78	30.02	16.76
"	10 "	1	Manganese	" " "	1.00	1.50	34.98	96.73	36.38	67.32	-31.06
"	15 Spr.	1	"	Cleveland F.& S.Co.	1.00	4.50	37.00	117.80	38.48	29.09	9.39
East.	7 Stiff	2	Manard H.P.	Penna.Steel Co.	0.25	2.24	44.00	100.00	177.66	47.50	130.16
"	7 "	2	" "	" " "	1.50	5.00	44.00	100.00	30.62	22.40	8.22
"	7 "	2	Manganese	Wharton	1.50	5.00	54.00	116.00	37.58	25.98	11.60
"	7 Spr.	1	Manard S.P.	Penna.Steel Co.	0.30	5.70	55.00	105.00	188.65	20.99	157.66
"	8 Stiff	1	" H.P.	" " "	1.00	4.92	43.00	115.00	44.72	26.72	18.00
"	10 "	2	" "	" " "	0.34	2.67	44.00	126.50	132.88	50.85	82.03
"	10 "	3	Manganese	Wharton	0.28	3.61	44.00	140.00	153.12	42.42	90.70
"	10 "	6	Manard S.P.	Penna.Steel Co.	0.53	3.30	50.50	117.83	97.97	38.77	59.20
"	10 "	2	Hard Center	Cleveland F.& S.Co.	0.60	1.30	44.00	115.00	75.68	90.58	-14.90
"	10 "	2	Manard H.P.	Penna.Steel Co.	0.67	3.33	44.00	130.00	67.94	42.51	25.43
"	10 "	1	Manganese	Wharton	1.50	3.30	56.00	114.00	38.98	37.51	1.47
"	15 "	5	Manard H.P.	Penna.Steel Co.	0.60	2.85	58.00	151.80	99.76	57.38	42.38
"	15 "	7	Manganese	Wharton	0.95	4.12	54.28	200.00	59.16	53.60	5.56
"	15 "	12	Manard S.P.	Penna.Steel Co.	0.56	4.59	35.66	149.00	102.24	36.31	65.93
"	15 "	11	" H.P.	" " "	1.36	4.17	52.00	144.27	40.04	38.23	1.81
"	15 "	1	Manganese	Wharton	0.70	4.80	52.00	220.00	76.96	51.26	25.70
"	15 "	2	Manard S.P.	Penna.Steel Co.	1.00	5.60	52.00	148.00	54.08	30.04	24.04
"	20 "	11	Manganese	Wharton	0.81	5.13	68.27	243.63	87.38	53.36	34.02
"	20 "	1	Manard S.P.	Penna.Steel Co.	0.50	3.00	63.00	171.00	129.78	61.56	68.22
"	20 "	3	" H.P.	" " "	2.22	5.26	65.00	219.33	31.14	47.15	-16.01
"	20 "	5	Manganese	Wharton	2.54	6.26	105.40	239.60	44.10	44.08	0.02
"	20 "	1	Manard S.P.	Penna.Steel Co.	2.00	4.30	63.00	174.00	33.99	43.65	- 9.66
West.	7 Stiff	25	Manard	Penna.Steel Co.	0.93	4.32	38.94	117.12	43.62	30.10	13.52
"	7 "	14	Manganese	Wharton	0.51	4.59	39.00	150.92	77.78	36.38	41.40
"	8 "	2	Manard	Penna.Steel Co.	0.66	5.67	29.00	105.50	45.53	20.10	25.43
"	8 "	2	Manganese	Wharton	1.00	5.34	28.00	89.00	29.12	17.98	11.14
	8 "	9	"	Morden F.& C.Wks.	2.77	4.75	30.00	88.00	11.67	20.68	- 9.01
"	10 "	4	Manard	Penna.Steel Co.	0.66	3.41	46.42	112.38	72.88	35.85	37.03
"	10 "	1	Manganese	Wharton	0.50	3.21	35.00	120.00	72.10	40.56	31.54
	20 "	1	"	"	0.50	3.17	71.00	231.00	146.26	78.77	67.49

TABLE XIX -- Continued.

Div.	Frog Number	No. of Frogs	Hardened Steel Frogs		Average Life in Years		Average Net Cost		Average Annual Charge		Average Annual Saving
			Type	Maker	Ord.	Hard.	Ord.	Hard.	Ord.	Hard.	
1	2	3	4	5	6	7	8	9	10	11	12
C.& P.	6 Stiff	1	Manard H.P.	Penna.Steel Co.	0.58	2.50	$27.25	$103.25	$48.23	$44.19	$ 4.04
"	6 "	1	Manganese	Wharton	0.58	3.66	28.00	97.00	49.56	29.00	20.56
"	7 "	12	Manard H.P.	Penna.Steel Co.	0.48	4.83	29.25	100.71	62.88	23.37	39.51
"	10 "	7	" "	" " "	1.19	4.19	33.00	105.00	29.84	27.72	1.22
"	10 "	1	" ... S.P.	" " "	0.66	5.75	33.00	105.00	51.81	20.79	31.02
"	10 "	1	Manganese	Wharton	0.33	3.66	33.00	93.00	102.63	27.81	74.82
"	15 "	1	Manard H.P.	Penna.Steel Co.	1.00	4.20	38.00	143.00	39.52	37.61	1.91
E.& A.	10 Stiff	1	Manard S.P.	Penna.Steel Co.	0.50	3.60	35.00	95.00	72.10	29.88	42.22
"	10 "	6	" H.P.	" " "	0.92	4.29	35.00	115.00	39.55	37.30	2.25
"	10 "	4	Manganese	Wharton	0.88	3.60	35.00	80.00	41.10	24.32	16.78
"	15 "	1	"	"	0.50	4.20	40.00	85.00	82.40	22.36	60.04
"	15 "	7	Manard H.P.	Penna.Steel Co.	1.14	3.63	40.00	155.00	36.60	46.66	-10.06
"	15 "	11	" S.P.	" " "	1.18	3.47	40.00	135.00	35.44	42.26	- 6.82
"	20 "	1	" S.P.	" " "	1.00	3.30	50.00	145.00	52.00	47.71	4.29

ORDINARY VERSUS HARDENED STEEL CROSSINGS.

Div.	Single Crossings	Hardened Steel Construction		Average Life		Average Net Cost		Average Annual Charge		Average Annual Saving
		Type	Maker	Ord.	Hard.	Ord.	Hard.	Ord.	Hard	
1	2	3	4	5	6	7	8	9	10	11
Pgh.	4	Manganese	Wharton	1.88	5.54	288.00	708.00	161.57	145.14	16.43
"	1	Manard	Penna.Steel Co.	2.00	7.00	288.00	549.00	152.64	90.23	62.41
Logan	5	Manganese	Wharton	1.27	3.82	286.80	562.80	236.03	162.08	73.95
"	2	Manard	Penna.Steel Co.	4.00	6.00	521.00	446.00	143.28	85.19	58.09
E.& A.	2	" H.P.	" " "	0.90	2.35	290.00	585.00	333.50	266.18	67.32
"	1	" S.P.	" " "	0.80	2.20	260.00	535.00	332.80	258.94	73.86
"	1	Manganese	Wharton	1.00	4.26	387.72	533.18	403.23	138.63	264.60
West.	6	Manard	Penna.Steel Co.	2.19	2.46	458.00	628.36	222.19	273.33	-51.14
"	3	Manganese	Wharton	1.50	4.69	405.33	854.00	282.11	117.85	164.26
"	1	" Stag.	Kent & Co.	2.00	4.25	459.00	654.00	243.27	170.69	72.58

EXPLANATION OF TABLE XX.

Column 1.	The interlocking or telegraph towers or cabins are designated in the United States by the Morse telegraph calls, as "FS" Tower. "Trk." is abbreviation for "Track." "Jct." is abbreviation for "Junction." "W.B.Trk." is abbreviation for "West Bound Track." "E.B.M." is abbreviation for "East Bound Main."
Column 2.	85# indicates rail weighing 85 pounds per yard.
Column 7.	The word "Manard" is the Pennsylvania Steel Co.'s trade name for "Manganese" and is a corruption of the words "Manganese-hard."
Column 8.	"Wm.W.Jr.Co." indicates "William Wharton Junior Co." "P.S.Co." indicates "Pennsylvania Steel Co." "C.F.& S.Co." indicates "Cleveland Frog and Switch Co."

TABLE XX.

Pennsylvania Lines West of Pittsburgh.

RECORD SHOWING THE RELATIVE MERITS OF SPECIAL HARD SERVICE OR MANGANESE STEEL SWITCH POINTS MADE BY DIFFERENT MANUFACTURERS AS COMPARED WITH ORDINARY BESSEMER STEEL SWITCH POINTS.

OFFICE OF CHIEF ENGINEER MAINTENANCE OF WAY, SOUTH-WEST SYSTEM.

PITTSBURGH, PA., SEPT. 1912.

		Ordinary Bessemer Switch Points			Special Hard Steel Switch Points in same Location.													
Location	Weight of Rail and Length of Point	Cost per Point	Life in Months	Cost per Point per Month	Length of Special Steel Point	Kind of Steel	Manufacturer	Date put in Track	Date Taken up	Life in Months	Av. No. of Trains per Day	Trains during Life	Cost per Point	Cost per Point per Month	First Cost Compared with Ordinary Point	Length of Life Compared with Ordinary Point.	Cost per Month Compared with Ordinary Point.	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Sharpsville-Turnout E.B.Trk to Pass.Siding at end Double Trk.	85#-18.0'	$21.00	18	$1.17	8'-0"	Mn	Wm.W.Jr.Co.	*9-06	*6-14	93	20	55800	$51.00	$0.55	2.4 - 1	5.1-1	1 - 2.1	Right Hand Point, good condition, cracked slightly where hard and soft parts join. Left hand point, about 2" cracked from point.
Wampum Jct. Crossover, Main Tracks in E.B.M.	" "	22.00	6	3.67	"	"	"	12-07	12-11	48	25	35200	55.00	1.15	2.5 - 1	8 - 1	1 - 3.2	
Lawrence Jct. Crossover, E.& P.- E.& W.B. Mains	" "	17.00	12	1.42	3'-6"	Manard	P.S.Co.	9-10	*9-14	48	25	35200	35.00	0.73	2 - 1	4 - 1	1 - 2.1	
Lawrence Jct. Crossover, E.& W.B.- P.Y.& A. in W.B. Track	" "	17.00	6	2.83	3'-6"	"	P.S.Co.	10-10	*7-14	46	30	41400	35.00	0.76	2 - 1	7.7-1	1 - 3.7	
Wampum Jct. Turnout W.B.M. to W.B. Passing Siding	" "	17.00	6	2.83	8'-0"	Mn	Wm.W.Jr.Co.	12-07	*12-12	60	30	54000	55.00	0.91	3.2 - 1	10- 1	1 - 3.1	
Wampum Jct. Turnout E.B.M. to E.B. Passing Siding	" "	17.00	6	2.83	8'-0"	"	"	12-07	*12-12	60	30	54000	55.00	0.91	3.2 - 1	10- 1	1 - 3.1	
Akron Jct. N. end Crossover	" "	20.00	1½	13.33	7'-6"	"	"	11-05	6-08	31	40	37200	60.00	0.94	3 - 1	20.7-1	1 - 7	Removed--worn out.
" " " " "	" "	20.00	1½	13.33	7'6"	"	"	6-08	8-09	14	40	16800	60.00	4.29	3 - 1	9.3-1	1 - 3	Removed on account of crack in Web at point Still in good condition in yard at busy point.
Lawrence Jct. Turnout E.B.M. and Passing Siding	" "	17.00	6	2.83	3'-6"	Manard	P.S.Co.	1-08	*11-11	46	40	55200	39.00	0.85	2.3 - 1	7.7-1	1 - 3.3	
Lawrence Jct. Crossover E.& W.B.-E.& P. in E.B. Track	" "	17.00	6	2.83	5'-6"	"	"	12-09	*2-14	50	40	60000	35.00	0.70	2.1 - 1	8.3-1	1 - 4	
Warwick C.L.& W."Y"	" "	20.00	30	0.67	5'-8"	"	"	12-07	*12-15	96	50	144000	55.00	0.57	2.75- 1	3.2-1	1 - 1.2	Good condition.

* Estimated

Warwick B.& O.to C.A.& C.-N.B.	85#-18.0'	$20.00	24	$0.83	7'-6"	Mn	Wm.W.Jr.Co.	1-07	*3-15	98	50	147000	$60.00	$0.61	3 - 1	4.1-1	1 - 1.3	Good condition.
" C.A.& C.to B.& O.-W.B.	" "	20.00	24	0.83	7'-6"	"	"	1-07	*3-15	98	50	147000	60.00	0.61	3 - 1	4.1-1	1 - 1.3	" "
Detour-Turnout P.Y.& A.and A.N.& A.-W.B.M.	" 30.0'	39.00	12	3.25	8'-0"	"	"	10-07	*10-11	48	50	72000	79.00	1.65	2 - 1	4 -1	1 - 2	
"H.F." Tower E.B.-P.Y.& A. to E.B.Yard.	" 18.0'	17.00	6	2.83	8'-0"	"	"	12-08	*12-12	48	50	72000	55.00	1.15	3.2 - 1	8 -1	1 - 2.45	
"M.N."Tower Turnout,W.B.Main to Yard	" "	22.00	18	1.22	3'-6"	Manard	P.S.Co.	11-10	*11-14	48	50	72000	35.00	0.73	1.6 - 1	2.6-1	1 - 1.7	Good condition.
"M.N."Tower, Turnout E.& W.B.Yard Tracks	" "	22.00	18	1.22	3'-6"	"	"	8-10	*8-14	48	50	72000	35.00	0.73	1.6 - 1	2.6-1	1 - 1.7	Good condition but point bent over.
Detour-Turnout P.Y.& A.and A.N.& A.-W.B.M.	" 30.0'	39.00	12	3.25	5'-6"	"	"	10-09	*11-13	49	50	73500	48.00	0.98	1.23- 1	4 -1	1 - 3.3	
"H.F." Tower,W.B.Yard to W.B.-P.Y.& A.	" 18.0'	17.00	18	0.94	5'-6"	"	"	8-09	*1-14	53	50	79500	35.00	0.66	2 - 1	3 -1	1 - 1.4	
Lawrence Jct.Crossover E.& W.B.-P.Y.& A.in E.B.Track	" "	17.00	6	2.83	5'-6"	"	"	11-09	*1-14	50	50	75000	35.00	0.70	2 - 1	8 -1	1 - 4	
Akron,Slip at N.end ladder	" "	20.00	12	1.67	7'-6"	Mn	Wm.W.Jr.Co.	10-08	*3-16	89	55	146850	55.00	0.62	2.75- 1	7.4-1	1 - 2.7	Four switches in good condition.
" Middle Slip	" "	20.00	12	1.67	7'-6"	"	"	10-08	*3-16	89	55	146850	55.00	0.62	2.75- 1	7.4-1	1 - 2.7	" "
" N.end N.B.ladder	" "	20.00	12	1.67	5'-8"	Manard	P.S.Co.	10-08	*3-16	89	55	146850	55.00	0.62	2.75- 1	7.4-1	1 - 2.7	Good condition.
" S.end No.5 Track	" "	20.00	12	1.67	5'-8"	"	"	10-08	*3-16	89	55	146850	55.00	0.62	2.75- 1	7.4-1	1 - 2.7	" "
" S.end No.3 Track	" "	20.00	12	1.67	5'-8"	"	"	10-08	*3-16	89	55	146850	55.00	0.62	2.75- 1	7.4-1	1 - 2.7	" "
" S.end N.B.ladder	" "	20.00	12	1.67	5'-8"	"	"	10-08	*3-16	89	55	146850	55.00	0.62	2.75- 1	7.4-1	1 - 2.7	" "
Detour Crossover E.B.M.to Sdg.	" "	17.00	6	2.83	3'-6"	"	"	10-09	*11-13	49	60	88200	35.00	0.71	2 - 1	8 -1	1 - 4	
Akron,Scissors Crossover	" "	20.00	12	1.67	7'-6"	Mn	Wm.W.Jr.Co.	9-08	*9-13	60	65	117000	55.00	0.92	2.75- 1	5 -1	1 - 1.8	Four switches in good condition.
"H.F." Tower,W.B.Y.Track, W.B. P.Y.& A.	" "	22.00	18	1.22	5'-6"	Manard	P.S.Co.	8-10	*8-14	48	70	100800	35.00	0.73	1.6 - 1	2.7-1	1 - 1.7	Good condition,point bent over.
"H.F." Tower,E.B.M.Track to E.B.Pass.Siding	" "	22.00	18	1.22	5'-6"	"	"	8-10	*8-14	48	70	100800	35.00	0.73	1.6 - 1	2.7-1	1 - 1.7	Good condition.
"H.F." Tower,Crossover Main Trks in W.B.M.	" "	22.00	18	1.22	3'-6"	"	"	8-10	*8-14	48	70	100800	35.00	0.73	1.6 - 1	2.7-1	1 - 1.7	Good condition,point bent over.
Market Street Yard, W.B.Track, East End	" "	22.00	3	7.33	8'-0"	Mn	Wm.W.Jr.Co.	5-09	6.10	13	75	29250	55.00	4.23	2.5 - 1	4 -1	1 - 1.7	

* Estimated

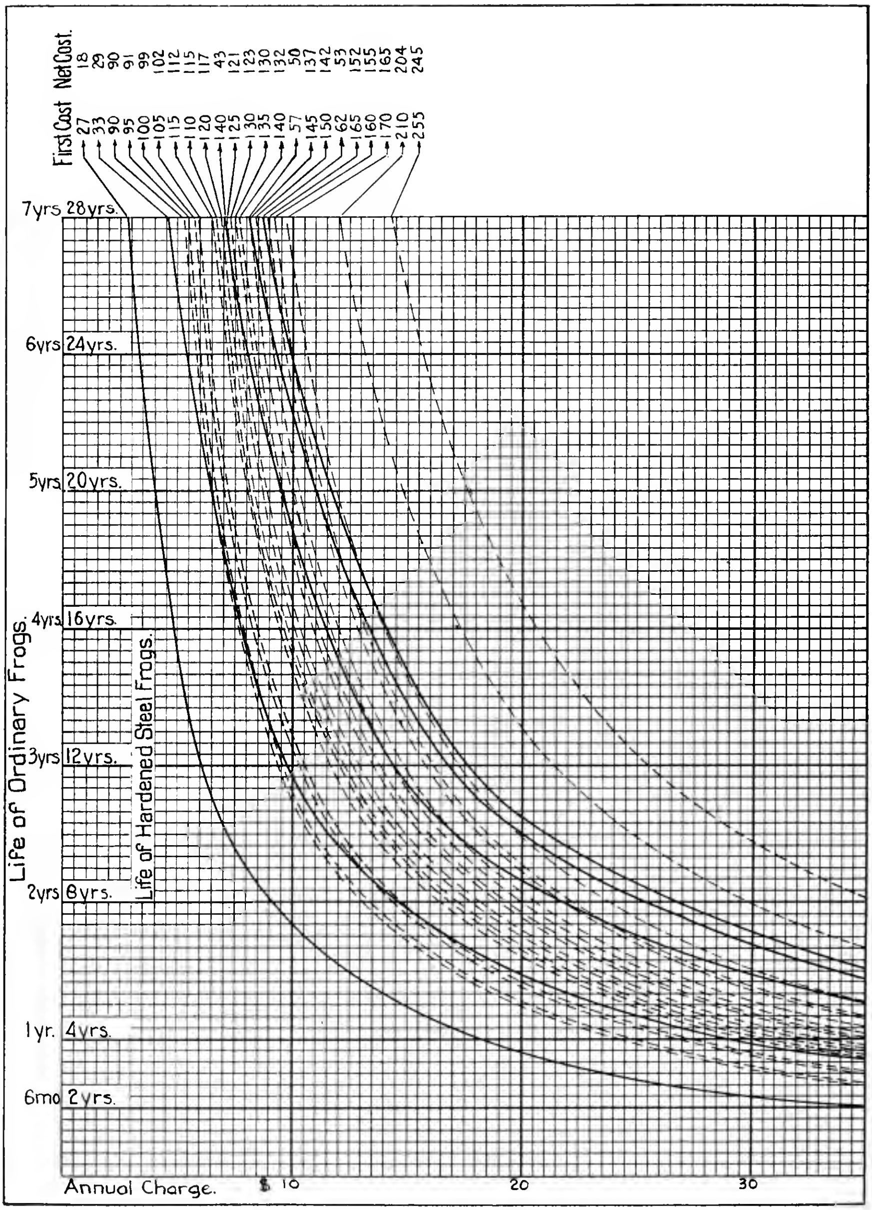
TABLE XX -- Continued.

Location	Weight of Rail and Length of Point	Ordinary Bessemer Switch Points			Special Hard Steel Switch Points in same Location.													Remarks
		Cost per Point	Life in Months	Cost per Point per Month	Length of Special Steel Point	Kind of Steel	Manufacturer	Date put in Track	Date Taken Up	Life in Months	Av.No. of Trains per Day	Trains during Life	Cost per Point	Cost per Point per Month	First Cost Compared with Ordinary Point.	Length of Life Compared with Ordinary Point.	Cost per Month Compared with Ordinary Point.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Market Street Yard, E.B.Track, West End	85#-18.0'	$22.00	3	$7.33	3'-6"	Manard	P.S.Co.	5-09	*5-11	24	75	54000	$35.00	$1.46	1.6 - 1	8 -1	1 - 5	Nearly worn out, badly chipped 8" from point.
Detour,E.end Double Crossover E.B.M.	" "	17.00	6	2.83	3'-6"	Manard	"	10-09	*11-13	49	75	110250	35.00	0.71	2 - 1	8 -1	1 - 4	
Columbus N.End Joint Tracks	" "	20.00	6	3.33	7'-6"	Mn	Wm.W.Jr.Co.	3-08	*3-14	72	85	183600	55.00	0.76	2.75- 1	12.0-1	1 - 4.4	Good condition.
"B.X." Tower West End Gauntlet	" "	22.00	3	7.33	8'-0"	"	"	4-09	5-10	13	100	39000	55.00	4.23	2.5 - 1	4 -1	1 - 1.7	
Lawrence Jct.Crossover P.Y.& A.Main Trks.in E.B.M.	" "	17.00	4	4.25	8'-0"	"	"	2-08	*2-13	60	100	180000	55.00	0.91	3.2 - 1	15.0-1	1 - 4.7	
"BY" Tower East End Gauntlet	" "	22.00	3	7.33	3'-6"	Manard	P.S.Co.	5-09	*6-10	13	100	39000	35.00	2.69	1.6 - 1	4 -1	1 - 2.7	
"BY" Tower East End Gauntlet	" "	22.00	3	7.33	3'-6"	"	"	6-10	12-11	18	100	54000	35.00	1.95	1.6 - 1	6 -1	1 - 3.8	
Lawrence Jct. Turnout E.& P. & P.Y.& A.	" "	17.00	6	2.83	5'-6"	"	"	6-10	*6-14	48	100	144000	35.00	0.73	2 - 1	8 -1	1 - 4	
"P.A."Tower	100#-30.0'	32.00	4	8.00	5'-10"	"	"	11-09	1-11	14	20	8400	51.00	3.64	1.6 - 1	3.5-1	1 - 2.2	R.H.Point only.
E.Sw.Slip No.2,Marion Ave.	" "	32.00	1½	22.86	12'-0"	Mn	Wm.W.Jr.Co.	8-07	*3-12	55	74	122100	128.00	2.33	4 - 1	33.3-1	1 - 9.8	
E.Sw.No.15 Crossover No.4 West Penn.	" "	32.00	1½	22.86	11'-6"	Manard	P.S.Co.	11-07	*3-13	64	82	157440	111.00	1.73	3.5 - 1	43.0-1	1 -13.2	
E.Sw.No.1 Jacks Run	" "	32.00	8	4.00	3'-0"	Mn	C.F.& S.Co.	9-10	*3-13	30	91	81900	75.00	2.50	2.3 - 1	3.7-1	1 - 1.6	
W.Sw.No.1 Jacks Run	" "	32.00	16	2.00	3'-0"	"	"	9-10	*3-13	30	91	81900	75.00	2.50	2.3 - 1	1.9-1	1 -1.25	

* Estimated

Crossover, Jacks Run	100#-30.0'	$32.00	1½	22.86	3'-0"	Mn	C.F.& S.Co.	2-11	*2-14	36	91	98280	$75.00	$2.08	2.3 - 1	14 -1	1 - 11	
Crossover, No.4 to No.3, Jacks Run	" "	32.00	1¼	27.43	3'-0"	"	"	2-11	*2-14	36	95	102600	75.00	2.08	2.3 - 1	29 -1	1 - 13.1	
Sw.No.4 to No.14 Jacks Run	" 18.0'	20.00	7	2.86	3'-0"	"	"	2-11	*2-14	36	95	102600	47.00	1.31	2.3 - 1	5 -1	1 - 2.2	
Crossover, No.3 to No.2, Jacks Run	" 18.0'	20.00	3	6.66	3'-0"	"	"	2-11	*2-14	36	99	106920	47.00	1.31	2.3 - 1	12 -1	1 - 5.1	
Sw.No.3 to O.C.Ry.Jacks Run	" 30.0'	32.00	1¼	27.43	3'-0"	"	"	2-11	*2-14	36	99	106920	75.00	2.08	2.3 - 1	29 -1	1 - 13.1	
Crossover, No.3 to No.4, Jacks Run	" 30.0'	32.00	1¾	19.59	3'-0"	"	"	2-11	*2-14	36	99	106920	75.00	2.08	2.3 - 1	21 -1	1 - 9	
W.end No.4,"B.H." Tower	" 30.0'	32.00	2	16.00	5'-10"	Manard	P.S.Co.	8-09	11-09	3	100	9000	51.00	17.00	1.6 - 1	1.6-1	1 - 1	Inside Sharp Curve
W.Sw.No.15 Crossover, No.4 West Penn.	" 30.0'	32.00	1¼	27.43	12'-0"	Mn	Wm.W.Jr.Co.	8-07	4-09	20	111	66600	128.00	6.40	4 - 1	16 -1	1 - 4.3	Removed account defect.Replaced by Manufacturer. To replace above.
W.Sw.No.15 Crossover, No.4 West Penn.	" 30.0'	32.00	1¼	27.43	12'-0"	"	"	9-07	*3-11	32	111	106560	128.00	4.00	4 - 1	26 -1	1 - 6.8	
E.Sw.No.2 Jacks Run	" 30.0'	32.00	13	2.46	3'-0"	"	C.F.& S.Co.	9-10	*3-13	30	111	99900	75.00	2.50	2.3 - 1	2.3-1	1 - 1	
Crossover, No.2 to No.3, Jacks Run	" 18.0'	20.00	1¼	17.14	3'-0"	"	"	2-11	*2-14	36	111	119880	47.00	1.31	2.35- 1	29 -1	1 - 13	
Crossover No.1 to No.2, Jacks Run	" 30.0'	32.00	2	16.00	3'-0"	"	"	2-11	*2-14	36	111	119880	75.00	2.08	2.3 - 1	18 -1	1 - 7.7	
E.Sw.Slip No.1,Marion Avenue	" 18.0'	20.00	1¼	17.14	8'-0"	"	Wm.W.Jr.Co.	10-08	4-09	6	189	34020	66.00	11.00	3.3 - 1	4.8-1	1 - 1.6	Removed account defect,Replaced by Mfgr, To replace above.
E.Sw.Slip No.1,Marion Avenue	" 18.0'	20.00	1¼	17.14	8'-0"	"	"	4-09	*3-12	35	189	198450	66.00	1.89	3.3 - 1	28 -1	1 - 9.0	
E.Slip No. 2 West Penn.	" 30.0'	32.00	1¼	27.43	11'-6"	Manard	P.S.Co.	11-07	*3-13	64	193	370560	110.00	1.73	3.5 - 1	51 -1	1 - 16	

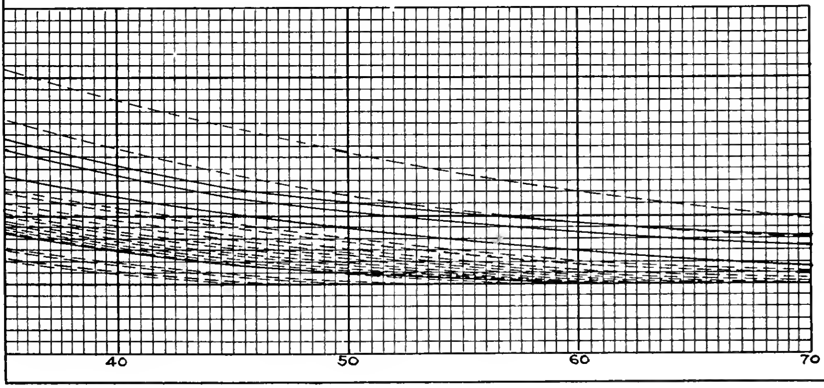
* Estimated

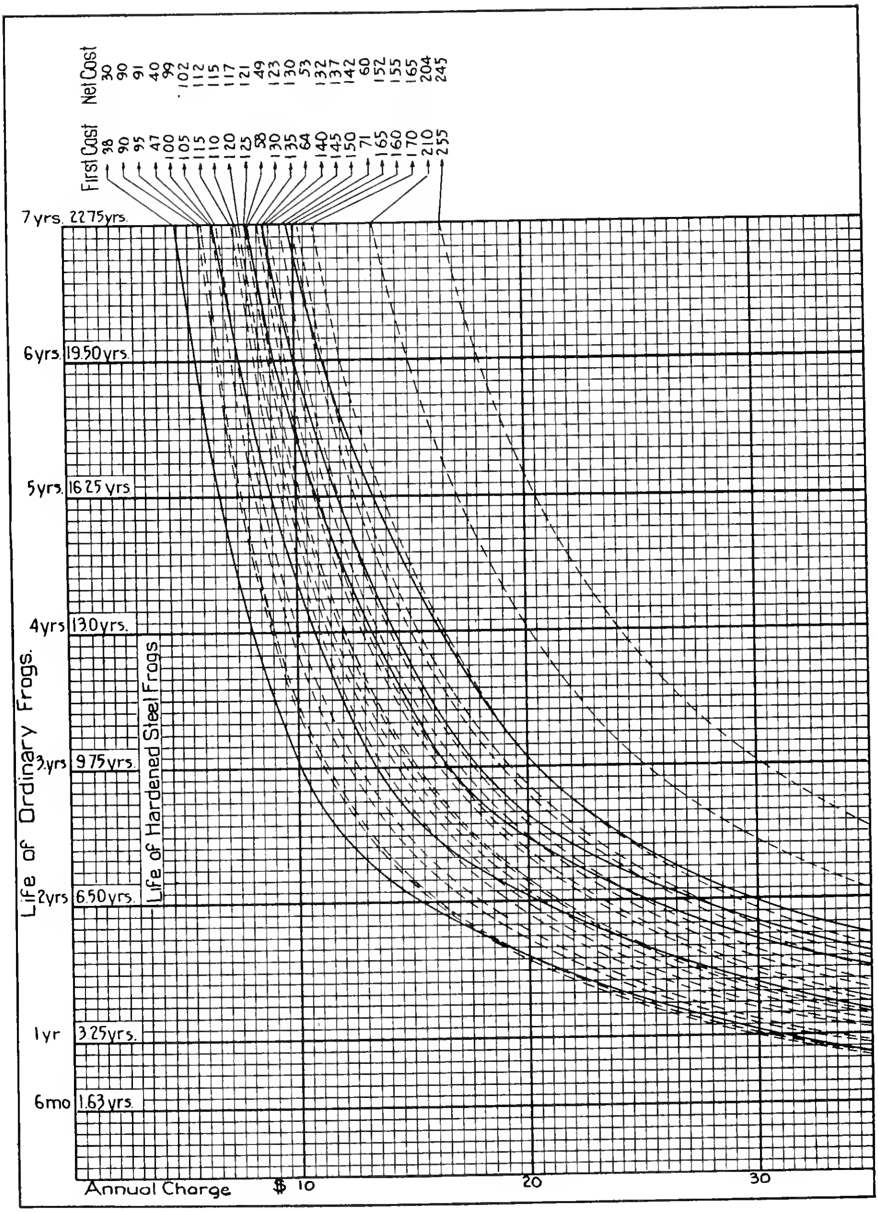

First Cost
27
33
90
95
100
105
115
110
120
140
125
130
135
140
57
145
150
62
165
160
170
210
255
Net Cost.
18
29
90
91
99
102
112
115
117
43
121
123
130
132
50
137
142
53
152
155
165
204
245
7yrs 28yrs.
6yrs 24yrs.
5yrs 20yrs.
4yrs 16yrs.
3yrs 12yrs.
2yrs 8yrs.
1yr. 4yrs.
6mo 2yrs.
Life of Ordinary Frogs.
Life of Hardened Steel Frogs.
Annual Charge.
$ 10
20
30

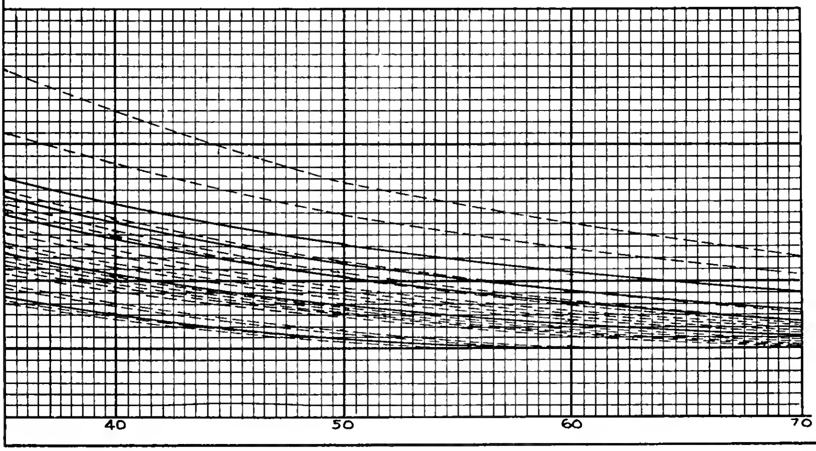
Note.

Ordinates are Life in Years.
Abscissas are Annual Charges.
Ordinary Frogs indicated by solid line.
Hardened " " " dotted line.
Annual Charges are based on Net Cost, but
are named for First Cost
Average life of Hardened Frogs is 4 times that of
Ordinary Frogs, therefore their Annual Charges
are platted for a life 4 times that of Ordinary
Frogs shown on same abscissa.

Fig. 64.
Chart showing Annual Charges
for Stiff Rail Frogs
Ordinary vs. Hardened Steel.




Net Cost
30
90
91
40
99
102
112
115
117
121
49
123
130
53
132
137
142
60
152
155
165
204
245
First Cost
38
90
95
47
100
105
115
110
120
125
58
130
135
64
140
145
150
71
165
160
170
210
255
7 yrs. 22.75yrs.
6yrs. 19.50 yrs.
5yrs. 16.25 yrs.
4yrs. 13.0 yrs.
3yrs. 9.75 yrs.
2yrs. 6.50 yrs.
1 yr 3.25 yrs.
6mo 1.63 yrs.
Life of Ordinary Frogs.
Life of Hardened Steel Frogs
Annual Charge
$ 10
20
30



NOTE.
Ordinates are Life in Years.
Abscissas are Annual Charges
Ordinary Frogs indicated by solid line
Hardened Steel Frogs indicated by dotted line
Annual Charges based on Net Cost, but named for First Cost.
Average Life of Hardened Frogs is 3.25 times that of Ordinary Frogs, therefore their Annual Charges are platted for a life 3.25 times that of Ordinary Frogs shown on same abscissa.

Fig 65.
Chart showing Annual Charges for Spring Rail Frogs.
Ordinary vs. Hardened Steel.

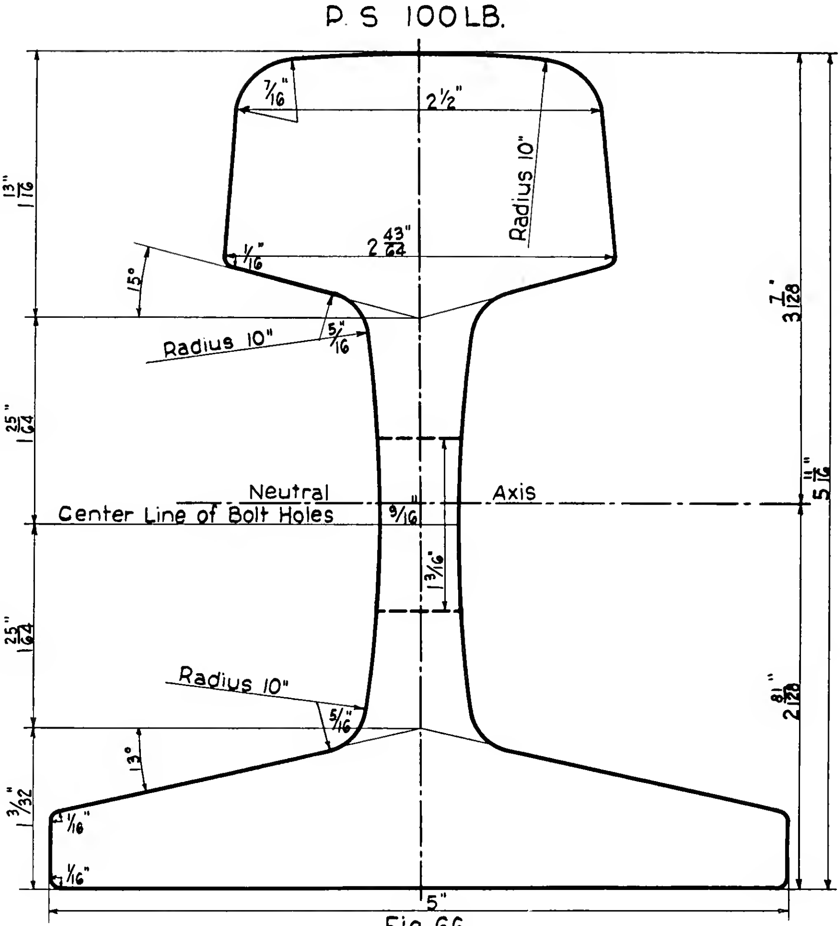


Fig. 66

Area of Head	4.09	sq. in	41.0%
" " Web	1.85	" "	18.6%
" " Base	4.03	" "	40.4%
Total	9.97	" "	100.0%

Moment of Inertia = 41.9

Section Modulus of Head = 13.71

" " " Base = 15.91

Appendix E.

REPORT OF THE ATCHISON, TOPEKA & SANTA FE RAILWAY SYSTEM ON TRIALS OF MANGANESE STEEL RAIL.

Herein are given the details of two experiments by the Atchison, Topeka & Santa Fe Railway System to determine the amount of abrasion from Manganese steel rail heads under a given tonnage. They were made on 10-degree curves (radius 574 ft.), one at the Mississippi River bridge and the other at the Horseshoe Curve in New Mexico.

The general data in regard to them are given in the following pages:

First Test.

NOTES ON RAIL SECTIONS OF MANGANESE STEEL RAIL ON 10-DEGREE CURVE AT WEST END OF MISSISSIPPI RIVER BRIDGE—ILLINOIS DIVISION.

Alinement—10-degree curve.

Sections taken at locations shown on sketch map.

Sections show—

- Theoretical original section of rail, dotted lines.
- Actual present section of rail, full lines.
- Vertical line—Taken with pantograph.
- Superelevation of track taken with "Wye" Level.
- Gage of track.
- Gage side of rails.

Grade—Level grade of bridge carried around curve, then 0.60 grade for 300 ft., followed by 0.33 grade.

Single Track.

Character of Track:

- Fully tie-plated and screw-spiked.
- Gravel ballasted.

Volume of Freight Traffic = 8,247,000 gross ton-miles per mile per annum.

Total number of scheduled passenger trains per day, 13.

CHARACTERISTICS OF FREIGHT AND PASSENGER ENGINES IN SERVICE.

Service	Class	Weight in pounds on	
		Drivers	Axle
Freight.......	566	135,000	48,670
Passenger.....	507	99,200	49,600

Rail laid November and December, 1909.

Measurements taken February 12, 1913.

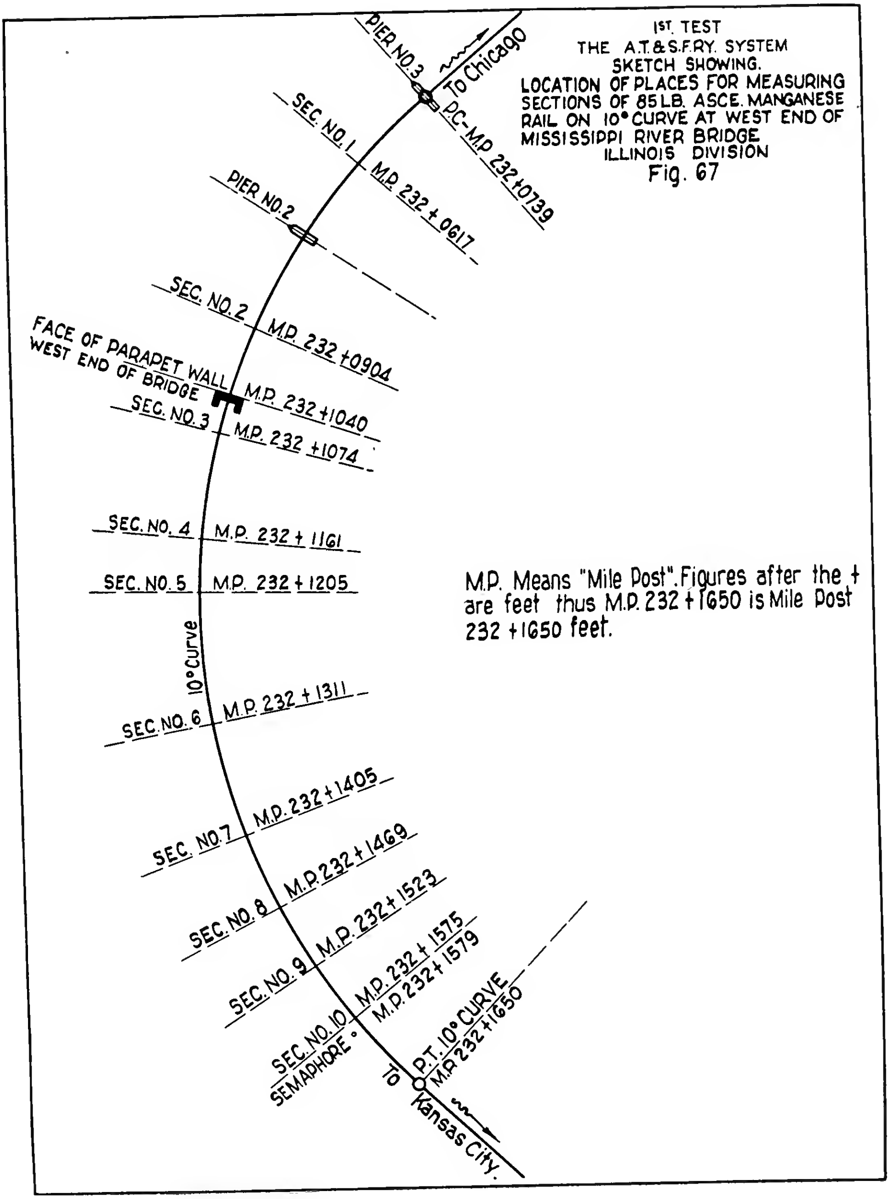
Rail in service 3 years 2 months.
Rail new when laid.
Rail manufactured for Manganese Steel Rail Co. by Illinois Steel Company.
85 lbs. per yard rail—A.S.C.E. Section.
Analysis stated by Manganese Steel Rail Company generally runs:

Manganese	11.50 to 12.00 per cent.
Carbon	1.10 to 1.20 per cent.
Phosphorus under	0.06 per cent.
Sulphur under	0.04 per cent.

CONDITION OF RAILS AT SECTIONS SHOWN ON LOCATION DIAGRAM, ON 10-DEGREE CURVE AT WEST END OF MISSISSIPPI RIVER BRIDGE, NEAR FORT MADISON.

DECEMBER, 1911.

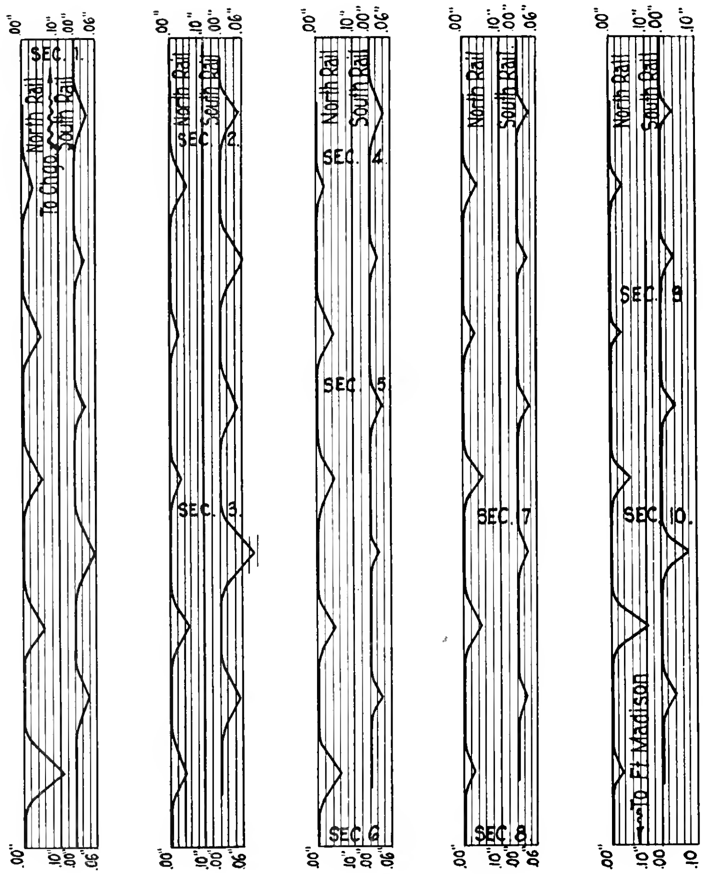
Sec. No. 1—Both rails in good condition.
Sec. No. 2—Both rails in good condition.
Sec. No. 3—Low rail shows slight fiber at center. High rail in good condition.
Sec. No. 4—Low rail badly burned and shows fiber. High rail in good condition.
Sec. No. 5—Low rail chipped at end shows brittleness—Badly burned. High rail chipped on inside corner 5 ft. from end, for 1 ft. shows brittleness.
Sec. No. 6—Low rail shows slight fiber and slightly burned. High rail slightly scaled on inside corner.
Sec. No. 7—Low rail shows fiber. High rail shows slivering in outside corner.
Sec. No. 8—Low rail very fibrous; chipped at end. High rail surface slivers in outside corner.
Sec. No. 9—Low rail badly burned; chipped at end, apparently by burn at same plate. High rail badly burned.
Sec. No. 10—Low rail slivered and badly burned. High rail badly burned.



1st. TEST
THE A.T.&S.F.RY. SYSTEM
SKETCH SHOWING.
LOCATION OF PLACES FOR MEASURING SECTIONS OF 85 LB. ASCE. MANGANESE RAIL ON 10° CURVE AT WEST END OF MISSISSIPPI RIVER BRIDGE
ILLINOIS DIVISION
Fig. 67

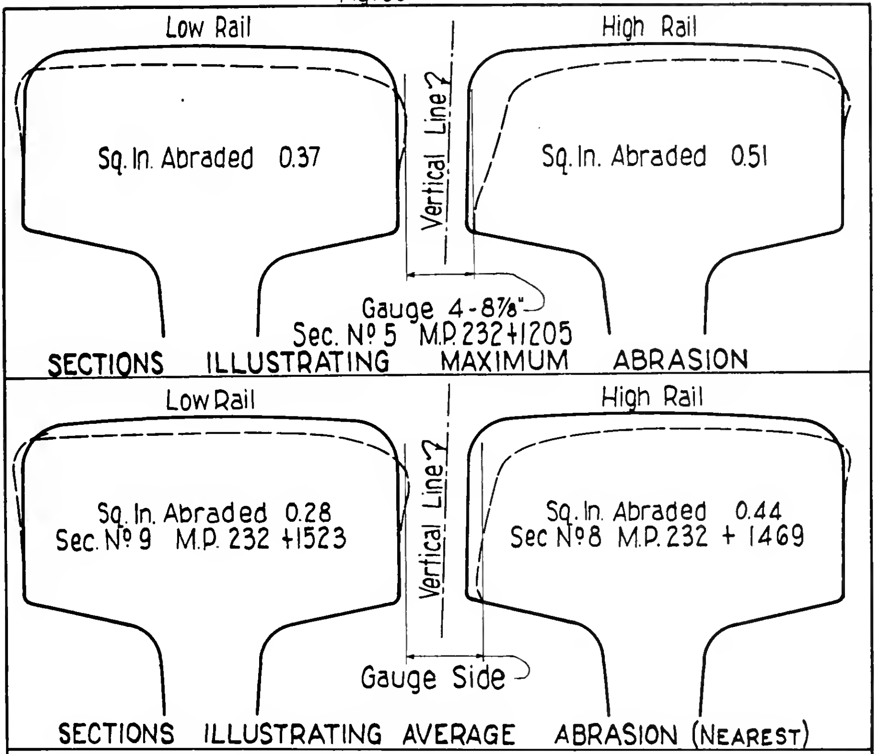
M.P. Means "Mile Post". Figures after the + are feet thus M.P. 232+1650 is Mile Post 232+1650 feet.

THE A.T.& S.F.RY. SYSTEM
SKETCH SHOWING
PERMANET SET IN RAILS AT JOINTS
ON 10° CURVE AT WEST END OF
MISSISSIPPI RIVER BRIDGE
ILLINOIS DIVISION
FIG. 68.



1ST. TEST
THE A.T.&S.F.RY. SYSTEM
SKETCH SHOWING
SECTIONS OF 85LB. A.S.C.E. MANGANESE
RAIL ON 10° CURVE AT WEST END
OF MISSISSIPPI RIVER BRIDGE
ILLINOIS DIVISION.

Fig. 69



SECTIONS ILLUSTRATING MAXIMUM ABRASION

SECTIONS ILLUSTRATING AVERAGE ABRASION (NEAREST)

FIRST TEST	LOW RAIL.	HIGH RAIL.
Area of Head New	3.50 Sq. In.	3.50 Sq. In.
Total Area Abraded, 10 Sections.	2.86	4.36 " "
Average " " per Section.	0.29	0.44 " "
Per Cent. " " " "	8%	12%
Wear per 10,000,000 Tons of Freight	0.11 Sq. In.	0.17 Sq. In.

Second Test.

RAIL WEAR COVERING MANGANESE RAIL ON HORSESHOE CURVE BETWEEN BLANCHARD AND RIBERA—NEW MEXICO DIVISION.

Sections taken at locations shown on location map.

Sections show—

Theoretical original section of rail (dotted lines).

Actual present section of rail (full lines).

Vertical line (taken with company rail-section instrument No. 1).

Gage of track.

Gage side of rails.

Heat number and brand of rail where discernible.

All sections are taken facing in the direction of mile posts.

Volume of traffic

Gross Ton-Miles Per Mile Per Annum.

Freight	Passenger	Total
3,108,000	1,200,000	4,308,000

CHARACTERISTICS OF ENGINES IN SERVICE.

Service	Class	Weight in pounds on	
		Drivers	Axle
Freight.......	1600	234,580	53,900
Passenger.....	1200	147,400	51,700

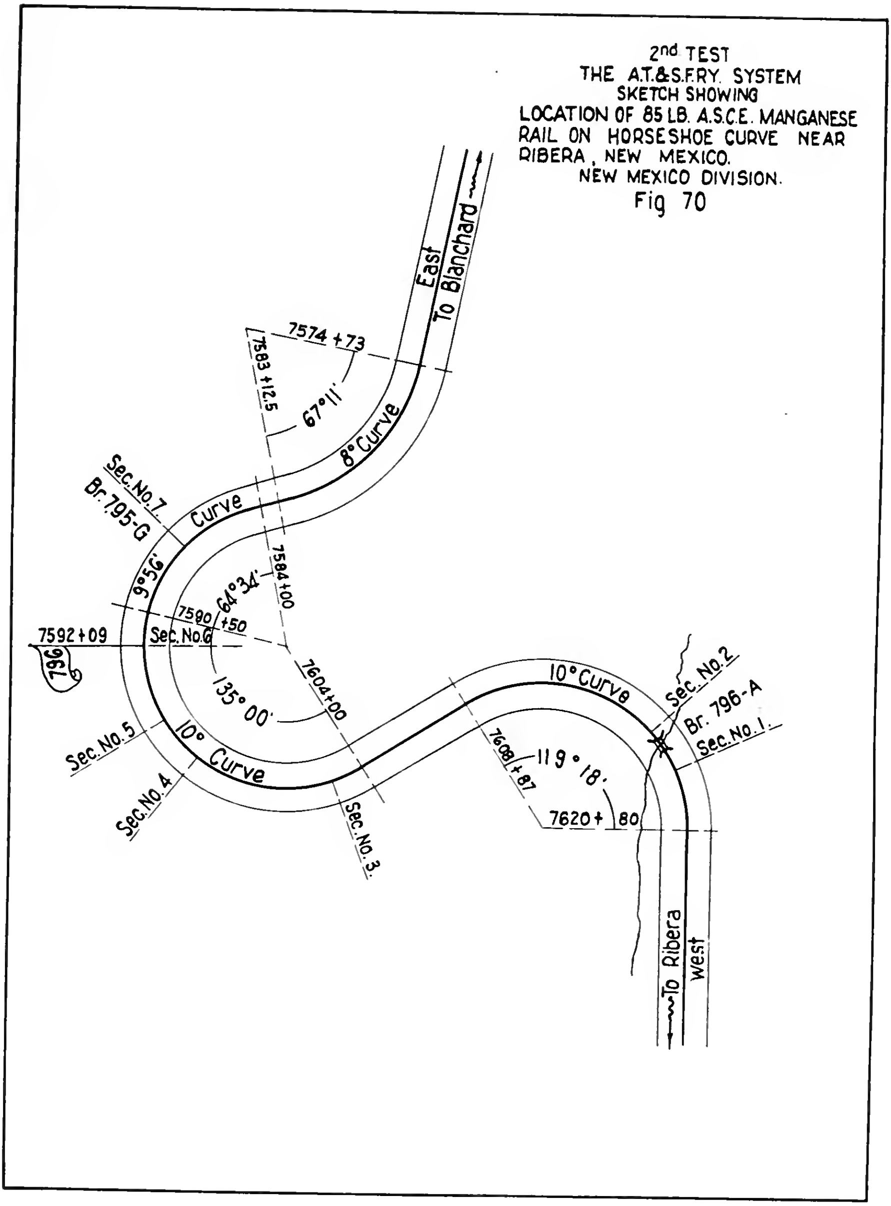
Rail laid December, 1909—New when laid.

A.S.C.E. 85 lbs. per yard rail.

Sections taken February 5, 1913.

Rail in service 3 years 2 months.

Grades are very heavy eastbound, varying from 1.02 per cent. to 1.42 per cent.

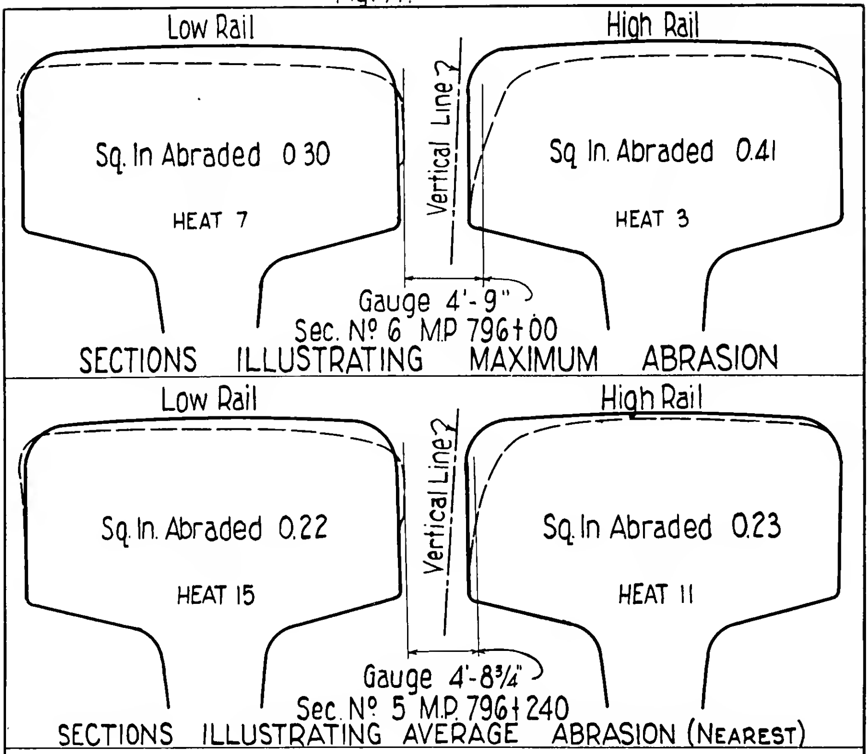


2nd TEST
THE A.T.&S.F.RY. SYSTEM
SKETCH SHOWING
LOCATION OF 85 LB. A.S.C.E. MANGANESE RAIL ON HORSESHOE CURVE NEAR RIBERA, NEW MEXICO.
NEW MEXICO DIVISION.

Fig 70

THE A.T.&S.F.RY. SYSTEM
SKETCH SHOWING
SECTIONS OF 85 LB. A.S.C.E. MANGANESE
RAIL ON HORSESHOE CURVE NEAR
RIBERA NEW MEXICO
NEW MEXICO DIVISION

Fig. 71.



SECOND TEST	LOW RAIL.	HIGH RAIL.
Area of Head New	3.50 Sq. In.	3.50 Sq. In.
Total Area. Abraded, 10 Sections	1.42 " "	1.73 " "
Average " " per Section	0.20 " "	0.25 " "
Per cent " " " "	6%	7%
Wear per 10,000,000 Tons of Frt. & Pass.	0.15 Sq. In.	0.18 Sq. In.

Appendix F.

BALTIMORE & OHIO RAILROAD COMPANY'S EXPERIMENTS WITH SPECIAL STEELS.

The Baltimore & Ohio Railroad Company has been conducting comparative experiments with Special Steel rails for many years, and the method of conducting them, and the records of the trials are given in the following pages:

A curve or curves, usually "sharp," that is, of short radius, are selected, and the different kinds of steel are laid in alternate stretches of greater or less length, one of the lots of steel being of Bessemer or Open-Hearth, the characteristics of which are known. The comparison is therefore made with a known standard, and as the conditions of traffic are the same, the question of tonnage is eliminated, as it is desired to know how much longer is the life, or how much greater is the abrasion of one over the other. Where possible to obtain it, a record of the tonnage passing over the rail is kept, as the square inches abraded from the rail head per 10,000,000 tons of traffic is a convenient unit to use for comparison with the results of other administrations.

After laying, the outline or profile of the section of several selected rails is measured with an instrument similar to the one illustrated in Figs. 47 and 48, and these measurements are made at the same points, about twice a year, as long as the rail is in service. At the end of the test the results are compiled into the form of "average square inches abraded per section," and "percentages of area abraded to total area of head of rail," for each kind, one of which usually indicates a superiority over the other. The "total square inches abraded" are recorded also for each measurement in the form of a diagram, the whole record being shown on one sheet, and then compiled into such other forms as may be desired. Test No. 911 is a comparative trial of Nickel-Chromium rail with Open-Hearth rail, and so on.

The chemical analyses of the different steels experimented with are given in the two following tables:

TABLE XXI.

CHEMICAL ANALYSIS OF ORDINARY STEEL

	C	P	Mn	Su	Si
Open-Hearth Rail.					
70-lb.to 85-lb.......	.53 .66	.04*	.60 .90	-	.20*
85-lb. to 100-lb.....	.63 .76	.04*	.60 .90	-	.20*
Bessemer Rail.					
70-lb.to 85-lb.......	.40 .50	.10*	.80 1.10	-	.20*
85-lb.to 100-lb......	.45 .55	.10*	.80 1.10	-	.20*
Open-Hearth Rail Joints.............	.40#	.05*	.80*	.055*	--
Cast Steel Joints....	--	.06*	--	.055*	--
Track Bolts and Nuts.	--	.04*	--	.04*	--

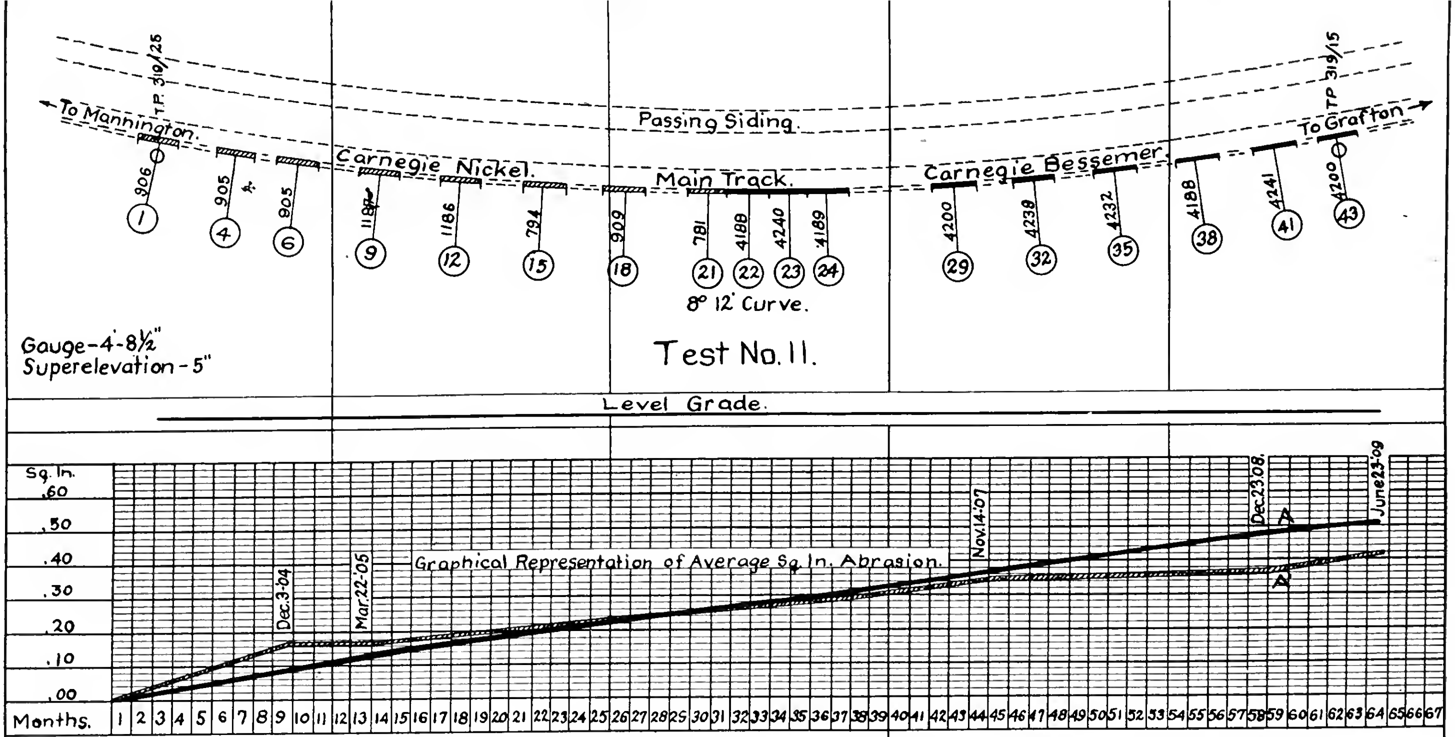
* Maximum allowable
\# Minimum allowable

TABLE XXII.

CHEMICAL ANALYSES OF SPECIAL STEEL

	Carbon	Phosphorus	Manganese	Silicon	Sulphur	Nickel	Cr.	Tit. Alloy
Titanium Alloy Steel.........	.45 to .55	.10*	1.00	.20*	--	--	--	1.00
Manganese Steel	1.05 to 1.25	.065*	11.00 to 13.00	--	--	--	--	--
High Silicon Steel.........	.596	.10	1.11	.69	.096	--	--	--
Nickel Chrome Steel.........	.65 .80	.04*	1.85	.20*	--	.20 2.50	.50 .90	-- --
Mayari Ore Steel	.46 .56	.10*	.80 1.20	.20*	.04	1.25	.45	--
Nickel Steel....	.48	.04	.87	--	--	3.32	--	--
Manganese for crossing.......			12.00)	Special Process of Manufacture				
Manganese for frogs..........			12.00)					
Manganese for switches.......			12.00)					
Manganese for knuckles.......			12.00)					
Manganese for lock tongues			12.00)					

Note.-- Titanium alloy contains 10 per cent. metallic titanium.
*Maximum allowable.



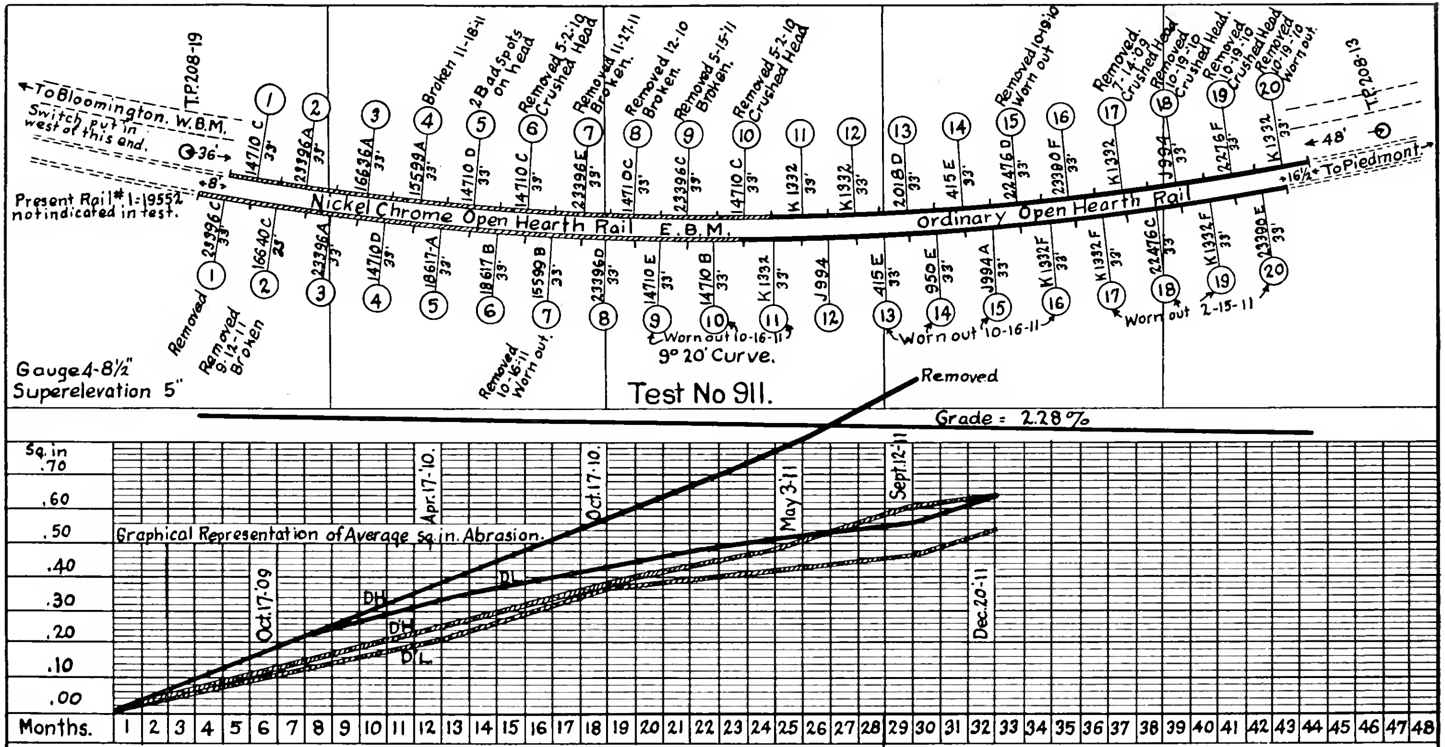
A' = Carnegie Nickel, shown thus ▨ A = Carnegie Bessemer, shown thus ▬

Summary.

Month and Year.	Dec. 3-'04		Mar. 22-'05		Nov. 14-'07.		Dec. 23-'08		June 23-'09			
Kind of Rail	A'	A	A'	A	A'	A	A'	A	A'	A		
Total Sq. in. abraded.	1.227	.780	1.255	1.125	2.558	3.273	2.937	4.356	3.354	4.577		
Average Sq. in. abraded per section.	.153	.087	.157	.125	.330	.364	.367	.484	.420	.509		
Percent of Area abraded to total area of head.	4.4%	2.5%	4.5%	3.7%	9.2%	10.6%	10.5%	14.2%	12.0%	14.9%		

B & O R.R. Wheeling Div.
Location Diagram of
Nickel and Bessemer Rails
Laid Mar. 19, 1904. Removed ________
Between Mannington and Downs.
Scale, 1 7/16" = 1 mile. July 15, 1909

Fig. 72



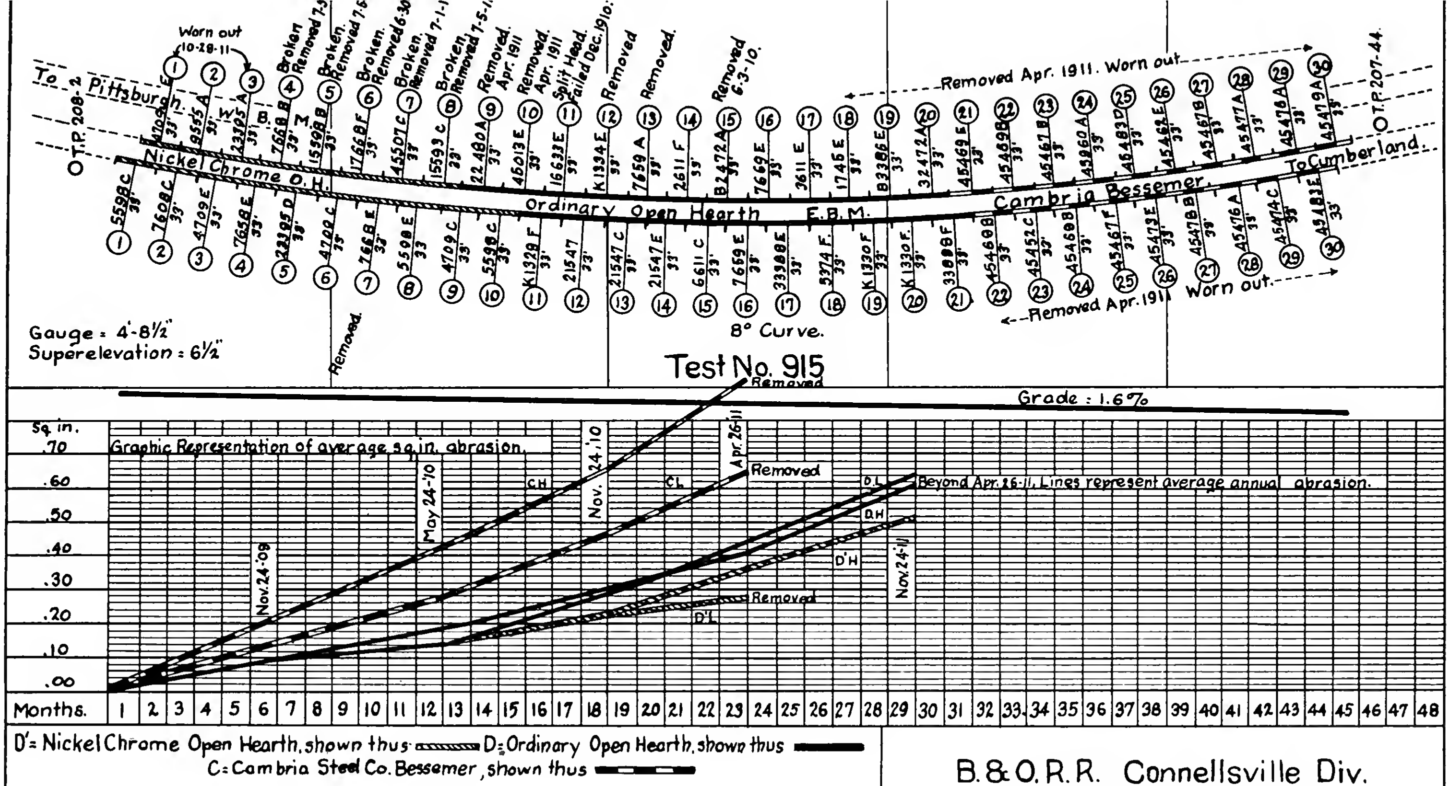
D': Nickel Chrome O.H. shown thus ▨ D= Ordinary O.H. shown thus ▬

Bethlehem Steel Co.
Summary.

Month and Year.		Oct. 17-'09		Apr. 17-'10.		Oct. 17-'10		May 3-'11.		Sept 12-'11		Dec. 20-11	
Kind of Rail.		D'	D	D'	D	D'	D	D'	D	D'	D	D'	D
Total Sq. in. Abraded.		2.305	3.482	4.242	6.601	6.418	7.189	7.300	6.510	7.841	7.714	4.648	3.237
Average Sq. in. abraded per section.	High	.134	.185	.289	.347	.383	.559	.485	.784	.631	.978	.624	.900
	Low.	.110	.182	.210	.386	.372	.432	.420	.518	.465	.565	.539	.647
Percent of area abraded to total area of head.		3.41%	5.13%	6.28%	10.25%	10.0%	14.31%	12.1%	18.2%	14.7%	21.6%	18.3%	18.0%

The above figures do not include rails removed prior to date of measurement.

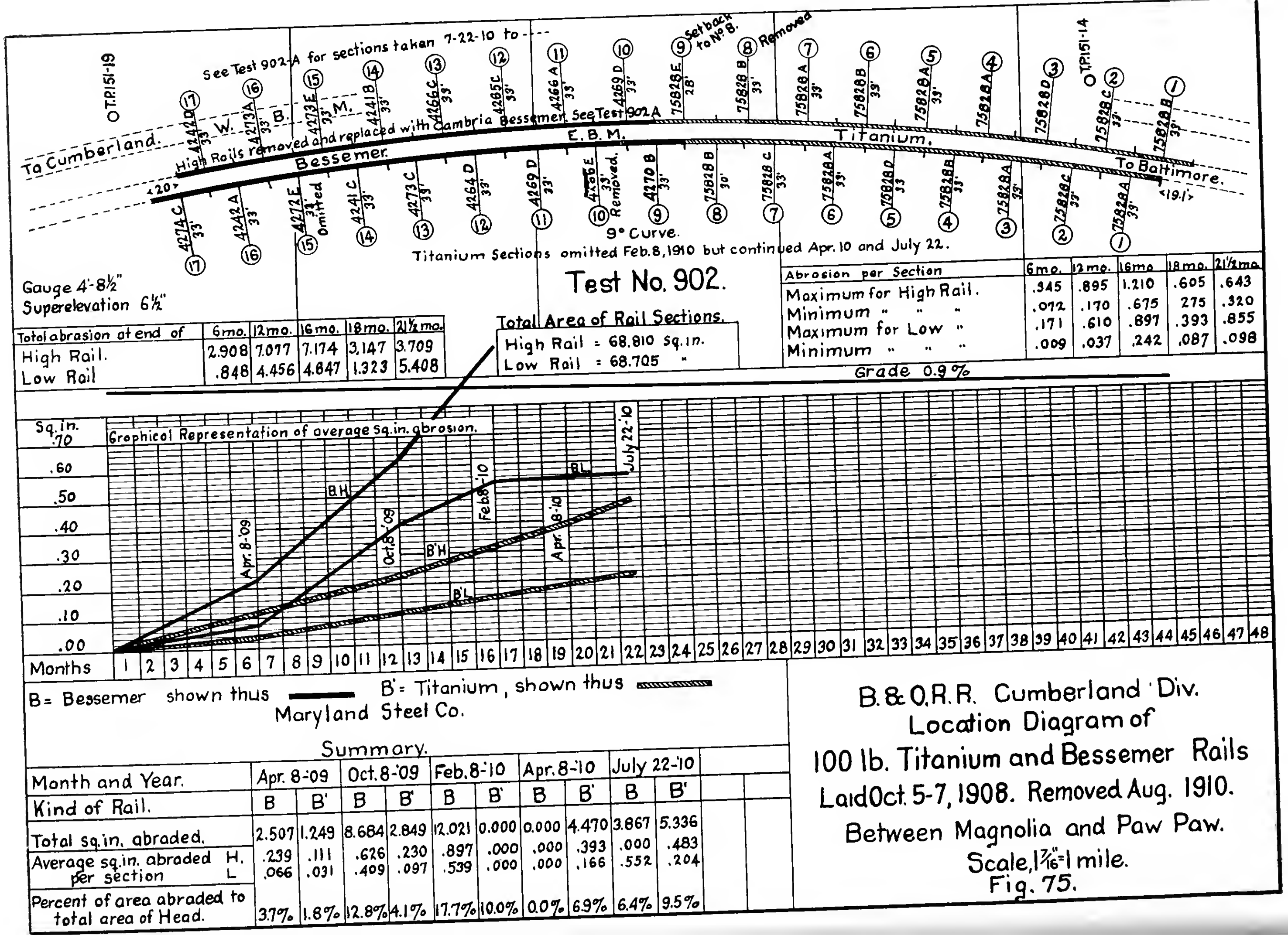
B. & O. R. R. Cumberland Div.
Location Diagram of
Nickel Chrome O.H. and Ordinary O.H.
Rails. 90 lb.
Laid Apr. 4-13, 1909. Removed Jan 1912
Between Bloomington and Piedmont.
Fig. 73



Summary.

Month and Year.	Nov. 24-'09.			May 24-'10			Nov. 24-10.			Apr. 26-'11.		
Kind of Rail.	D'	D	C	D'	D	C	D'	D	C	D'	D	C
Total sq. in. abraded.	1.364	1.831	3.403	2.426	3.573	6.344	9.916	6.406	10.708	4.364	7.550	13.747
Average sq. in. abraded per section. H	.076	.085	.214	.141	.186	.424	.222	.302	.666	.363	.410	.845
Average sq. in. abraded per section. L	.078	.082	.148	.127	.128	.273	.212	.280	.472	.275	.435	.655
Percent of area abraded to total area of head	2.1%	2.37%	5.2%	3.8%	4.4%	10.0%	6.1%	8.0%	16.4%	9.5%	11.8%	23.3%

B. & O. R. R. Connellsville Div.
Location Diagram of
Nickel Chrome and Ordinary O.H.
and Bessemer Rails 90 lb.
Laid May 17-18, 1909 Removed Jan. 1912
Between Manila and Mance
Fig. 74



Titanium Sections omitted Feb. 8, 1910 but continued Apr. 10 and July 22.

Test No. 902.

Gauge 4'-8½"
Superelevation 6½"

Total abrasion at end of	6 mo.	12 mo.	16 mo.	18 mo.	21½ mo.
High Rail.	2.908	7.077	7.174	3.147	3.709
Low Rail	.848	4.456	4.847	1.323	5.408

Total Area of Rail Sections.
High Rail = 68.810 sq. in.
Low Rail = 68.705 "

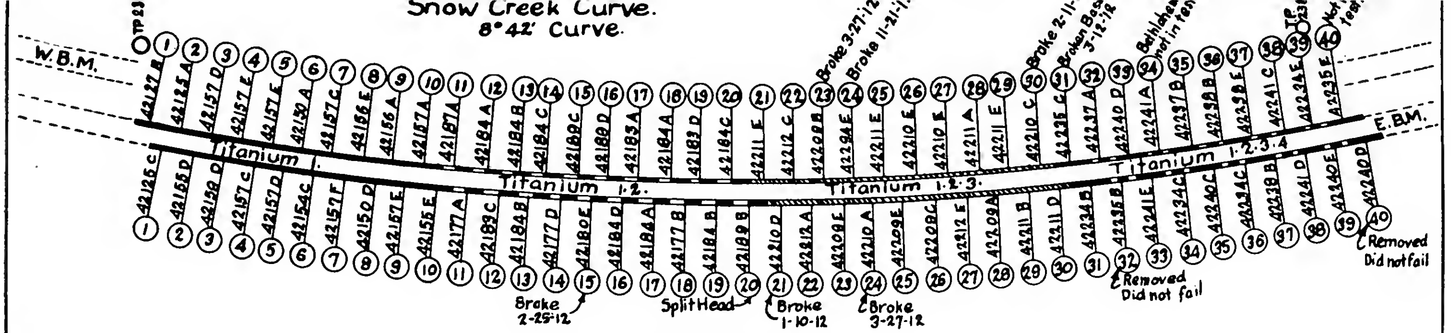
Abrasion per Section	6 mo.	12 mo.	16 mo.	18 mo.	21½ mo.
Maximum for High Rail.	.345	.895	1.210	.605	.643
Minimum " " "	.072	.170	.675	275	.320
Maximum for Low "	.171	.610	.897	.393	.855
Minimum " " "	.009	.037	.242	.087	.098

B = Bessemer shown thus ▬ B' = Titanium, shown thus ▨
Maryland Steel Co.

Summary.

Month and Year.	Apr. 8-'09		Oct. 8-'09		Feb. 8-'10		Apr. 8-'10		July 22-'10		
Kind of Rail.	B	B'	B	B'	B	B'	B	B'	B	B'	
Total sq. in. abraded.	2.507	1.249	8.684	2.849	12.021	0.000	0.000	4.470	3.867	5.336	
Average sq. in. abraded per section H.	.239	.111	.626	.230	.897	.000	.000	.393	.000	.483	
Average sq. in. abraded per section L	.066	.031	.409	.097	.539	.000	.000	.166	.552	.204	
Percent of area abraded to total area of Head.	3.7%	1.8%	12.8%	4.1%	17.7%	10.0%	0.0%	6.9%	6.4%	9.5%	

B. & O. R. R. Cumberland Div.
Location Diagram of
100 lb. Titanium and Bessemer Rails
Laid Oct. 5-7, 1908. Removed Aug. 1910.
Between Magnolia and Paw Paw.
Scale, 1 7/16" = 1 mile.
Fig. 75.



Test No. 919.

Total Areas of Original Heads.

Titanium 1. H.&L.R. = 68.795 sq.in. Av. = 3.440 sq.in. has 0.3 per cent of a 10 per cent ferro-titanium alloy
" 1.2 " = 69.006 " " = 3.451 " " 0.5 " " " " " " " "
" 1.2.3 " = 68.551 " " = 3.428 " " 1.0 " " " " " " " "
" 1.2.3.4 " = 68.528 " " = 3.427 " " 1.5 " " " " " " " "

Gauge = 4'-8¾"
Superelevation 6"

To Grafton. Grade = 0.75% To Cumberland

Kind of Steel.	1	1.2	1.2.3	1.2.3.4	1	1.2	1.2.3	1.2.3.4	1	1.2	1.2.3	1.2.3.4	1	1.2	1.2.3	1.2.3.4	1	1.2	1.2.3	1.2.3.4	1	1.2	1.2.3	1.2.3.4
Month and Year.	Dec. 8, 1910				Mar. 17, 1911				July 31, 1911				Nov. 2, 1911				Feb. 2, 1912				May 3, 1912			
Total sq. in. abraded	2.039	2.279	1.994	1.849	2.980	3.199	3.077	2.803	3.907	4.130	4.303	3.553	4.556	4.769	4.870	3.832	4.887	5.228	4.920	4.097	5.131	5.222	4.389	4.081
Average sq. in abraded per section H	.118	.122	.112	.109	.163	.158	.155	.153	.226	.227	.239	.242	.284	.276	.285	.274	.302	.302	.300	.313	.321	.327	.327	.329
	.102	.114	.100	.093	.149	.160	.154	.140	.196	.207	.221	.193	.228	.239	.244	.214	.245	.262	.261	.245	.257	.277	.275	.255
L	.086	.106	.088	.077	.139	.162	.153	.122	.165	.186	.202	.143	.172	.201	.202	.153	.187	.220	.222	.177	.192	.227	.233	.181
Percent of area abraded to total area of head.	3.0%	3.3%	2.9%	2.7%	4.3%	4.7%	4.5%	4.1%	5.7%	6.0%	6.4%	5.8%	6.5%	6.9%	7.1%	6.2%	7.1%	7.5%	7.6%	7.0%	7.5%	8.0%	8.0%	7.44%

Month and Year	Aug. 6, 1912.				Nov. 21, 1912			
Total sq. in. abraded.	5.859	5.434	4.926	4.540	6.717	6.274	5.160	4.979
Average sq. in. abraded per Section H	.357	.362	.347	.360	.405	.413	.387	.394
	.293	.308	.308	.284	.336	.355	.341	.328
L	.229	.254	.269	.207	.267	.287	.293	.261
Per cent of area abraded to total area of head	8.5%	8.9%	9.0%	8.3%	9.8%	10.3%	10.0%	9.5%

B.&O.R.R. Cumberland Div.
Location Diagram of
90 lb. Titanium Test Rails.
Laid Aug. 3, 1910. Removed ______
Between Terra Alta and Corinth.

Fig. 76.

TEST No. 919

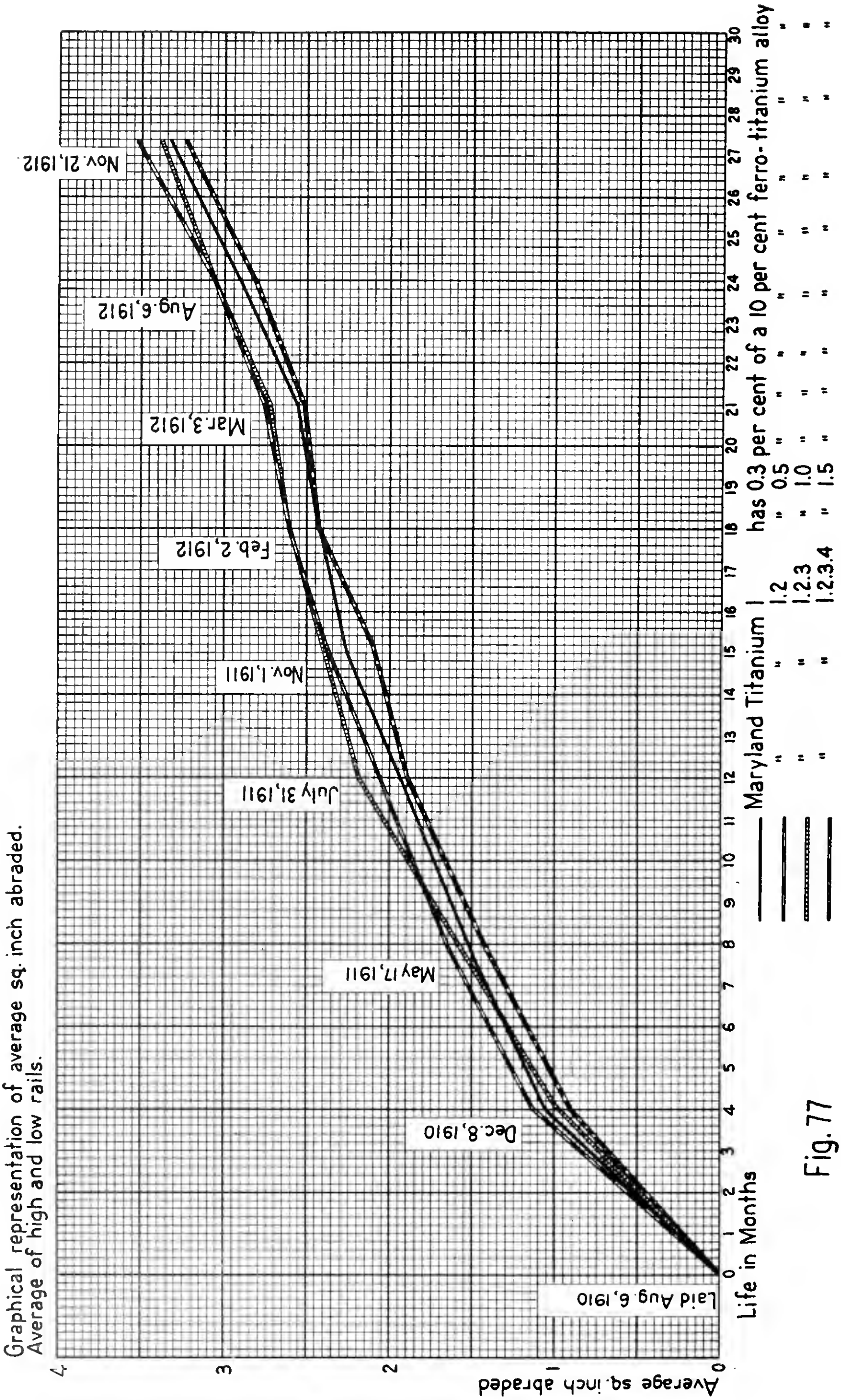
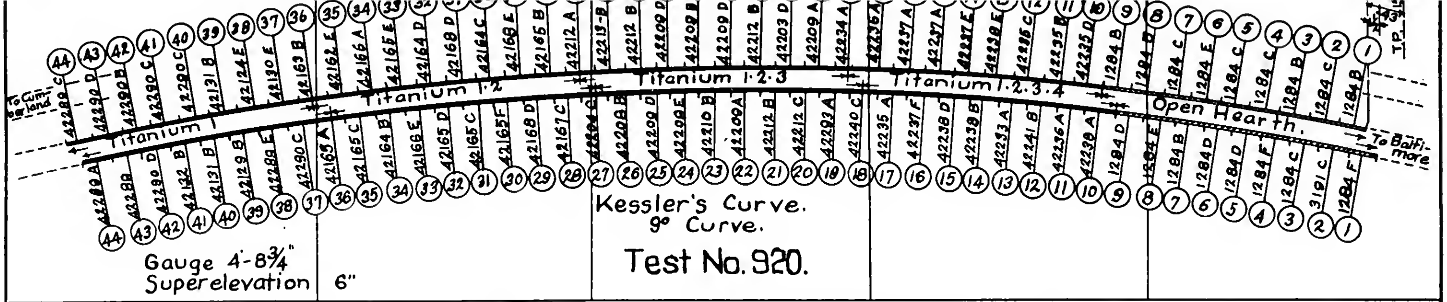
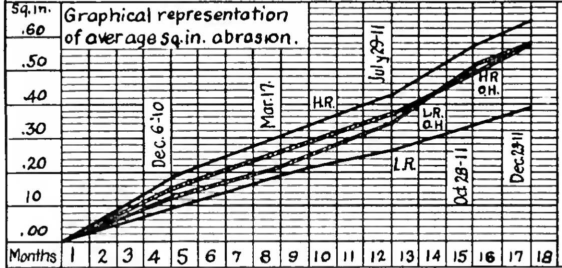


Fig. 77



Grade 0.21%.



Total Area of Rail Sections.
High Rail 150.025 sq.in. Std=156.508
Low " 150.050 " " 156.508

Total Abrasion at end of	4 mo.	7½ mo.	12 mo.	15 mo.	18 mo.
High Rail.	7.194	11.929	17.516	23.210	26.359
Low "	4.843	8.011	11.763	15.357	22.834

Abrasion per Section	4 mo.	7½ mo.	12 mo.	15 mo.	18 mo.
Maximum for High Rail.	.265	.493	.690	.932	1.108
Minimum " " "	.110	.179	.272	.361	.393
Maximum " Low "	.203	.360	.520	.916	.729
Minimum " " "	.043	.099	.168	.220	.250

Titanium shown thus ——— Open Hearth shown thus ═══

Summary. Maryland Steel Co.

Month and Year.	Dec. 6, 1910					Mar. 17, 1911					July, 29, 1911.				
Kind of Rail	1	1·2	1·2·3	1·2·3·4	O.H.	1	1·2	1·2·3	1·2·3·4	O.H.	1	1·2	1·2·3	1·2·3·4	O.H.
Total sq.in. abraded.	2.089	2.359	2.691	2.322	2.573	3.830	4.018	4.229	3.867	3.996	5.487	5.822	6.026	5.514	6.430
Aver. sq.in. abraded per Section. H.	.165	.163	.187	.152	.151	.304	.280	.296	.239	.241	.427	.412	.427	.360	.369
L.	.097	.099	.112	.106	.136	.178	.167	.174	.191	.203	.259	.235	.243	.252	.346
Percent of area abraded to total area of head.	3.8%	3.8%	4.4%	3.8%	4.2%	7.0%	6.5%	7.0%	6.3%	6.5%	10.1%	9.5%	9.8%	9.0%	10.5%
Month and Year.	Oct. 28, 1911.					Dec. 23, 1911.									
Kind of Rail.	1	1·2	1·2·3	1·2·3·4	O.H.	1	1·2	1·2·3	1·2·3·4	O.H.					
Total sq.in. abraded.	6.866	7.264	8.116	7.283	9.044	7.513	7.560	9.166	7.672	7.882					
Aver. sq.in. abraded per Section H.	.555	.531	.576	.480	.499	.640	.592	.656	.535	.580					
L.	.303	.276	.328	.329	.506	.342	.280	.364	.323	.534					
Percent of area abraded to total area of head.	12.6%	11.8%	13.3%	11.9%	14.7%	14.4%	12.8%	15.0%	12.6%	16.3%					

In tables 1 has 0.3 percent of a 10 percent ferro-titanium alloy
1·2 " 0.5 " " " " " " "
1·2·3 " 1.0 " " " " " " "
1·2·3·4 " 1.5 " " " " " " "

B. & O. R. R. Cumberland Div.
Location Diagram of
90 lb. Titanium and Open Hearth Rails
Laid Aug 8, 1910. Removed Dec. 23, 1911
Between Magnolia and Paw Paw.
Scale, 1 7/16" = 1 mile.
Fig 78

Appendix G.

PENNSYLVANIA LINES—COMPARATIVE EXPERIMENTS WITH HIGH-CARBON STEEL RAILS AND RAILS OF BESSEMER AND OPEN-HEARTH STEEL.

In order to make a trial of the relative abrasive resistance of rails of different kinds of steel, an 8-degree curve (radius 717 ft.) at the north end of the Ohio Connecting Railway Bridge over the Ohio River at Pittsburgh was selected, for the reason that the grinding action of the wheels is very severe, owing to the fact that the traffic is made up entirely of slow-speed, heavy freight trains. There are no passenger trains. The freight traffic is principally coal in one direction and iron ore in the other, and is carried in large heavy steel cars with an axle loading of 38,000 to 50,000 lbs., including car weight. Ordinary Bessemer rail usually lasted on this curve from 4 to 10 months, according to the density of traffic.

Several different kinds of rail were selected for trial, and laid on the curve successively, one being worn out and removed before the next one was laid. In this kind of test it was therefore necessary to keep a record of the tonnage passing over each lot in order to reduce the amount of abrasion to the same unit of "square inches abraded per 10,000,000 tons of traffic." The abraded areas were measured with the usual instrument on selected rails at stated intervals, as already described under the caption, "Manganese Steel for Rails," and in Appendix F. Some selections from the records are given in the following pages.

For two of the kinds of rail experimented with, Nos. 4 and 6 of the tables, 2 sets of rail sections (Figs. 79 to 83), a set consisting of two, the high or outside rail and the low or inside rail, are displayed, one being the nearest representation of the average wear or abrasion, the second being the nearest representation of the maximum wear. A location diagram showing the points of measurement is also added.

The chemical constituents of the various kinds of steel are given in Table XXIII, both from the analyses of the ladle test ingot, and the analyses of the finished rail after having been in service, the former being made by the manufacturers and the latter by the railway company. The High-Carbon rail is No. 6. The physical properties and the results of the abrasion tests are given in Table XXIV.

This table shows the superiority of No. 6, the Pennsylvania Steel Company's High-Carbon rail, in resistance to the abrasive action of the wheels, over the rails made from the ordinary Bessemer or Open-Hearth steel, and this advantage is twice as great as for the best of the others, which is No. 2, Bessemer rail of the Carnegie Steel Company, but the differences between the ordinary and Open-Hearth rails are small and entirely within the limits of error of the observations and records.

The large amount of abrasion of the Maryland Bessemer rail, No. 3, is very noticeable, the chemical elements of rather low carbon and low

TABLE XXIII.

PENNSYLVANIA LINES WEST OF PITTSBURGH - SOUTH WEST SYSTEM.
CHEMICAL CONSTITUENTS OF DIFFERENT KINDS
OF RAILS USED ON OHIO CONNECTING RAILWAY BRIDGE.

No.	Kind of Steel	Carbon		Phosphorus		Manganese		Silicon		Sulphur		Nickel		Chromium	
		Ladle	Rail	Ladle	Rail	Ladle	Rail	Ladle	Rail	Ladle	Rail	Ladle	Rail	Ladle	Rail
1	Carnegie Bess.85-ASCE	0.55		.07		1.05		.13							
2	Carnegie Bess.85-ASCE	0.51		.093		.88		.103		.045					
3	Maryland Bess.85-PS	0.50	0.42-0.672	.077	.06 -.121	.95	.71-.95	.091	.042-.066	.056	.051-.136				
4	Cambria Bess.85-PS	0.52	.488-.532	.096	.092-.110	.90	.92-.109	.085	.105-.122	.090	.071-.097				
5	Gary O.H.-B 85-PS	0.65	.679-.685	.032	.037-.041	.69	.69-.72	.14	.119-.123	.041	.027-.028				
6	Penna.Steel O.H. 85 - PS	0.805	.82 -.87	.022	.023-.031	.87	.82-.89	.17	.168-.182	.035	.025-.035	.97	.92-1.01	.21	.24-.29
7	Carnegie O.H.-A 85-PS		.67 -.86		.017-.035		.62-.94		.083-.157		.019-.041				
8	Gary O.H.-A 85-PS		.72 -.78		.022-.038		.59-.70		.077-.103		.017-.023				

Notes.--The names above are of the following manufacturers:
Carnegie Steel Company. Maryland Steel Company. Cambria Steel Company.
Pennsylvania Steel Company. Illinois Steel Company (Gary Mill).
"Bess" means Bessemer.
"O.H." means Open-Hearth.
"O.H.-A" means Open-Hearth Classification A, which specifies that carbon shall be from 0.70 to 0.83, and phosphorus not to exceed 0.03.
"O.H.-B" means Open-Hearth Classification B, which specifies that carbon shall be from 0.62 to 0.75, and phosphorus not to exceed 0.04.
"85" means rail weighing 85 pounds per yard.
"ASCE" means rail section standard of the American Society of Civil Engineers.
"PS" means rail section standard of the Pennsylvania Railroad System.

TABLE XXIV.

PENNSYLVANIA LINES WEST OF PITTSBURGH - SOUTH WEST SYSTEM.
PHYSICAL PROPERTIES OF DIFFERENT KINDS OF RAILS USED ON
OHIO CONNECTING RAILWAY BRIDGE.

No.	Kinds of Steel and Total Tonnage over Rail.	Pounds per square inch		Elongation		Reduction of area; per cent. of original section.	Area of head of rail abraded		Square inches abrasion per 10,000,000 tons of traffic
		Tensile Strength	Elastic Limit	Per Cent in 2 inches	Per Cent. of original length		Time in Weeks	Per Cent.	
1	Car.Bess. 85 - ASCE						13	19.2	
2	37,060,713 tons Car.Bess. 85 - ASCE						41	19.5	.18
3	11,350,744 tons Mary.Bess.85 - PS	95800 - 106800	47200 - 53600	.38-.52	19 - 26	23.6-36.6	16	13.9	.39
4	27,798,760 tons Camb.Bess.85 - PS	111350- 119620	68970 - 75800	.30-.36	15 - 18	24.74-31.96	32	18.07	.23
5	34,414,894 tons Gary O.H.-B 85 - PS	115790- 117470	68310 - 82270	.28-.29	14 - 14½	21.14-22.87	45	21.62	.22
6	67,216,756 tons Penna.O.H. 85 - PS	112695- 154350	75420 - 93150	.02-.16	1 - 8	1.02-14.8	84	16.67	.09
7	36,602,261 tons Car.O.H.-A 85 - PS	114950- 155800	53800 - 80250	.18-.30	9 - 15	10.84-19.84	40	19.05	.19
8	36,602,261 tons Gary O.H.-A 85 - PS	117050- 127650	59400 - 63175	.22-.34	11-1/4-17	13.44-29.67	40	20.17	.20

Note.-- The same notes of explanation as for the previous table apply to this one.

phosphorus for Bessemer rail, and the physical properties showing it to be a soft and ductile material, somewhat approaching the softness of European rail steel. It was unfit for the service required of it, as the metal began to flow or be kneaded out towards the outside of the low rail in 4 days after laying, as shown by Fig. 84.

The extent to which some of the rails were allowed to wear, because of the nature of the traffic, all of it being freight at slow speed, is shown by Figs. 85 and 86 of a rail, which is of Open-Hearth steel from the Gary Mill of the Illinois Steel Company, Lot No. 5, this particular rail being a "B" rail, that is, the second from the top of the ingot, with the chemical composition shown in Fig. 86. The tensile strength was 117,470 lbs. per square inch, and the elastic limit 82,270 lbs. per square inch, with 21.14 per cent. reduction of area.

While the High-Carbon rails, No. 6, developed such admirable qualities with reference to the resistance to abrasive forces, yet a serious defect was found which precluded their further use. Five of the rails broke in service, being at the rate of 1 failure in 14 rails laid, and 4 of them displayed the silvery oval spot in the head, which has come to be known under the name of "Transverse Fissure." The oval spots in two of these rails are illustrated in Fig. 87, and the chemical and physical properties with the etchings and micro-photographs of each are given in Tables XXV and XXVI and Figs. 88 and 89. These indicate very hard rails, high in carbon, with nickel and chromium, and but little ductility, but the elastic limit is very great and the Brinell hardness is very high. The axle loads, as previously stated, are not nearly as heavy as those in passenger service. The properties of another rail of the same lot, which did not break, but wore out in service, are given in Table XXVII, and they are about the same as the ones which failed. It seems, however, that the nuclei of the spots of all of the rails which broke had slag inclusions in them.

This type of failure, although known to *Austrian Engineers as far back as 1900 at least, has only been known, that is, by experience, to American railway Engineers since 1911, and the cause of it has not yet been agreed upon. Up to the present time, in the great majority of cases of its occurrence, it has been in very hard, high-carbon rail, but it has also occurred in low-carbon Bessemer steel in this country, as well as in Austria. In many cases, slag inclusions have been found in the spots, while in some cases no foreign material whatever has been discovered. Many have been found on railroads where neither the quantity of traffic, the speed of trains, nor the axle loads of locomotives or cars has been as great as on other lines, where none has been discovered, and certainly the axle loads in Austria are not nearly as great as in America.

Additional information will be found in Proceedings, American Railway Engineering Association, Vol. 14, for 1913, page 413, et seq.

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*Besizt Thomaseisen die Eigenschaften eines guten Brückmateriales? H. K. Baurath, Carl Haberkalt und Ober-Ingenieur Anton Ritter v. Dormus. Wien 1901. Some of the photographs from this have been reproduced by Robt. Job in Railway Age Gazette, Feb. 6, 1914, p. 266.

*A recent theory is that the rails having this defect or the causes of it have been rolled at too low a temperature, and it is also claimed that the marks of the "gagging" or straightening press have been found at the points where it was disclosed by fracture.

The oval spot is usually found in its developed condition on the gage side of the head, or over the web, because that is the side on which the wheel pressures are greatest in the United States, on account of the wheel tread being coned at a slope of 1 in 20, while the rail stands at right angles to the crosstie, but the "transverse fissures" or cracks, which are the origin of the defect, have been found in all parts of the head, and some of the developed spots even have the appearance of being on the side opposite the gage side in the case of those illustrated by Professor Anton Ritter v. Dormus.

The weight of the evidence is on the side which believes that this type of failure is due to defects in manufacture which result in minute cracks in the finished product, whether they be caused by tearing the skin of the ingot by too great and too rapid reduction in blooming, or by finishing the rail bar at too high or too low a temperature, or by improper cooling and shrinkage of the rail on the cooling beds, or careless straightening in the gagging press, or, in advance of all these operations, in the manufacture of the molten steel itself by not allowing sufficient time for the escape of the impurities and for the various chemical elements to perform their functions in the Bessemer converter, Open-Hearth furnace and ladle, and in the proper and careful casting of the ingot. Fault has been justly found with all these operations, and it is the general belief of the railway Engineers that they must undergo improvements.

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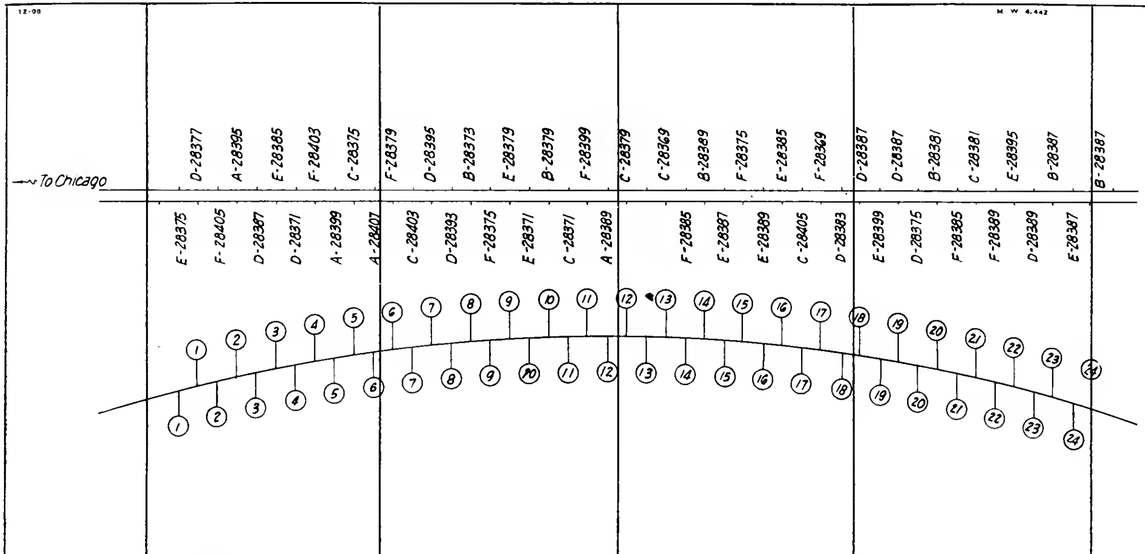
*Railway Age Gazette, Feb. 27, 1914. "Interior Transverse Fissures in Rail Heads," by P. H. Dudley, C. E., Ph.D.

EXPLANATION OF ABBREVIATIONS.

Sq. in	Square inch.
H	High Rail.
L	Low Rail.
E. & W. B. Frt	East and West Bound Freight.
Mi. per Hr	Miles per hour.
Bess	Bessemer.
P. S.	Pennsylvania System.
C	Carbon.
P	Phosphorus.
Mn	Manganese.
Si	Silicon.
S	Sulphur.
Ni	Nickel.
Chr	Chromium.
"ON"	Morse code name for Signal or Telegraph Tower.
Diff	Difference.
L-W	Low rail at West end of Curve.
H-E	High rail at East end of Curve.
L. Stone	Low Rail, Stone.
H. None	High Rail, None (On Bridge).
N	North.
S	South.
E	East.
W	West.
St	Street.
m	Mile.



Position in Ingot	A.			B			C.			D			E			F		
Date of Sections	1-22-09	4-26-09	7-30-09	1-22-09	4-26-09	7-30-09	1-22-09	4-26-09	7-30-09	1-22-09	4-26-09	7-30-09	1-22-09	4-26-09	7-30-09	1-22-09	4-26-09	7-30-09
Average Sq In. Abraded	.102	.250	.589	.133	.322	753	.117	.268	.600	.113	.254	.625	.125	.269	.587	.129	.302	.716
% of Head Abraded.	2.86	700	16 9	3.72	9.02	21 5	3.28	7.51	17.1	3.16	7.11	17.9	3.50	7.53	16.8	3.61	8.46	20.5

Total Tonnage over Rails 27,798,760

Fig. 79.

No. 4 of Tables.

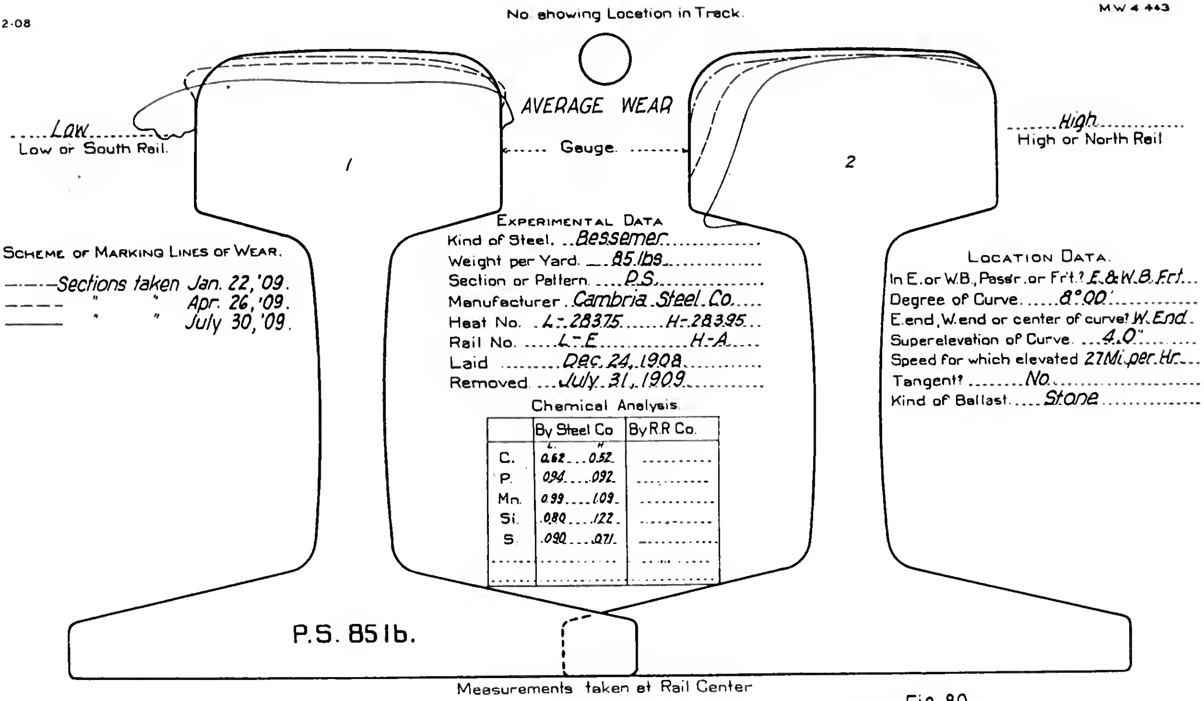
Summary.

Month and Year	1-22-09	4-26-09	7-30-09		1-22-09		4-26-09		7-30-09.			
Kind of Rail.	A.	A.	A.		High.	Low.	High.	Low.	High.	Low.		
Total sq. in abraded	5.70	13.05	30.37		3.23	2.47	7.29	5.76	17.42	12.95		
Aver. sq in abraded per Section	.121	.278	.645		.135	.107	.304	.250	.726	.563		
Percentage of Area abraded to total Area of Head.	3 39	7.78	18.07		3.77	3.00	8.51	7.00	20.33	15.77		

PENNSYLVANIA LINES
WEST OF PITTSBURGH.
..O.C.Ry............Pittsburgh......Div
Location Diagram
of
.85 lb. P.S. Cambria,.....Bessemer... Rails.
LAID IN 19.08,.......... REMOVED IN 19.09..........
Between..."ON" Tower.... and..Ontaric. St........
Office of Chief Engineer M of W....S.W.... System.
Scale 1 in.= 1 m Date...Jan. 1909....

12-08

MW 4 443



SCHEME OF MARKING LINES OF WEAR.

–·–·–Sections taken Jan. 22,'09.
– – – – " " Apr. 26,'09.
——— " " July 30,'09.

EXPERIMENTAL DATA

Kind of Steel. ..Bessemer..............
Weight per Yard. ...85 lbs..............
Section or Pattern. ....P.S..............
Manufacturer. .Cambria Steel Co.....
Heat No. ..L-28375......H-28395...
Rail No. .....L-E...........H-A.....
Laid ....Dec. 24, 1908............
Removed ....July 31, 1909............

Chemical Analysis.

	By Steel Co	By R.R Co.
	L. ... H.	
C.	0.62 ... 0.52	
P.	.094 ... .092	
Mn.	0.99 ... 1.09	
Si.	.080 ... .122	
S.	.090 ... .071	

LOCATION DATA.

In E. or W.B., Passr. or Frt.? E.&W.B. Frt...
Degree of Curve. .....8°00'............
E. end, W. end or center of curve? W. End.
Superelevation of Curve. ....4.0"......
Speed for which elevated 27 Mi. per Hr....
Tangent? ....No..................
Kind of Ballast......Stone.............

Fig. 80.

Date of Measurement.	Sq. in. Abraded Low Rail. Area Abraded	Low Rail. Diff.	High Rail. Area Abraded	High Rail. Diff.
Jan. 22,'09	0.11		0.14	
Apr. 26,'09	0.28	0.17	0.31	0.17
July 30,'09	0.56	0.28	0.72	0.41

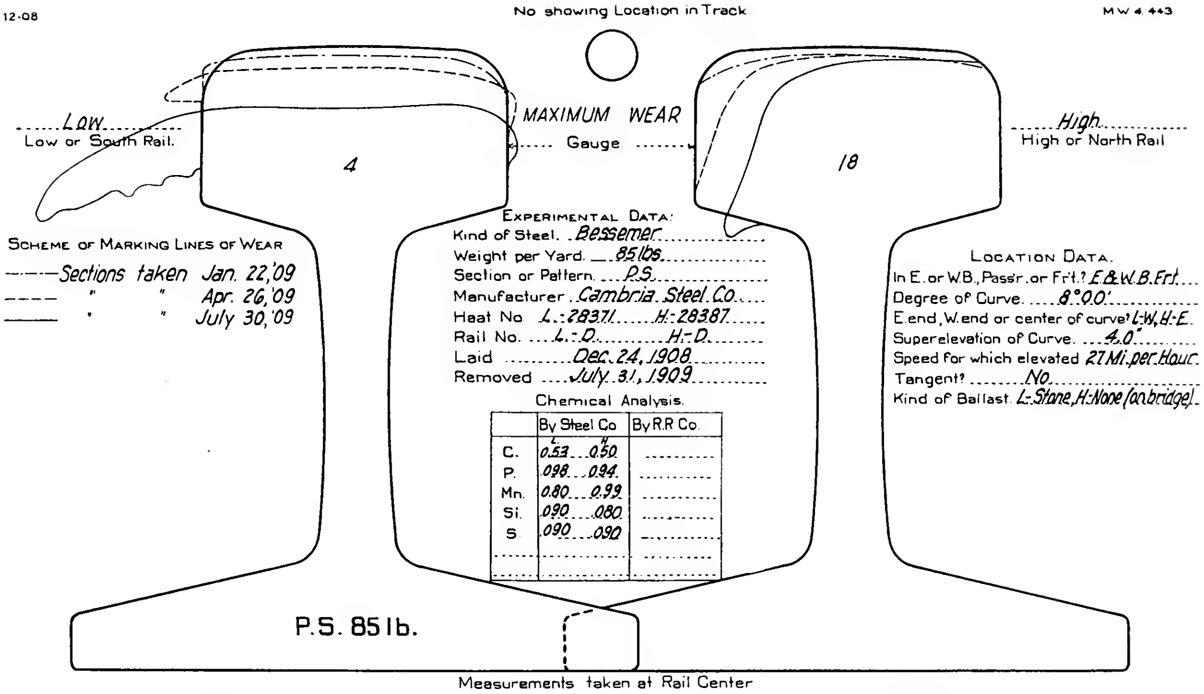
Measurements of Area Abraded

No 4 of Tables.

PENNSYLVANIA LINES
WEST OF PITTSBURGH.
..O.C. Ry.........Pittsburgh..........Div.
Diagram Showing Lines of Wear
of
85 lb. P.S. Cambria Steel Co. Bessemer.. Rail
LAID IN 19 08...................REMOVED IN 1909.....
Between .."ON" Tower.......and Ontario St. Foot Br..
Office of Chief Engineer M. of W. S.W...System.
Scale Full Size. Date. January 1909....

12-08

MW 4.443



SCHEME OF MARKING LINES OF WEAR

-·-·- Sections taken Jan. 22,'09
- - - - " " Apr. 26,'09
——— " " July 30,'09

EXPERIMENTAL DATA:

Kind of Steel. Bessemer
Weight per Yard. 85 lbs.
Section or Pattern. P.S.
Manufacturer. Cambria Steel Co.
Heat No. L.:28371 H:28387
Rail No. L.-D. H.-D.
Laid Dec. 24, 1908
Removed July 31, 1909

Chemical Analysis.

	By Steel Co	By R.R Co.
C.	L. 0.53 H. 0.50	
P.	.098 .094	
Mn.	0.80 0.99	
Si.	.090 .080	
S.	.090 .090	

LOCATION DATA.

In E. or W.B., Pass'r. or Fr't.? E.& W.B. Frt.
Degree of Curve. 8°00'
E. end, W. end or center of curve? L-W, H-E.
Superelevation of Curve. 4.0"
Speed for which elevated 27 Mi. per Hour.
Tangent? No.
Kind of Ballast. L-Stone, H-None (on bridge).

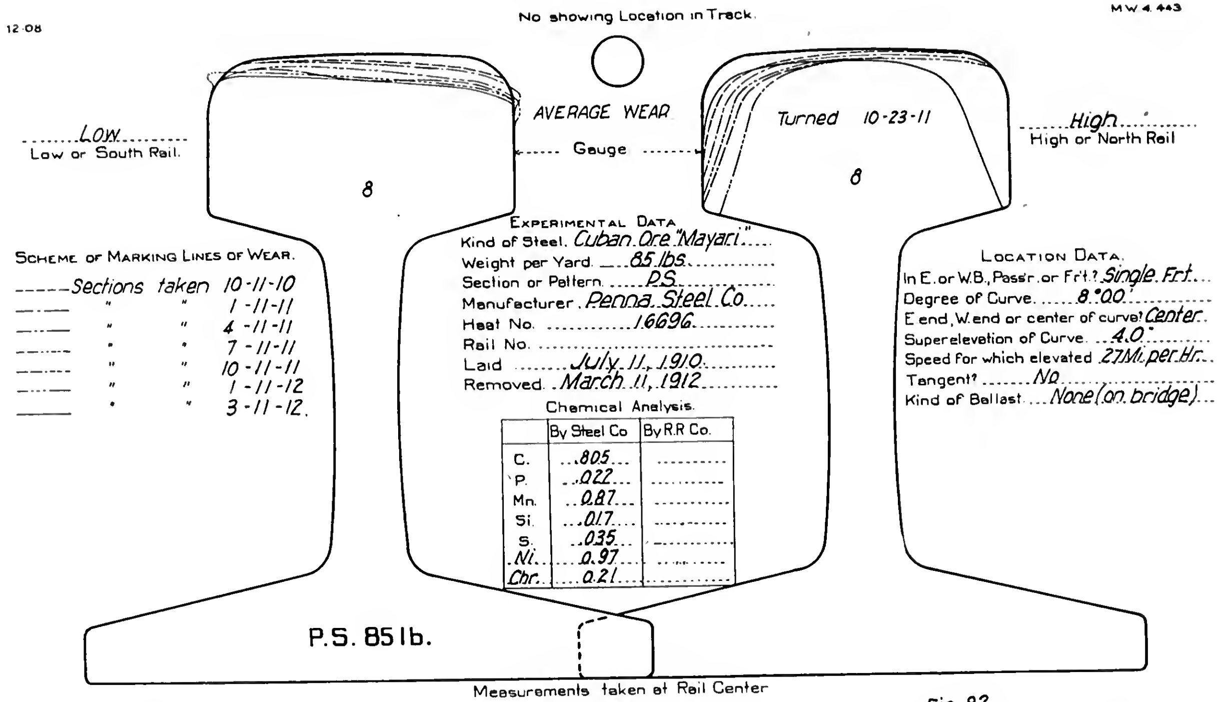
Measurements of Area Abraded

Date of Measurement	Sq. in. Abraded Low Rail Area Abraded	Low Rail Diff.	High Rail Area Abraded	High Rail Diff.
Jan. 22,'09	0.14		0.13	
Apr. 26,'09	0.40	0.26	0.31	0.18
July 30,'09	1.16	0.76	0.92	0.61

No. 4 of Tables.

Fig. 81.

PENNSYLVANIA LINES
WEST OF PITTSBURGH.
O.C.Ry. Pittsburgh Div.
Diagram Showing Lines of Wear
of
85 lb. P.S. Cambria Steel Co. Bessemer Rail
LAID IN 1908 REMOVED IN 1909
Between "ON" Tower and Ontario St. Foot Br.
Office of Chief Engineer M. of W. S.W. System.
Scale Full Size. Date. Jan. 1909



SCHEME OF MARKING LINES OF WEAR.

- - - - - Sections taken 10-11-10
" " 1-11-11
" " 4-11-11
" " 7-11-11
" " 10-11-11
" " 1-11-12
" " 3-11-12.

EXPERIMENTAL DATA

Kind of Steel. Cuban Ore "Mayari."
Weight per Yard 85 lbs.
Section or Pattern PS.
Manufacturer. Penna. Steel Co.
Heat No. 16696.
Rail No.
Laid July 11, 1910.
Removed. March 11, 1912.

Chemical Analysis.

	By Steel Co	By R.R Co.
C.	.805	
P.	.022	
Mn.	0.87	
Si.	.017	
S.	.035	
Ni.	0.97	
Chr.	0.21	

LOCATION DATA.

In E. or W.B., Pass'r. or Frt.? Single. Frt.
Degree of Curve. 8°00'
E end, W. end or center of curve? Center.
Superelevation of Curve. 4.0"
Speed for which elevated 27 Mi. per Hr.
Tangent? No
Kind of Ballast. None (on bridge).

Measurements of Area Abraded

Date of Measurement.	Sq. in Abraded.			
	Low Rail		High Rail	
	Area Abraded	Diff.	Area Abraded	Diff.
10-11-10	0.12		0.17	
1-11-11	0.22	0.10	0.35	0.18
4-11-11	0.28	0.06	0.40	0.05
7-11-11	0.28	0.00	0.51	0.11
10-11-11	0.38	0.10	0.65	0.14
1-11-12	0.42	0.04	0.72	0.07
3-11-12	0.48	0.06	0.72	0.00

No. 6 of Tables.

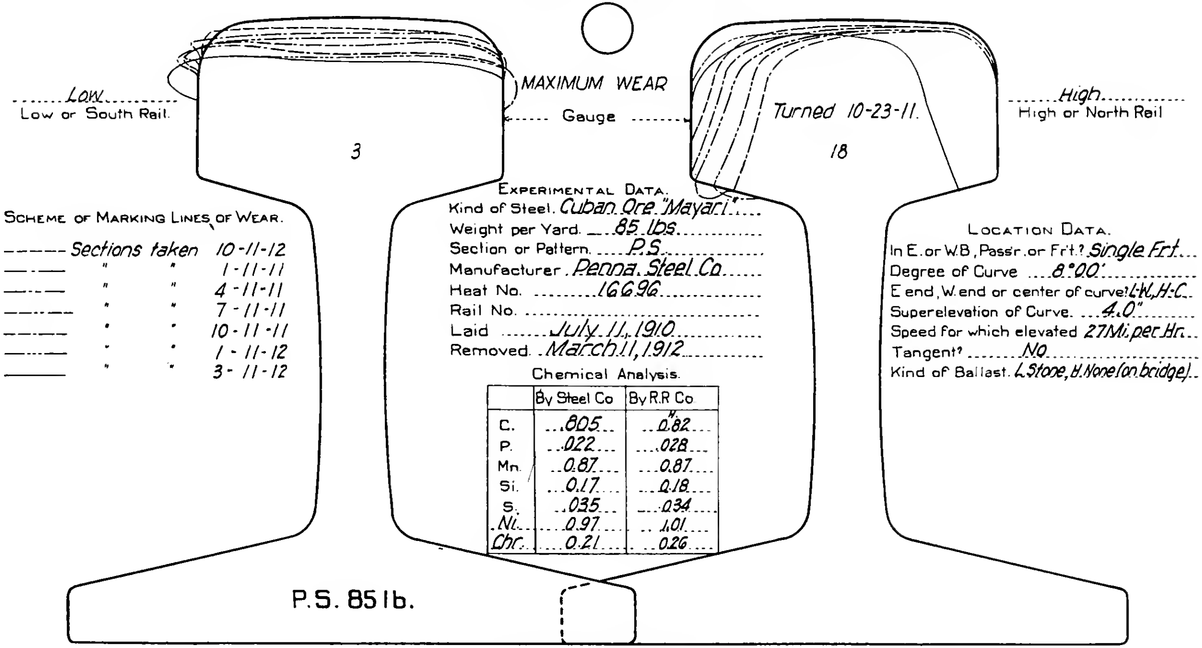
Fig. 82.

PENNSYLVANIA LINES
WEST OF PITTSBURGH.
O.C.Ry. Pittsburgh Div.
Diagram Showing Lines of Wear
of
85 lb. P.S. Penna. Steel Co. "Mayari." Rail
LAID IN 1910 REMOVED IN 1912
Between W. Leg. N. End and O.C. Bridge
Office of Chief Engineer M. of W. S.W. System.
Scale Full Size. Date 3-11-12

12-08

No showing Location in Track

M W 4 443



SCHEME OF MARKING LINES OF WEAR.

- ------ Sections taken 10-11-12
- —·— " " 1-11-11
- —··— " " 4-11-11
- —·-·— " " 7-11-11
- —··— " " 10-11-11
- —···— " " 1-11-12
- ——— " " 3-11-12

EXPERIMENTAL DATA.

Kind of Steel. Cuban Ore "Mayari"
Weight per Yard. 85 lbs.
Section or Pattern. P.S.
Manufacturer. Penna. Steel Co.
Heat No. 16696
Rail No.
Laid July 11, 1910
Removed. March 11, 1912

Chemical Analysis.

	By Steel Co	By R.R Co
C.	.805	0.82
P.	.022	.028
Mn.	0.87	0.87
Si.	0.17	0.18
S.	.035	.034
Ni.	0.97	1.01
Chr.	0.21	0.26

LOCATION DATA.

In E. or W.B., Pass'r. or Fr't.? Single Frt.
Degree of Curve 8°00'
E end, W. end or center of curve? L.W., H.C.
Superelevation of Curve. 4.0"
Speed for which elevated 27 Mi. per Hr.
Tangent? No
Kind of Ballast. L. Stone, H. None (on bridge).

Measurements taken at Rail Center

Measurements of Area Abraded

Date of Measurement.	Sq in Abraded. Low Rail Area Abraded	Low Rail Diff.	High Rail. Area Abraded	High Rail Diff.
10-11-10	0.19		0.26	
1-11-11	0.30	0.11	0.38	0.12
4-11-11	0.38	0.08	0.55	0.17
7-11-11	0.47	0.09	0.72	0.17
10-11-11	0.67	0.18	0.90	0.18
1-11-12	0.73	0.08	1.02	0.12
3-11-12	0.82	0.09	1.06	0.04

No 6 of Tables

Fig. 83.

PENNSYLVANIA LINES
WEST OF PITTSBURGH.
O.C. Ry. Pittsburgh Div.
Diagram Showing Lines of Wear
of
85 lb. P.S. Penna. Steel Co. "Mayari" Rail
LAID IN 1910 REMOVED IN 1912
Between W. Leg., N. End and O.C. Bridge
Office of Chief Engineer M. of W. S.W. System.
Scale Full Size. Date 3-11-12

FIG. 84. FLOW OF METAL, MARYLAND RAIL. OHIO CONNECTING BRIDGE.

Fig. 85.

Photo No. 502.
R. W. H. & Co.
8/30/10.

No. 376 DEPT. OF METALLOGRAPHY, ROBERT W. HUNT & CO., ENGINEERS

DESCRIPTION

85# Illinois Steel Co. Gary Works rail submitted per Pennsylvania Lines letter June 22, 1910. Rail E. Sample from worst worn rail laid on high side of 8 deg. curve on West Leg of North End of High Connecting Bridge, Aug. 2, 1909. Taken up during June 1910. Ill. Steel Co. O.H. Classification B rail rolled Gary Works March 1909. Heat No. 60541. Microphotograph taken at center of head of rail.

MICROPHOTOGRAPH

MAGNIFIED 500 DIAMETERS
OBJECTIVE 4mm EYE-PIECE X10
EXPOSURE 7 sec PLATE NHO
LIGHT direct
DEVELOPER Metol Hydrochinon
ETCHING 5% picric acid.

DATE Aug. 30 1910 191

PHYSICAL PROPERTIES

TENSILE STRENGTH
ELASTIC LIMIT
ELONGATION IN INCHES
REDUCTION OF AREA
CHARACTER OF FRACTURE

CHEMICAL COMPOSITION

TOTAL CARBON	
GRAPHITIC CARBON	
COMBINED CARBON	.685
SILICON	.119
MANGANESE	.69
SULPHUR	.027
PHOSPHORUS	.037

Fig. 86.

No. 454.
Lab. No. 569.
(See Table XXV.)

No. 453.
Lab. No. 568.
(See Table XXVI.)

Fig. 87.
"Tranverse Fissures" or
"Silvery Oval Spots."

Report No. 569. TABLE XXV M. W. 34 F

2 10 1913
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PENNSYLVANIA RAILROAD COMPANY

P., B. & W. R. R. N. C. RY. W. J. & S. R. R.

LABORATORY REPORT

CHEMICAL AND PHYSICAL EXAMINATION OF RAIL AND OTHER TRACK MATERIAL

Referred to in letter W.C.Cushing to J.T.Wallis, dated Feb.14,1912.

Laboratory No. 23297-9 Sample Represents rail which failed 594 ft. west of "OK" Tower, Pittsburgh Div., O.C.Ry., 2-6-12. (85-lb. rail, P.S.Sec., P.S.Co., 1910-11-67-A, Heat No. 16686). Laid July, 1910.

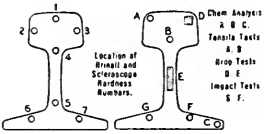
Place and Date Altoona, Pa., April 27th, 1912.

CHEMICAL ANALYSIS								PHYSICAL TESTS					
Location of Borings	C.	Mn.	P.	Si.	S.	Ni.	Cr.	Mill Drop Test Permanent Set-Inches	Tensile Strength Lbs. Per Sq. In.	Elastic Limit Lbs. Per Sq. In.	Elongation Per Cent. in 2 ins.	Reduction of Area—< of Original Sec.	Character of Fracture
Head	.86	.87	.029	.165	.034	1.03	.27		136850	84575	1.0	4.57	G
Web	.84	.87	.028	.167	.036	.97	.27						
Base	.86	.90	.026	.170	.035	1.00	.27						
Average	.86	.88	.027	.167	.035	1.00	.27						
Heat Analysis	.805												

NOTE
The word "Borings" refers also to "Chippings" and other kinds of test fragments.

DROP TEST. SUPPORTS 12" APART WEIGHT OF TUP, 50 LBS.										Impact Test. No. of Double Vibrations
Test Piece at "D" 29/32" x 29/32"					Test Piece at "E" ½" x 1"					
Blows at 5 Ft.	Blows at 10 Ft.	Blows at 15 Ft.	Initial Deflec.	Accum. Ft. lbs.	Blows at 3 Ft.	Blows at 6 Ft.	Blows at 10 Ft.	Initial Deflec.	Accum. Ft. lbs.	
5	1	-	5/16"	1750	Note					688

	Location	1.	2.	3.	4.	5.	6.	7.	Average
Hardness Number	Brinell	309	320	338	341	338	341	328	331
	Scleroscope	36	37	39	37	36	39	41	38

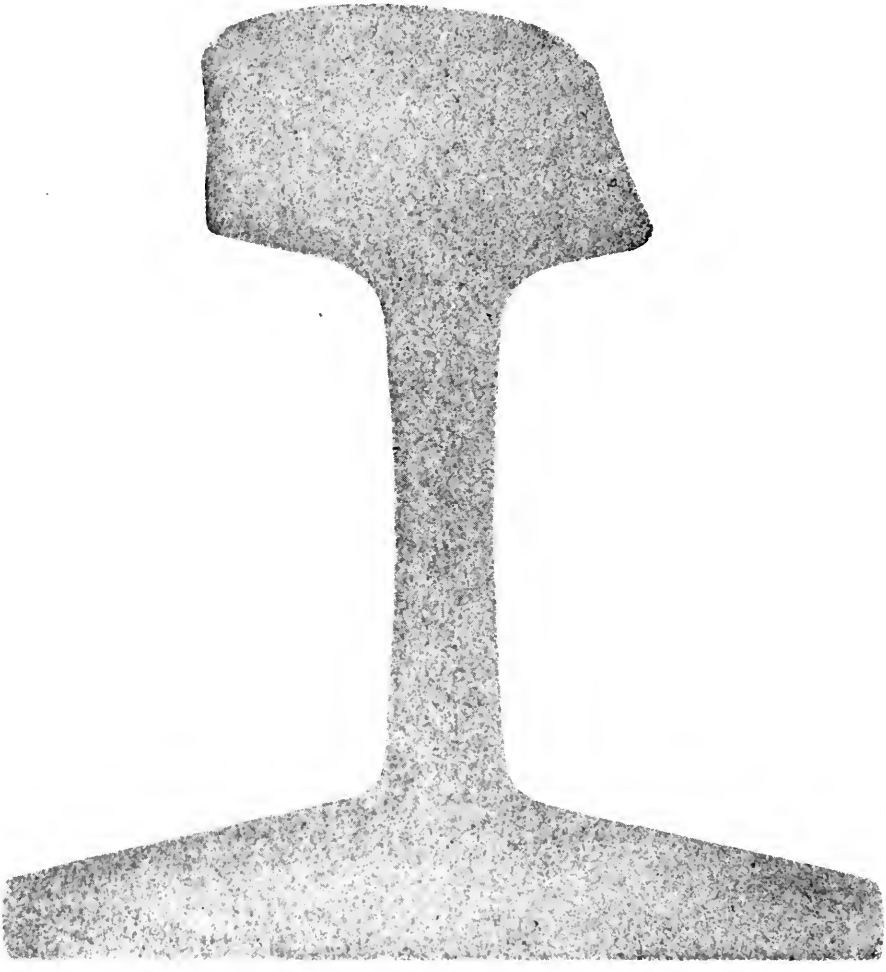


REMARKS — Note: No material.

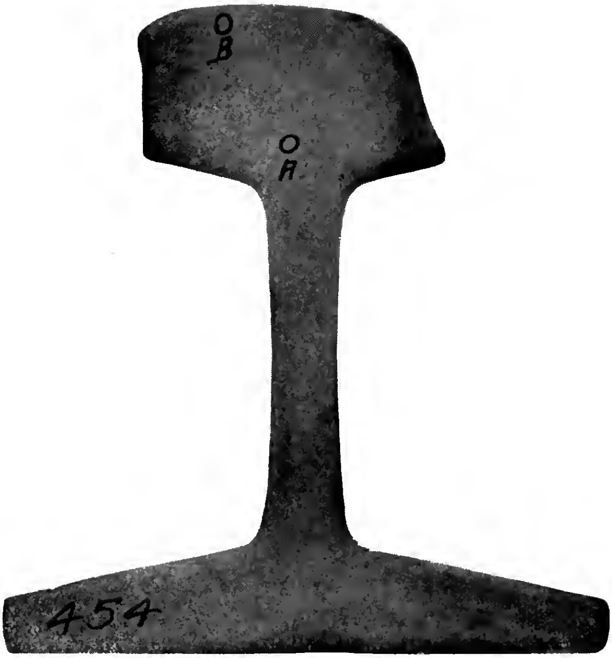
This Mayari rail is high in carbon, and contains chromium and nickel, resulting in a very hard and brittle metal. A well developed "transverse fissure" was visible at the break.

Test Dept. No. 454.

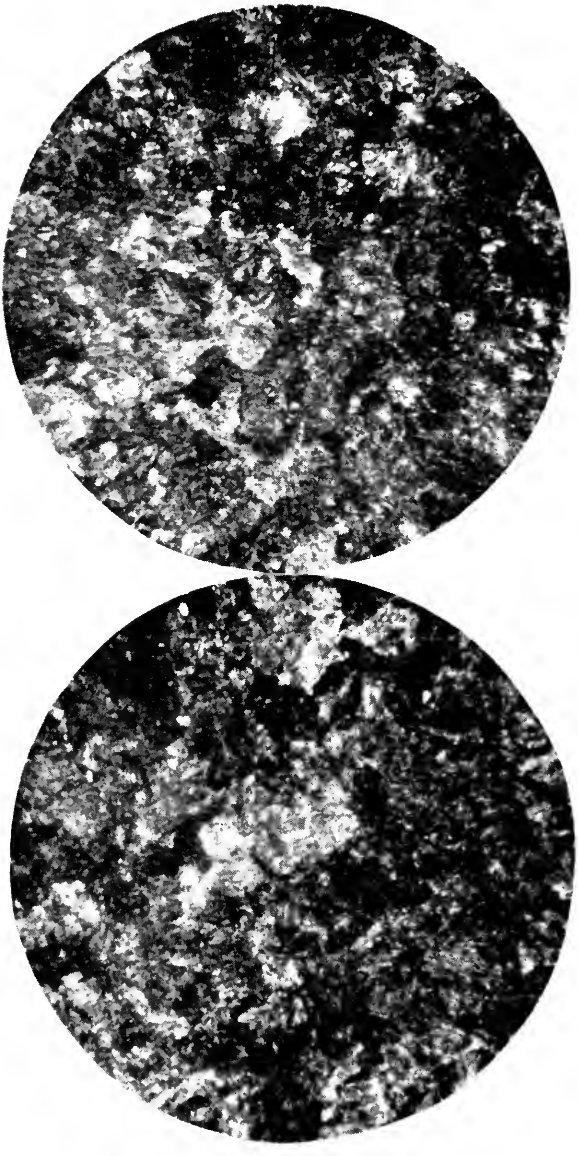
APPROVED —
F. N. Pease,
Chief Chemist, P. R. R.



Deep Etching of Fig. 88.
Chem. Lab. No. 23297-8-9. T. D. No. 454.



Light Etching of Fig. 88.



100 Diameters.

Micro-Photo A. Micro-Photo B.

Chem. Lab. No. 23297-8-9. T. D. No. 454.

Fig. 88.

Report No 568. TABLE XXVI M. W 34 F

2 10 1911
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PENNSYLVANIA RAILROAD COMPANY

P., B. & W. R. R. N. C RY. W J. & S R R.

LABORATORY REPORT

CHEMICAL AND PHYSICAL EXAMINATION OF RAIL AND OTHER TRACK MATERIAL

Referred to in letter W.C.Cushing to J.T.Wallis, dated Feb. 14, 1912.

Laboratory No. 23294-6 Sample Represents rail which failed 1024 feet west of "ON" Tower, Pittsburgh Div., O.C.Ry., 2-6-12, (85-lb. rail, P.S.Sec. O.C.Ry. P.S. Co., 1910-11-67-A, Heat No. 16696). Laid July, 1910.

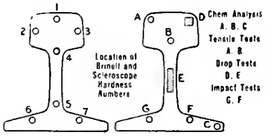
Place and Date Altoona, Pa., April 27, 1912.

CHEMICAL ANALYSIS								PHYSICAL TESTS					
Location of Borings	C.	Mn	P	Si	S.	Ni.	Cr.	Mill Drop Test Permanent Set Inches	Tensile Strength Lbs Per Sq In	Elastic Limit Lbs Per Sq In	Elongation Per Cent. in 2 ins.	Reduction of Area—% of Original Sec	Character of Fracture
Head	.87	.88	.025	.172	.034	1.01	.27		124795	93150	1.0	1.02	G
Web	.85	.88	.024	.172	.035	0.99	.27						
Base	.87	.89	.024	.167	.034	1.00	.28						
Average	.86	.88	.024	.170	.034	1.00	.27						
Heat Analysis	.805												

NOTE
The word ''Borings'' refers also to ''Chippings'' and other kinds of test fragments

DROP TEST SUPPORTS 12" APART WEIGHT OF TUP, 50 LBS.										Impact Test, No. of Double Vibrations
Test Piece at "D" $\frac{29}{33}$" x $\frac{29}{32}$"					Test Piece at "E" $\frac{1}{2}$" x 1"					
Blows at 5 Ft	Blows at 10 Ft	Blows at 15 Ft.	Initial Deflec	Accum Ft. lbs	Blows at 3 Ft.	Blows at 6 Ft.	Blows at 10 Ft.	Initial Deflec.	Accum. Ft. lbs.	
5	3	-	5/16"	2750	Note					498

Hardness Number	Location	1	2	3	4	5	6.	7	Average
	Brinell	320	328	320	328	328	338	347	330
	Scleroscope	39	38	37	36	36	40	42	38



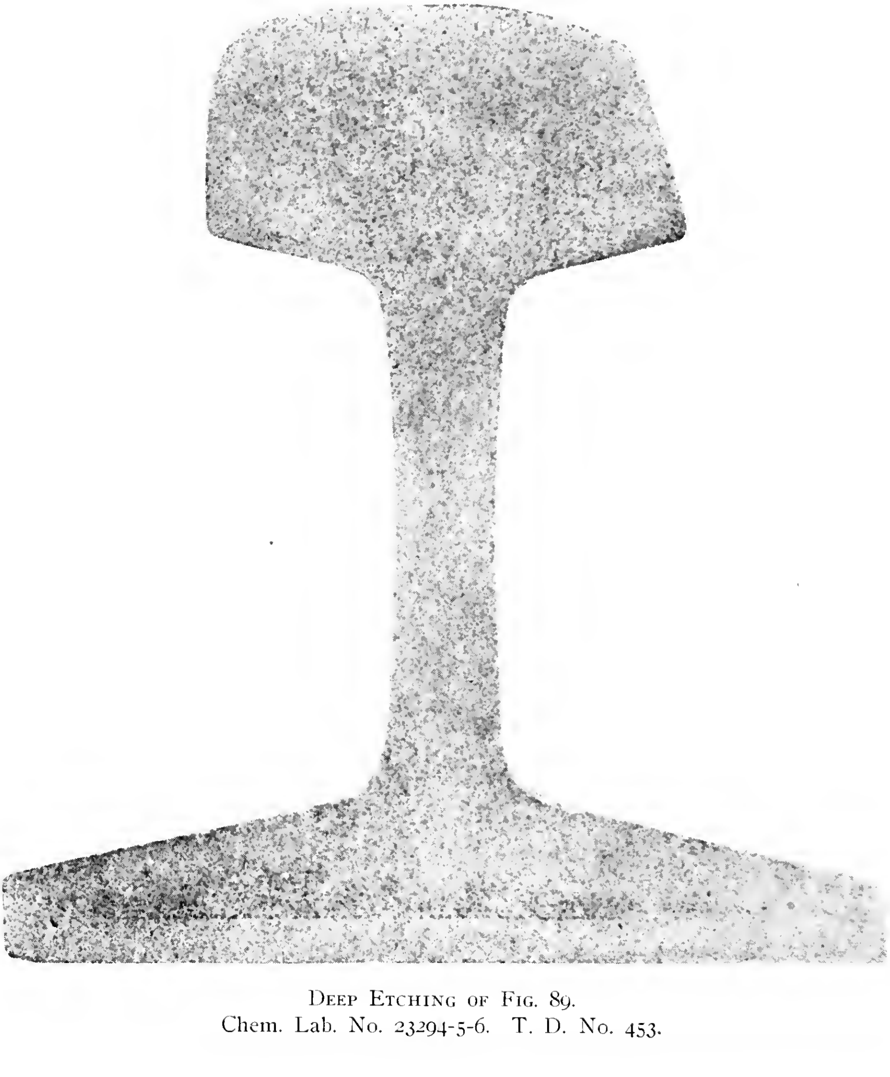
REMARKS – Note: No material.

A Mayari rail high in carbon and containing chromium and nickel, resulting in high Brinell hardness. The physical properties in general indicate brittle material. A "transverse fissure" was found at the break, located on the gauge side.

Test Dept. No. 453.

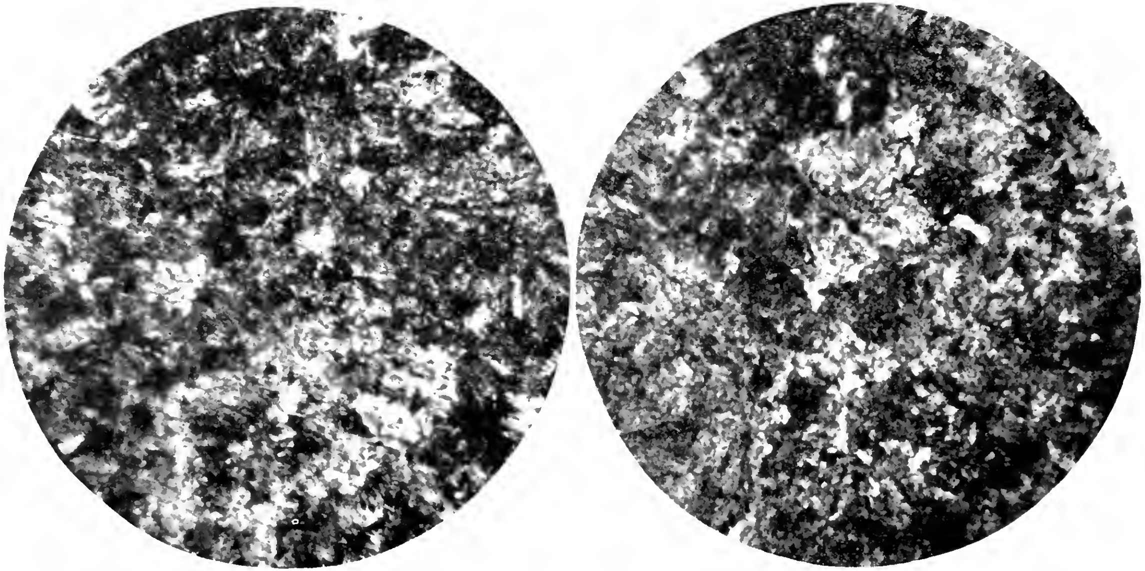
APPROVED.–

F. N. Pease.
Chief Chemist, P R. R.



DEEP ETCHING OF FIG. 89.
Chem. Lab. No. 23294-5-6. T. D. No. 453.

Light Etching of Fig. 89.



100 Diameters.

Micro-Photo A. Micro-Photo B.

Chem. Lab. No. 23294-5-6. T. D. No. 453.

FIG. 89.

Report No. 798. TABLE XXVII M. W. 34 F

2 10 1913
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PENNSYLVANIA RAILROAD COMPANY

P., B. & W. R. R. N. C. RY. W. J. & S. R. R.

LABORATORY REPORT

CHEMICAL AND PHYSICAL EXAMINATION OF RAIL AND OTHER TRACK MATERIAL

Referred to in letter W.C.Cushing to J.T.Wallis, dated April 24, 1912.

Laboratory No. 24960-2 Sample Represents rail which failed 719 ft. west of "ON", Pittsburgh Div., O.C.Ry., 3-11. (85-lb. rail, P.S.Sec., P.S.Co. 67-A, O.H. Mayari, Heat No. 16696). Laid July 12, 1910.

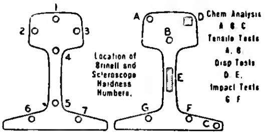
Place and Date Altoona, Pa., July 24, 1912.

CHEMICAL ANALYSIS								PHYSICAL TESTS					
Location of Borings	C.	Mn.	P	Si.	S.	Cr.	Ni.	Mill Drop Test Permanent Set-Inches	Tensile Strength Lbs Per Sq In	Elastic Limit Lbs Per Sq In	Elongation Per Cent in 2 ins.	Reduction of Area—% of Original Sec	Character of Fracture
Head	.86	.89	.027	.183	.033	.24	1.02		118200	84870	2	1.9	G
Web	.86	.88	.026	.179	.031	.24	.99						
Base	.85	.89	.026	.179	.032	.24	.96						
Average	.86	.89	.026	.180	.032	.24	.98						
Heat Analysis													

NOTE The word "Borings" refers also to "Chippings" and other kinds of test fragments

DROP TEST SUPPORTS 12" APART WEIGHT OF TUP, 50 LBS.										Impact Test. No. of Double Vibrations
Test Piece at "D" $\frac{29}{32}" \times \frac{29}{32}"$					Test Piece at "E" $\frac{1}{2}" \times 1"$					
Blows at 5 Ft.	Blows at 10 Ft.	Blows at 15 Ft	Initial Deflec.	Accum. Ft. lbs.	Blows at 3 Ft.	Blows at 6 Ft.	Blows at 10 Ft.	Initial Deflec.	Accum. Ft lbs.	
4	-	-	7/16	1000	Note					567

Hardness Number	Location	1	2.	3.	4.	5.	6.	7	Average
	Brinell	323	309	309	309	323	338	320	318
	Scleroscope	30	32	33	34	34	35	36	33



REMARKS:— Note: No material.

The physical tests indicate hard and brittle material. The head of a portion of the rail left after cutting samples for test was broken under a steam hammer. No transeverse fissures detected.

Test Dept. No. 697.

APPROVED.—

F. N. Pease,
Chief Chemist, P. R. R.

Appendix H.

CARBON STEEL RAIL WITH THE ADDITION OF FERRO-TITANIUM ON THE NEW YORK CENTRAL & HUDSON RIVER RAILROAD.

The metallic element Titanium belongs to the Tin Group, which consists of Tin, Germanium, Lead, Titanium, Zirconium and Thorium, and it is only within the last few years that it has been possible to obtain it for manufacturing purposes.

The use of ferro-titanium was begun experimentally by Dr. P. H. Dudley, for the New York Central Lines, in 1908, and that company bought and furnished it for the first two years to the mills where the rail was being rolled. The cost of the ferro-titanium was $1.08 per ton of rails manufactured, and in addition 25 cents per ton were paid to the manufacturers for the extra work, making a total cost of $29.33 per ton for the finished rails. When ingots were spoiled, it resulted in a loss to the railway company, on account of having furnished the ferro-titanium, and therefore arrangements were made with the mills to furnish their own titanium and manufacture the rails for a fixed price, which was $29.30 in 1911.

The amount added to Bessemer rail steel in the beginning was from 0.3 to 0.33 of 1 per cent. of a 10 per cent. ferro-titanium alloy for each one ton of metal, which is equal to 0.03 per cent. of metallic titanium. The ferro-titanium alloy is made separately. The iron is blown in the converter in the usual way, then recarburized and held for 2½ minutes before pouring into the ladle, this requirement having been introduced into the New York Central Lines specifications for steel rails in 1908, to enable the chemical reactions to have time for completion. While the steel is being poured into the ladle, the 0.3 to 0.33 of 1 per cent. of the ferro-titanium alloy is added, and is then held 3 minutes before teeming into the ingot molds, which is done through 1½-in. nozzles, a requirement also of the New York Central Lines specifications since 1908. At this same period, Dr. Dudley introduced another change in the specifications, which he considers an improvement. The length of ingots about 19 in. square was limited to 3 lengths of 33-ft. rails for the 100 lbs. per yard section, and 4 lengths of 33-ft. rails for the 80-lb. section, which makes the ingot about 48 in. high. Fig. 90 shows a photograph of the 100-lb., 3-length ingots, the steel of which set quiet, as indicated by the flat tops.

Dr. Dudley says that one advantage of the short ingot is that, inasmuch as the shrinkage cavity is a definite percentage of the volume of the metal, it is thereby reduced; an additional advantage occurs during rolling, because the 3-rail bar does not have time to become too cool for rolling. The 3-rail bar goes through the blooming and roughing trains and finishing pass in from 4½ to 5 minutes, while in the case of the 4-rail

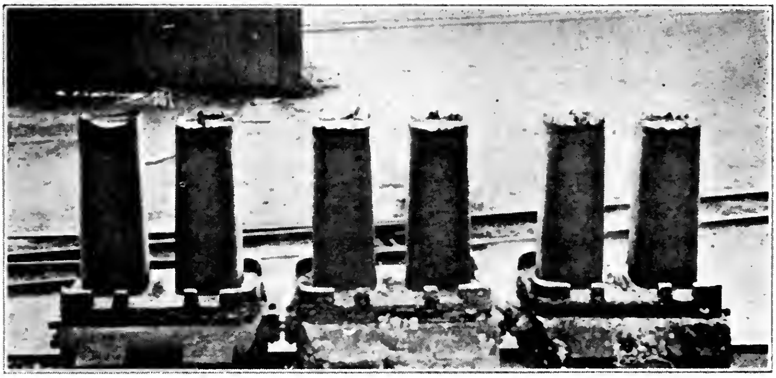


FIG. 90. REPRODUCTION OF A PHOTOGRAPH TAKEN MARCH, 1908, OF A HEAT OF RED HOT INGOTS, 19 IN. BY 19 IN., ON BASE, WITH CORNER RADIUS OF 3¾ IN. FOR THREE LENGTHS OF 100-LB. 33-FT. RAILS, WITH SMOOTH, FLAT TOPS. LACKAWANNA STEEL COMPANY, BUFFALO, N. Y.

ingot, the time was from 6 to 6½ and often 7 minutes, allowing the rails in many cases to be rolled too cold for proper working.

Five thousand tons of 100-lb. rails were made in December, 1908, and were laid in the following year, in May, on the Electric Division of the New York Terminal, where the density of traffic, all passenger, is nearly 2,000,000 tons per month, and where there had been many breakages of the Bessemer rails formerly laid. Up to June, 1913, none of these rails had failed in service. One rail was removed in the second year on account of seams in the head, due to the ingot mold having been spattered slightly in pricking the stopper of the ladle.

In 1909, 13,200 tons of 100-lb., and 2,500 tons of 80-lb. Bessemer rail were treated with 0.03 per cent. of metallic titanium, and in 1910, 34,800 tons of 100-lb., and 49,200 tons of 80-lb. Bessemer rail were treated with it.

From the tests conducted up to that time, and because the total phosphorus was increasing in the Bessemer ores, the metallic titanium was increased to 0.1 per cent. for the 1911 rails, to check segregation, lower the manganese and increase the carbon a few points. Twelve thousand seven hundred and sixty (12,760) tons of 100-lb. and 13,500 tons of 80-lb. were rolled for the New York Central & Hudson River Railroad.

In the same years ferro-titanium was used in the Bessemer rail steel of the Boston & Albany Railroad, a subsidiary of the New York Central Lines.

The Bessemer steel with the 0.03 per cent. and the 0.1 per cent. metallic titanium added was without interior blow holes in the metal or in the exterior columnar structure, but the latter was so rigid and solid in blooming that the butt of the ingot sometimes checked and did not always roll out, an invisible trace being left in the base of the rail.

The chemical composition of Bessemer rails from 1899 to 1908, after it was impossible to obtain low phosphorus ores for rail steel, was:

Carbon	0.45 to 0.55
Phosphorus, not to exceed	0.10
Manganese	0.80 to 1.10
Silicon	0.10 to 0.15
Sulphur, not to exceed	0.075

Except that the carbon was raised about 3 points for 1904, and January, 1905, rails.

This chemical composition was intended to give a tensile strength from 105,000 to 110,000 lbs. per square inch, with elastic limits from 52,000 to 56,000 lbs. per square inch, and from 12 to 14 per cent. ductility. The cold rolling reduced this in many rails and it was quite irregular per heat. The test butts stood the weight of 2,000 lbs. falling 20 ft., some giving 5 per cent. elongation in the maximum inch, while some sheared over the supports, indicating that the rails were cold rolled.

The sulphur restrictions were omitted in the 1910 specifications, owing to a demand by the manufacturers for an increased price of 5 cents per 100 lbs. if it were included. It was not considered worth it, as it is to the advantage of the manufacturer to keep the sulphur as low as possible.

The above composition was used for the Bessemer steel, which was treated with titanium from 1908 to 1910, inclusive. The tensile strength was 106,000 to 115,000 lbs. per square inch, the elastic limit from 53,000 to 58,000 lbs. per square inch, and the ductility 8 to 14 per cent. per inch under the drop.

The chemical composition for plain Bessemer 100-lb. rails for 1908, 1909 and 1910 was as follows:

Carbon	0.45 to 0.55
Phosphorus, not to exceed	0.10
Manganese	0.90 to 1.10
Silicon	0.13 to 0.20

The chemical composition for the Bessemer steel rails for 1911, to which 0.1 per cent. of metallic titanium was added, was as follows:

TABLE XXVIII.

Chemical Elements	80-pound section	90-pound section	100-pound section
Carbon	0.55 to 0.65	0.58 to 0.68	0.60 to 0.70
Phosphorus, not to exceed	0.10	0.10	0.10
Manganese	0.40 to 0.70	0.40 to 0.70	0.40 to 0.70
Silicon	0.10 to 0.15	0.10 to 0.15	0.10 to 0.15

The ductility was from 8 to 16 per cent. per inch under the drop test, but with Bessemer steel with 0.10 phosphorus was never under full control.

At the same time that the use of ferro-titanium was begun, several changes in the conditions of manufacture, as noted above, were introduced, and in considering the effect of the metallic titanium it is somewhat uncertain how much benefit to ascribe to each. These changes, which were as follows, must be taken into account:

(1) Holding the metal in the converter 2½ minutes.

(2) Teeming through a 1½-in. nozzle into the ingot molds, instead of through one 2½-in. as formerly.

(3) Making 3-rail ingots instead of 4-rail ingots for 100-lb., and 4-rail ingots instead of 5-rail ingots for 80-lb. rail.

Notwithstanding these simultaneous changes, Dr. Dudley believes that some of the superiority of the Titanium-treated rail is due solely to the titanium.

At the same time that ferro-titanium was introduced into the rail steel, the New York Central Lines began the use of Basic Open-Hearth rails, and in 1908 laid 3,000 tons on the Electric Division at the New York Terminal, in competition with the Titanium-treated rail, and 2,300 tons in the Mohawk Valley, where the temperature often falls to 40 degrees Fahrenheit below zero. The object of their use was to secure increased ductility and toughness, which was possible by reason of the low phosphorus, and it is reported that they have rendered excellent service, as not a defective rail has been found in 700 tons in 4½ years' service with 80,000,000 tons of traffic.

For 1911, 19,746 tons of 100-lb. and 20,422 tons of 80-lb. Basic Open-Hearth rails were ordered for the parent company, and other quantities for the subsidiary companies.

This steel, teemed into the same molds, had a much tougher columnar structure, and when bloomed in the same train checked less than the Bessemer steel. The use of the Bessemer steel was therefore discontinued for the 1912 and future rails. In 1912, 43,350 tons of 100-lb. and 20,320 tons of 80-lb. Basic Open-Hearth rails were laid on the New York Central & Hudson River Railroad, and other quantities by the subsidiary lines.

The chemical composition of the Basic Open-Hearth steel was as follows:

Carbon	0.62 to 0.75
Phosphorus, not to exceed	.04
Manganese	0.70 to 1.00
Silicon	0.10 to 0.20

The tensile strength ranges from 115,000 to 125,000 lbs. per square inch for the 100-lb., and from 110,000 to 120,000 lbs. per square inch for the 80-lb. rails, while the elastic limits are from 52 to 56 per cent. of the ultimate. The ductility in an order of 20,500 tons of 80-lb. averaged 19.8 per cent. out of a calculated possible ductility of 21 per cent. For the 100-lb. section, the average ductility was 16 per cent. in a large order. It is usually from 12 to 18 per cent. The Brinell hardness is from 241 to 260.

It is reported that in the case of this rail, even where the temperature goes as low as 30 degrees Fahrenheit below zero, there is but 1 failure in 10,000 rails laid.

The wear or abrasion of the rail heads in service is shown in Figs. 91 to 94 in terms of loss in pounds per yard, and also in pounds per million tons of traffic. The rails in Figs. 91 and 92 are in the Fourth Avenue Tunnel, but do not show loss of metal from oxidation under the electric service, as was the case formerly with steam locomotives. Fig. 91 is Bessemer rail treated with Titanium and Fig. 92 is Basic Open-Hearth rail, and the rate of abrasion is the same with each.

Figs. 93 and 94 show that the amount of metal in pounds per million tons of traffic abraded from the head of Bessemer rail treated with Titanium in 1908 is less than that from plain Bessemer rail of 1907, at the location shown, which is on tangent alinement in New York City in both cases, where the traffic is heavy and the conditions severe.

Metallic titanium is being added also to Open-Hearth steel, but no information has been sent to the reporter.

NEW YORK CENTRAL & HUDSON RIVER RAILROAD—ELECTRIC DIVISION.

Sections showing wear on Dudley 6-in. 100-lb. rail.

F. Boardman,
Division Engineer.

A. C. Sherman,
Assistant Engineer.

Meaning of abbreviations used in figures:
A, B, C, etc., denote position of rails in ingot from top.
F.T. means Ferro-Titanium.
L.S. means Lackawanna Steel Company.
M.T. means Million tons of Traffic.
O.H. means Open-Hearth.
E. means East.
W. means West.

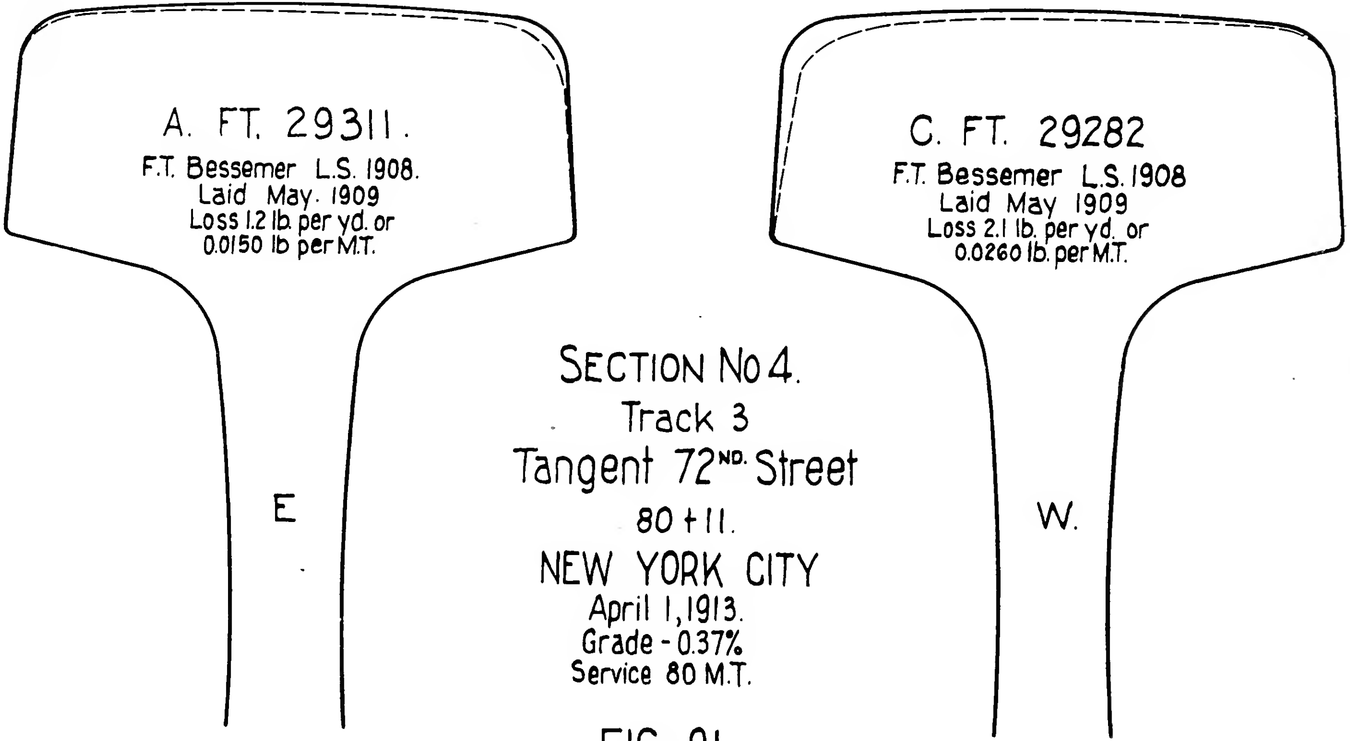


FIG. 91.

Some of the first Bessemer Ferro-Titanium Rails.

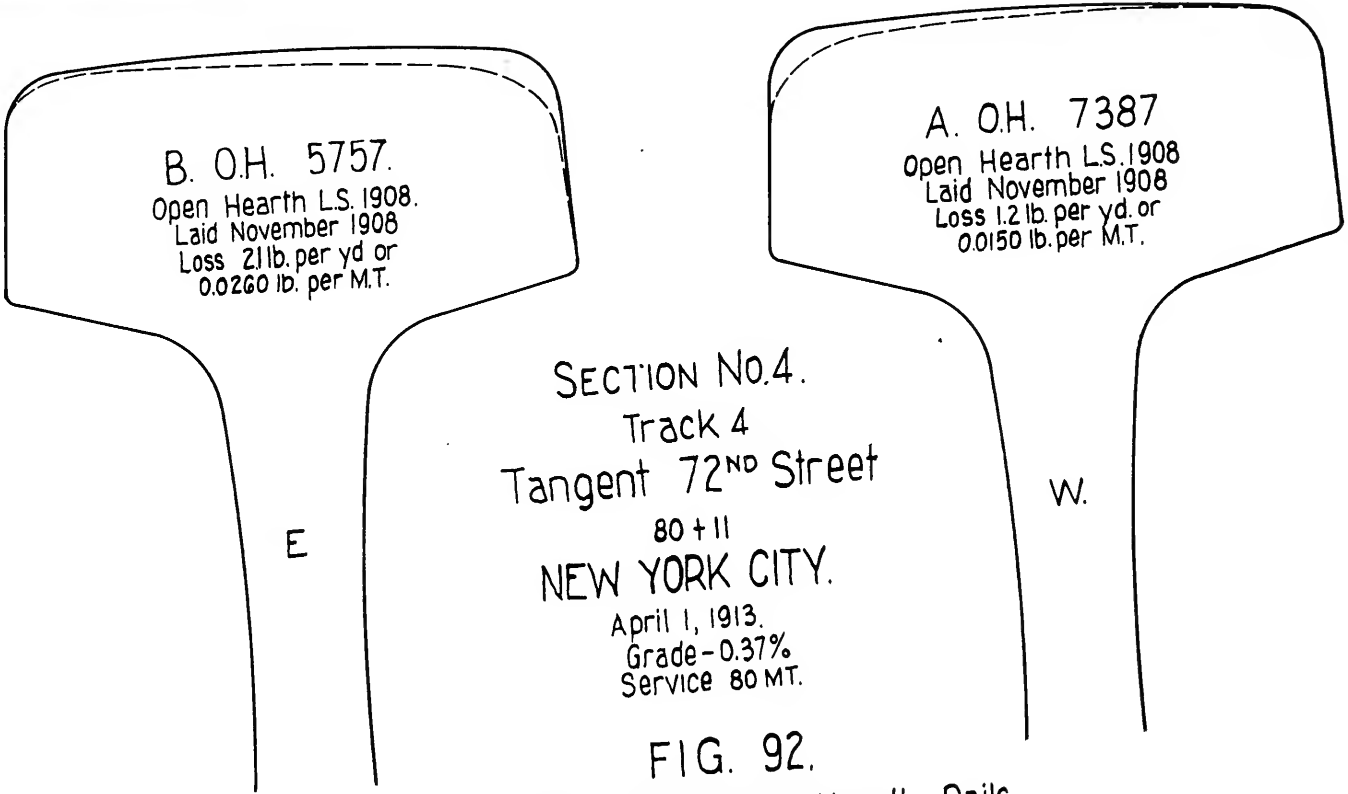


FIG. 92.

Some of the first Basic Open Hearth Rails.

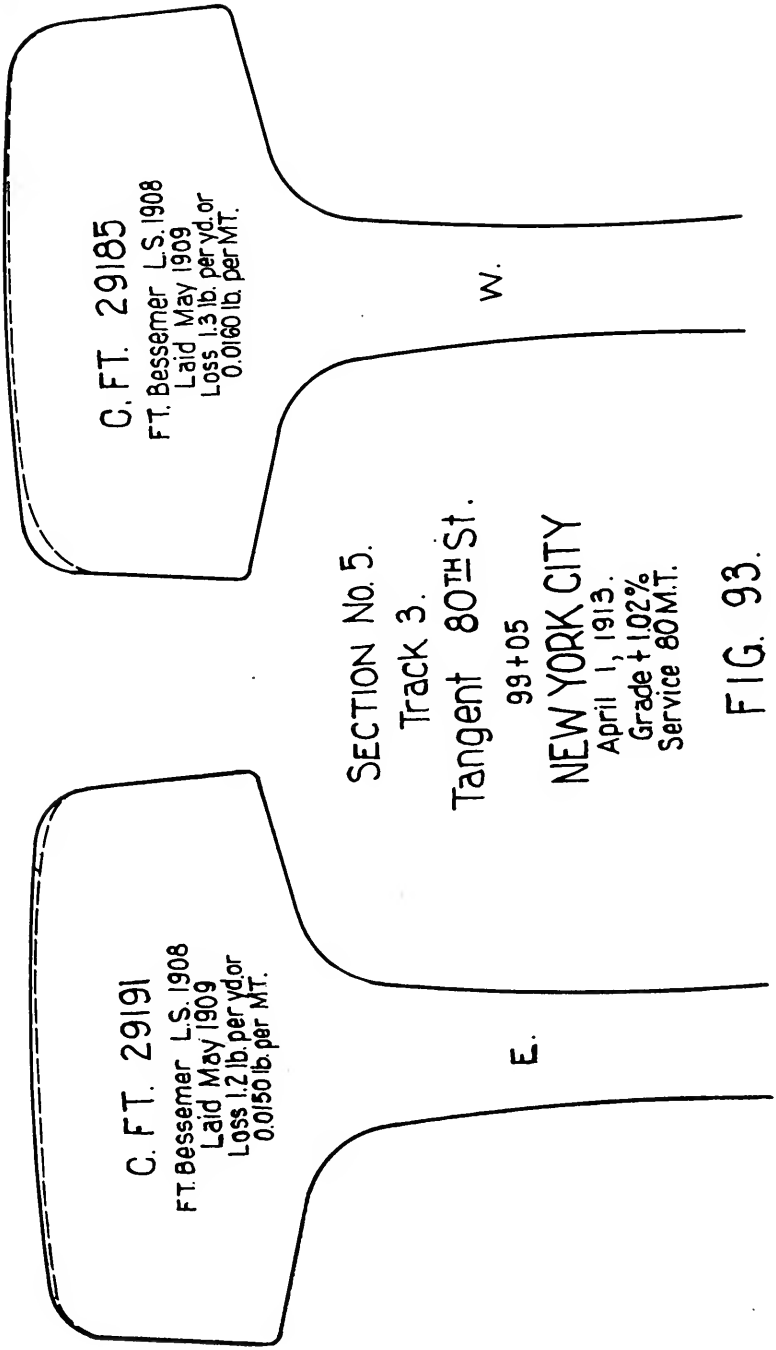
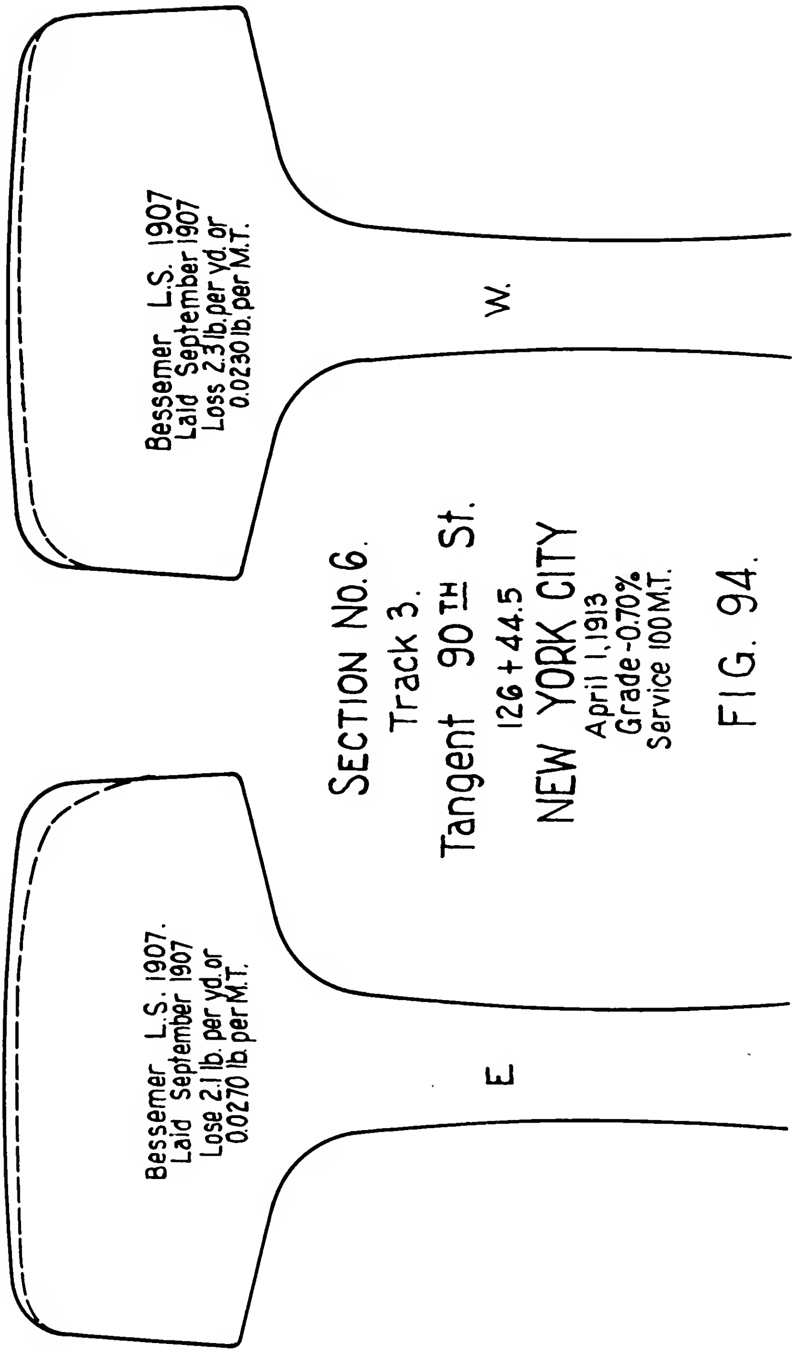

C. FT. 29185
FT. Bessemer L.S. 1908
Laid May 1909
Loss 1.3 lb. per yd. or
0.0160 lb. per M.T.
W.
SECTION No. 5.
Track 3.
Tangent 80TH St.
99+05
NEW YORK CITY
April 1, 1913.
Grade +1.02%
Service 80 M.T.
C. FT. 29191
FT. Bessemer L.S. 1908
Laid May 1909
Loss 1.2 lb. per yd. or
0.0150 lb. per M.T.
E.

FIG. 93.



Bessemer L.S. 1907
Laid September 1907
Loss 2.3 lb. per yd. or
0.0230 lb. per M.T.

Bessemer L.S. 1907.
Laid September 1907
Lose 2.1 lb. per yd. or
0.0270 lb. per M.T.

SECTION No. 6.
Track 3.
Tangent 90TH ± St.
126 + 44.5
NEW YORK CITY
April 1, 1913
Grade -0.70%
Service 100 M.T.

FIG. 94.

BALLAST TAMPERS FOR RAILWAY TIES.

By Geo. W. Vaughan,

Engineer Maintenance of Way, New York Central Railroad, East of Buffalo.

It has been found essential, in tamping ballast under railway ties, that the ballast should be tamped solidly under the ties at each end along the central line, as well as from that line laterally toward each of the edges. Heretofore this work has been practically performed entirely without the aid of mechanical appliances, other than the usual tamping implements. These implements consisted of a pick having one end properly formed to tamp the ballast, and a shovel with which the ballast was first cleared away at the sides of the tie and subsequently shoveled back in small quantities as the tamping operation proceeded. This method, which is practically in universal use, is slow and requires the employment of a large number of men to straighten up a comparatively short stretch of track.

While numerous efforts have been made to provide mechanical appliances for assisting in the operation of tamping the ballast beneath the ties, up to the present time nothing has appeared which was found acceptable to the Engineers or workmen employed by them. The work performed by the apparatus was either defective in that it did not form a solid foundation at the center of the tie, or else the labor handling the apparatus was so great as to preclude its use by the workmen ordinarily available for such work. For example, it has been proposed to make use of power-driven rammers. With this type of apparatus the tamping bar or tool which is brought into contact with the ballast is reciprocated, and its successive strokes permit the ballast to fall down in front of it so that it has been found practically impossible to effectually tamp the ballast at the center portion of the tie. Furthermore, such apparatus when designed to be held manually, has had to be supported entirely by the workmen during the entire tamping operation, for none of the weight could be allowed to rest on the reciprocating tool, because this would immediately result in a reciprocation of the body of the implement, while the tool or bar remained stationary, much to the discomfort of the workmen.

Owing to this and to the fact that such apparatus was necessarily heavy and cumbersome, it has been proposed to mount the same on mechanical supports. An apparatus of this character, attached to the track or to a truck adapted to run on the track, is obviously a failure, because of the difficulty in setting the implement laterally or along the tie and at the proper angle necessary for it to assume in effecting the proper tamping of ballast. Such apparatus, furthermore, will interfere with the progress of trains, it being well-understood that any apparatus employed must be of such character that the workmen may instantly remove it from the track when a train is approaching.

Previous to 1913, the only practical machine of this character was invented and patented by Albert Collet, Paris. This tamping outfit, as shown on Plate 1, is composed of a gasoline motor of 23, 35 or 45 H.P., depending upon the amount of power, directly connected with dynamo D of corresponding power, and which gives a continuous current at 240 volts. This is equipped with two tanks, one for gasoline and the other for water, ensuring a working capacity of ten days without recharging. The characteristic feature of this apparatus is the mode of transverse motion, of which two phases can be seen in Figs. 2 and 3. The action of the crank enables one man to make the whole system rest alternately on the big or little wheels, these latter being able to turn through an angle of 90 degrees on their axis. It is, therefore, easy for the apparatus standing on the road to leave it by means of two short lengths of rail placed perpendicularly to the line under the small wheels, freed and turned, as has been stated. The contrary operation, to put it on the road, is done in the same way. This operation takes five minutes. Large wheels and the shafts are for use on macadam roads. This same apparatus is made with steam motive power (Fig. 4). The weight of the 35 H.P. outfit is 4.45 tons.

PLATE 1.

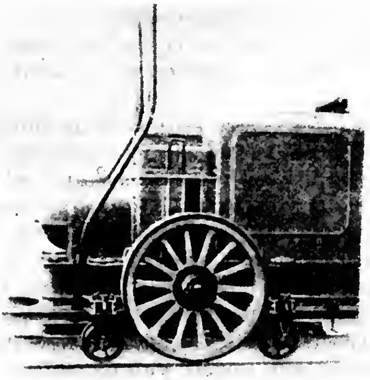


FIG. 1.

To convey along the road the electric current produced by the outfit above described, an electric line is provided of ladder insulated supports, as shown on Plate 2. These require 160 ft. of line, composed of two high-conductivity copper wires of $\frac{7}{32}$-in. diameter. The tension of this line is governed by the reel R, Fig. 2. Two trained men in a day will install 25 of these supports, i. e., 4,100 ft. of line. The perfect insulation is obtained by insulating loops. The current passes the ladder insulated supports to cable C. The leg is sliding so as to enable the apparatus to be put even against a wall. The setting up of the ladder insulating supports has never met with any practical difficulty, either on embankments, in tunnels or on viaducts. Its dimensions are such that it can even be set up in 6 ft. It can be used to support the electric lamps to light the work. The drum, T, is for storing the double line when not in use. The weight of one insulated support is 116 lbs. The weight of the drum, T, with 165 ft. of double line, is 75 lbs.

PLATE 1-A.

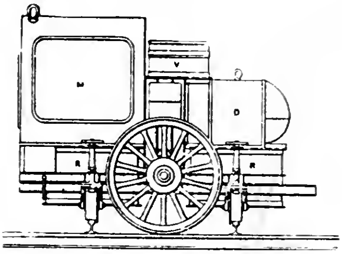


FIG. 2.

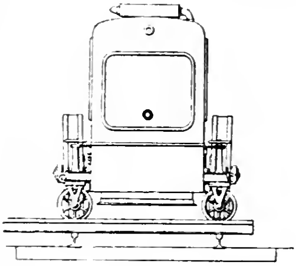


FIG. 3.

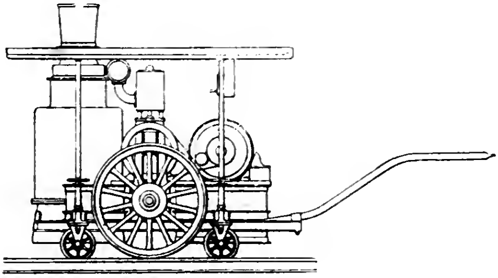


FIG. 4.

The current brought by the double line, L, Fig. 2, as shown on Plate 3, is collected by the trolley, T. The cable, F, takes it to the special switch, I, leading to the motor, by means of a horizontal shaft, A. The motor is set on a frame, C, which carries a step-bearing to receive the supporting pivot, P, of the rail truck. The rail truck is formed of two articulated pairs of ball-bearing wheels at the gage of the line. It is used for moving the apparatus on the rail during the work. This arrangement allows the apparatus to be instantly taken to pieces on the line. The motor is raised by means of the arms, B, and set down on the side and the rail truck lifted off separately, the road being freed from the whole plant in one minute. The power of the motor is 5 H.P., the weight of the motor is 300 lbs., and the weight of the rail truck is 200 lbs.

The packer, as shown on Plate 4, is mounted on a rail truck, and driven by current from the dynamo, which has been previously described, to which has been added speed-reducing gear, R, Fig. 2. This apparatus enables the rapid packing in depth of ballast of whatever kind. The inclination of the packer facilitates the work, as the packing, which is effected first, at the base of the bottom of the ballast, is transmitted upward as far as the lower surface of the tie. There results from this absolute uniformity in the foundation of the road. At the hammer, F, the work per minute corresponds to that of 400 blows produced by the release of a spring of 440 lbs. enclosed in the head, C.

PLATE 2.

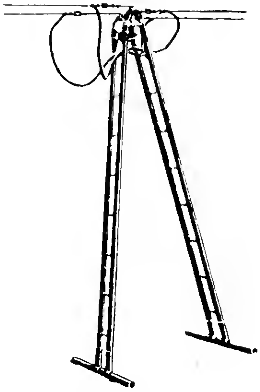


Fig. 1.

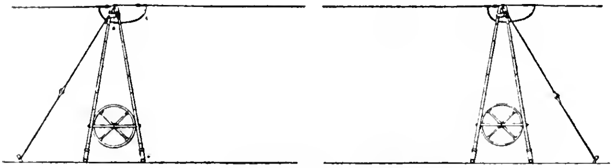


Fig. 2.

The mechanical packing allows the movement of trains at full speed to be resumed immediately, thus obviating the necessity for slow orders and the resulting delays. It allows of considerable economies to be realized in the maintenance and the wear of material. In the case of metallic ties, it enables the workmen to quickly fill up the hollow of the ties and to insure immediately a perfect packing. The work, generally done by 2 sets of 4 packers each, is from 60 to 100 ties per hour, according to the thickness and kind of ballast. To each kind of ballast corresponds a type of packer easily interchangeable. The power used by the apparatus is 1½ H.P.; the weight of the apparatus alone is 121 lbs., and the total weight of the motor and frame is 514 lbs.

A test of these machines was made by M. Muntz, formerly Chief Engineer of the French Eastern Railway Company. The track chosen for the test was the line from Paris to Rheims, and the work consisted of two parts, one the repairing of 4.58 miles of track; the other a section of 4.9 miles where the track was repaired and ballast renewed. The old track had been laid with 66-lb. rail, 8M (26 ft. 3 in.) long, with 11 ties to the rail. This rail was replaced with 97-lb., 18M (59 ft. 0.5 in.) long, with 25 ties to the rail. The agreement with M. Collet and the company provided that he furnish five sets of machines for tamping, and one electric power machine.

PLATE 3.

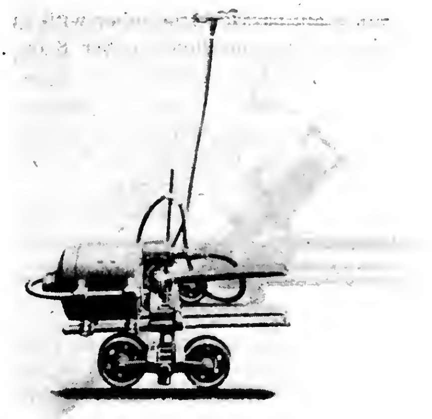


FIG. 1.

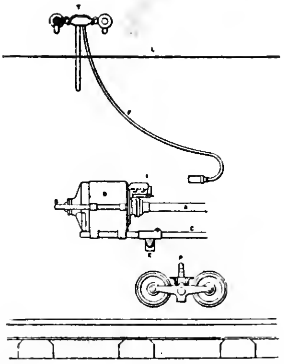


FIG. 2.

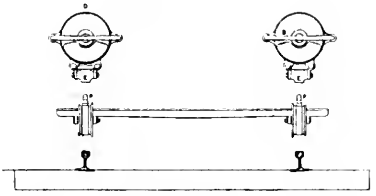


FIG. 3.

PLAN OF THE WORK.

In order that the work might be as uniform as possible, from day to day, a definite organization was developed, which was divided into two parts, one dealing with the repair of the track and the other with track repair and ballast renewals.

TRACK REPAIR.

The workmen were divided in two groups, the first, 45-50 men and two foremen, charged with relaying rail, taking out screw spikes and strengthening track for train passage; the other with 23-29 men, with one foreman, operated the tamping machines, either 8 or 12 machines, and finished the surfacing of track. The plan provided that each group finish the same amount of work each day, and to that end the two groups worked on the track distant from one another to the extent of a day's work.

PLATE 4.

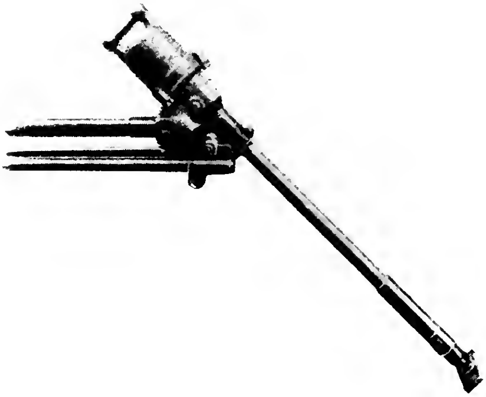


FIG. 1.

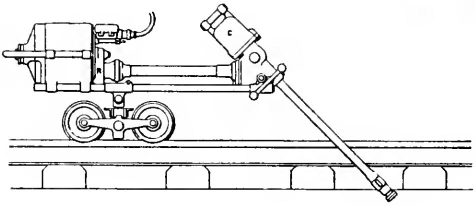


FIG. 2.

REPAIR OF TRACK AND BALLAST.

The workmen were grouped as in the first case, but a separate lot of men unloaded ballast. In order to facilitate the work, three divisions were established; in the first, the track was exposed, ballast removed, etc.; in the second, ballast was unloaded; in the third, the ballast was tamped with the machines and the track surfaced. The distance separating the groups of men was about twice the length of track finished each day. In addition to the men enumerated, there were 14 men assigned to operate the motors, set up the trolley line, etc. Six additional men were necessary to place guard rails, gage rods, etc., this to make the track safe as quickly as possible, owing to the large number of trains passing.

PROGRESS OF THE WORK.

The work at first was very slow, owing to the newness of the machines, the unfamiliarity of the men with their operation and the training of the various groups to rapid work. In addition to these difficulties, bad weather interfered considerably. Then also frequent repairs were necessary to the power machine. The work may be considered in two parts: The first, while it was being organized and the men becoming familiar with the operations, this including work on 4 K 400 M (2.73 miles), at the rate of 243 meters a day (797 ft.); the second, where faster work was done, 361 meters (1,185 ft.) per day, or a total of 3 K 250 meters (2.02 miles). The last rate could have been maintained and certainly would have been exceeded if there had not been such frequent interruptions due to the breaking down of the power machine, and particularly the tamping groups.

RESULTS OF THE TESTS WITH THE COLLET MACHINES.

In these tests the round tamping bars, having a diameter of .12 meters (4.72 in.), were tried in comparison with bars having rectangular face of the same area. The latter were found to be preferable for sawed ties, but not as good in tamping of joint ties. The experiment showed that it was not necessary to tamp joint ties separately: in other words, it was found that it was sufficient to arrange the tamping machines (see diagrams) in such a manner as to tamp the ballast so as to form a cushion under the two-joint ties (see Diagram A).

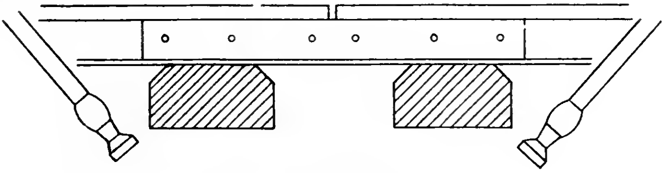


DIAGRAM A.

The angle to which the tools were laid seemed to be a little too nearly vertical. If one were to assume on a cross-section of track two tamping bars at the extreme position which they could occupy, one would find that their extended prolonged axes would join at a point 7.87 in. below the lowest face of the tie, as shown in Diagram B.

This might give considerable trouble if the layer of ballast were thin, or the sub-ballast of poor character, because it might permit the ballast to penetrate into the sub-ballast. In any event, the best results are not produced in the layer of ballast immediately in contact with the ties. At M. Muntz's request, M. Collet modified the tamping machines by inclining the face of the tool, which strikes the ballast, so as to give a more horizontal impact. This seemed to give good results. The length of time necessary for tamping a tie increases with the thickness of the layer of the ballast to be tamped. With the Paris "to Mary," which has been in use for a year, it was found necessary to tamp one tie one minute, using four machines. For repairing of track and the ballast this time was extended to two and three minutes, per tie, depending on whether the work was done on old track or on a track laid at a definite level. The density of the ballast as obtained with these machines, and above all, the uniformity of the tamping, were observed during the entire time of the repair work by means of stakes set at various points along the track. The proper level was maintained either by means of rods placed on the two rails, or by means of a level having a flexible tube, which was placed at their disposal by M. Collet.

The conclusions drawn from many accurate measurements during these tests were as follows:

(1) The mechanical tamping does not raise the track.

(2) The average settling of the track was as follows:

After the first train..Nothing
After 50 trains (.08 in. to .12 in.)....................2 to 3 millimeters
After 150 trains (.2 in. to .24 in.)....................5 to 6 millimeters
After more than this number of trains had passed over the track, the settling appeared to have stopped.

(3) No appreciable difference was noted as regards the settling of the track between settling at the joints and in the middle of the rail.

(4) The settling of the track which was tamped by hand was not uniform, and the minimum noted was 12 millimeters (0.47 in.) after 50 trains had passed.

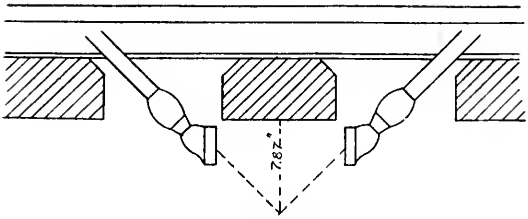


DIAGRAM B.

From the very beginning of the repair work, it was found that the amount of ballast put at their disposal was entirely insufficient to keep the two gangs of men busy. M. Collet furnished 12 tamping machines; four, however, were used only occasionally. All of the machines worked without serious difficulty, and at no time were the difficulties encountered such as to stop the work for any length of time, although the tamping machines were frequently repaired. A number of the opposing springs, compressed by the rotation of the cogs, had to be replaced, but this, however, only took a few minutes in each case. There were also now and then breaks in the transmission line.

MOTOR CARS.

The motor car, having a nominal capacity of 25 H.P., gave an average of 18 to 20 H.P., that is, it kept going as many pieces of machinery as were used. It might be said that this also included the machines for driving screw spikes. The following energies were required: 7½ H.P. for a pair of screw-spike driving machines, equivalent to 15 H.P., 4½ H.P. for a group of four tamping machines, equivalent to 9 H.P. for 8 or 13½ H.P. for 12 machines, making a total of 24 or 28½ H.P. for both the screw-spike driving machines and the tamping machines, depending on whether 8 or 12 machines were used, while the screw-spike driving machines were working. This is a general estimate, but it means considerable additional strain on the motor, when operated under the above conditions. Nothing has been taken into account to provide for losses from the daily wear itself, which may attain 0.5 to 0.6 H.P. per hectometer (328 ft.).

If we consider the work of the tamping machines alone, we find that it requires 13½ plus 5, that is 18½ H.P., which is greater than the effective power on the motor under ordinary circumstances. Taking into consideration then all the various failures, breakages of tubes, in a word, all of the difficulties encountered in operating the machine, it was found that the motor required two entire stoppages and eventually the premature withdrawal of the tamping machines.

TRANSMISSION LINE.

There was nothing particularly to be noted about the transmission line. No accidents occurred in connection therewith. The setting up of the posts was rapid. The only inconvenience was that the line was too short, requiring the taking down at one end and setting up at the other. This probably was also due largely to the overloading of the motor. It required 10 men to move the motor, which took 30 minutes; this means putting the motor on the track, moving it one kilometer (.62 miles), setting it off the track and starting it going. In this respect the machine was well constructed, and all the parts were built so as to simplify the moving operation as far as possible.

COST OF APPARATUS.

The cost of this apparatus was as follows:

Packers complete with motor and truck	$2,000.00
35 H.P. gasoline motor, dynamo and car	4,500.00
20 pole power line	1,300.00
Total	$7,800.00

COST OF OPERATION.

The cost of the labor, including the placing of the apparatus for the different stages of the work, was as follows:

Repair of the track, starting period, 2.04 francs (41 cents) per meter ($0.125 per ft.); normal period, 1.91 francs (38 cents) per meter ($0.117 per ft.), that is, an average of 1.97 francs (39 cents) per meter ($0.12 per ft.).

Comparing this with the cost of doing the same work by hand during the preceding year, which was for the line Paris to Rheims: 1.80 francs per meter (36 cents), or $0.11 per ft., and for the line Paris to Strasburg, 1.88 francs per meter (38 cents), or $0.115 per ft.

Repair of the track and ballast with mechanical apparatus, 2.83 francs (57 cents), or $0.173 per ft., and by hand, 2.60 francs (52 cents), or $0.159 per ft. This last price is not absolutely certain, because the work from which these figures were taken was not completed. On the whole the use of the Collet mechanical tools is an additional expense of about 370 ($74.00) to 230 ($40.00) francs per kilometer of track, $119.40 to $74.20 per mile. This is insignificant if one remembers that the first cost of a kilometer of new track is from 18,000 francs ($3,600.00) to 20,000 francs ($4,000.00), ($5,800 to $6,450 per mile) a deduction being made for the value of the material not used.

Even if a direct economy is not realized by using the Collet machines in track work, it does not prove that with the improvements that may be made in these machines, it will be impossible to lower the net cost of operation. However this may be, there are a number of advantages from a technical standpoint that would appear to more than compensate the additional expense. There is certainly a greater security and a more finished piece of work obtained with the mechanical tool and a greater guarantee against subsequent deformation, which would have to be corrected by subsequent maintenance.

The work can be organized in a very regular manner. Thus in renewals they worked every day without exceptions. Looking back to former renewals, it was found that in the preceding years, on the line, Strasburg to Paris, there were renewed 15 kilometers 475 meters, or 9.6 miles of track, in 76 days, of which 53 days were occupied by taking up and replacing rail, and in normal repairs. Final surfacing and tamping was not attempted until after a certain number of trains had passed over the track, after the same had been repaired and tamped temporarily. This means that they had to keep working on the track for several days, generally three. The mechanical tamping brings about a permanent settling of the track in a few minutes, which ordinarily would be obtained only after many trains had passed over the track. This means that with the mechanical tamping, slow-speed signals can be removed in less than 24 hours after the complete renewal of the track. The total length of track over which trains must reduce speed is reduced to a minimum. In renewal work of 36 meters (1,182 ft.) this length can be represented by the following scheme as shown in Diagram C.

Repair work done by hand would require a zone of reduced speed of 700 additional meters (2,300 ft.).

Speaking of the character of the work done with the machine, a very few days suffice to so train the men that the same degree of proficiency was obtained from one end of the track to the other. Where the work was well directed, the same tools used, and where in particular the ballast was evenly distributed while the men were at work, the best results were obtained. The good results of mechanical tamping are not only found in the early permanency given to the track, but especially to the regularity of the settling, which takes place later on.

DESIRABLE IMPROVEMENTS.

The tests which were made show, without a doubt, that in order to renew track, such as they did, with daily length of 350 to 450 meters (1,150 to 1,478 ft.), this meaning a complete renewal of the track to put it in first-class condition, it is necessary to have a motor machine capable of furnishing 40 or 50 H.P., and to have effectively working at the same time three or four groups of tamping machines. The machine used was 25 H.P., and would be sufficient if the laying of the track be done without consecutive tamping, or if ballasting alone be done, but not more than 8 tamping machines should be used.

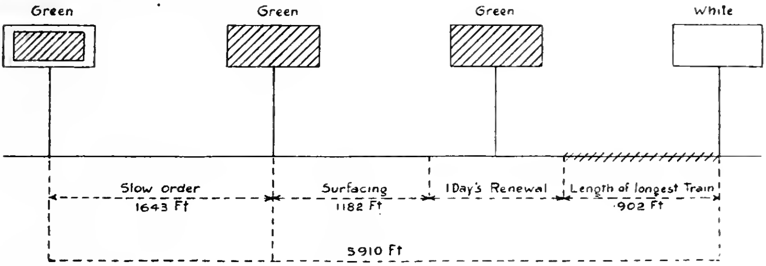


DIAGRAM C.

The agreement with M. Collet provided for certain spare machines, and separate parts for the machines. These were not enough. When workmen start to repair track with these machines, they should be sure that a sufficient number of extra machines are on hand, so that the breaking down of one machine in a group (especially the tamping machine) will not render the whole group ineffective. During the course of these tests, M. Collet found it would be necessary to make modifications and, since the tests were made, he has made notable changes in the tamping machines.

CONCLUSIONS.

(1) That the mechanical tamping machine does not raise the track, but gives it a base which is ordinarily obtained after the passage of a very large number of trains only.

(2) That, without increase in expense, the length of time necessary for making repairs can be diminished by a third.

(3) That the length of slow-speed track can be very appreciably reduced and normal track restored in less than 24 hours.

The construction of the above machines is such that they are ballast packers instead of tampers, in that they compress the ballast up against the tie, instead of tamping it under the tie as is done ordinarily by manual labor. Owing to the tendency to drive the ballast down into the subgrade and the wide spacing of the ties necessary for the practical operation of this machine, it does not seem practical or suitable for work on American railways, where the ties are spaced close together.

Another bad feature is that owing to its construction, the tampers and motor being mounted on a supporting pivot attached to the truck, the ballast tamper is forced to work and compress the ballast at an angle to the axis of the tie. For this reason, its position is confined and it necessarily can work efficiently in one position only, namely, at right angles to the tie, as it necessarily has to work at an angle in all other positions.

A tie tamper has been designed with the object in view of overcoming defects which prior apparatus has developed, and providing a tamper which may be handled readily by an ordinary workman, the operation of which will be more efficient and rapid than the ordinary hand-tamping process, where a single workman may effectually tamp the ballast under a greater number of ties than ever before. This tamper embodies in its construction a body portion or housing which, although made as light as possible, necessarily is of some considerable weight, and in which there is a reciprocatory impact or percussion member adapted to be reciprocated and momentum imparted thereto for delivering effective blows at a high rate of speed, for example, by pneumatic pressure, or by electricity.

The lower end of the casing or housing is adapted for holding a projecting tamping bar in such wise that its end within the casing will be in a position to receive the blows of the impact or percussion member. The connection with the casing is preferably such that the movement of the bar in the casing is limited. Therefore, the weight of the casing may be allowed to rest on the tool or bar during the tamping operation, although the bar is permitted a limited outward movement with relation to the casing, so as to obtain the full advantage of the energy transmitted through the same to the ballast. The tamping bar is preferably curved somewhat, so as to drive the ballast directly under the bottom of the tie, and is held against rotation in the casing, so that by the manipulation of the casing the position of the extremity of the bar may be accurately located. The bar itself is made relatively short in order that the weight of the casing and impact member may be brought down as close to the ground or tamping end of the bar as possible.

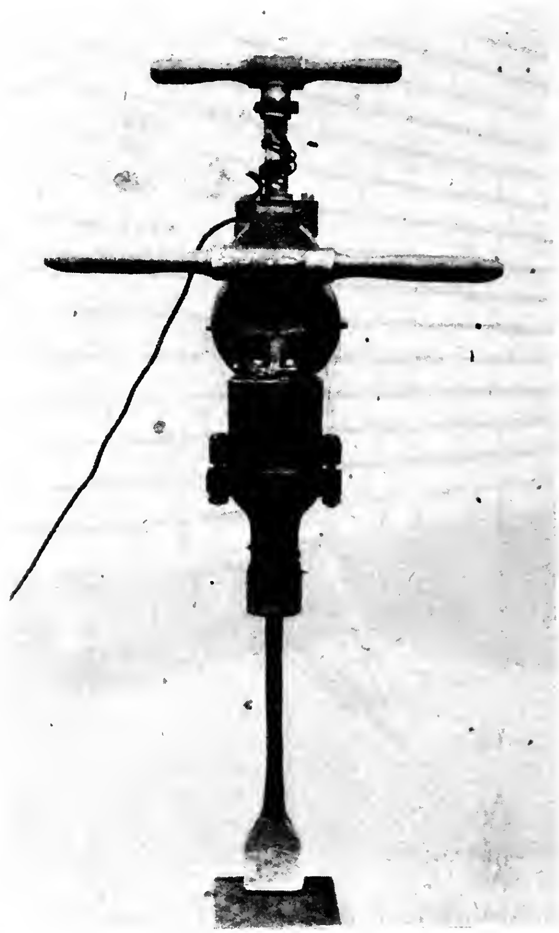
To enable workmen to properly position and handle the implement or tamper, the casing is provided at its end opposite the tamping bar with a stock or axial prolongation, the upper extremity of which is adapted to form or has applied thereto a handle for one hand of the workman to grasp; and at a point in proximity of the casing the stock is provided with a second handle located in such relation thereto and to the center of gravity of the implement that when the implement is suspended from the second handle, it will assume approximately the angle which is proper for it to assume in the major portion of the tamping operation. The two handles being thus located above the center of gravity or above the heaviest portion of the tool, permits the tool to be more readily handled and manipulated, and for this reason the load to be supported by the workman is less than would be the case if the weight were near the upper end.

Plate 5 shows such a ballast tamper operated by pneumatic pressure; Plates 6 and 6-A show a form of tamper operated by electricity. The pneumatic tamper here shown, including the bar, weighs 37 lbs., and consumes approximately 19 cu. ft. of free air per minute at a pressure of 70 lbs. The electric tamper here shown, including the bar, weighs approximately 90 lbs., and consumes 3.5 amperes at 220 volts, or .77 kilowatt, and delivers from 1,000 to 1,200 blows per minute.

PLATE 5.

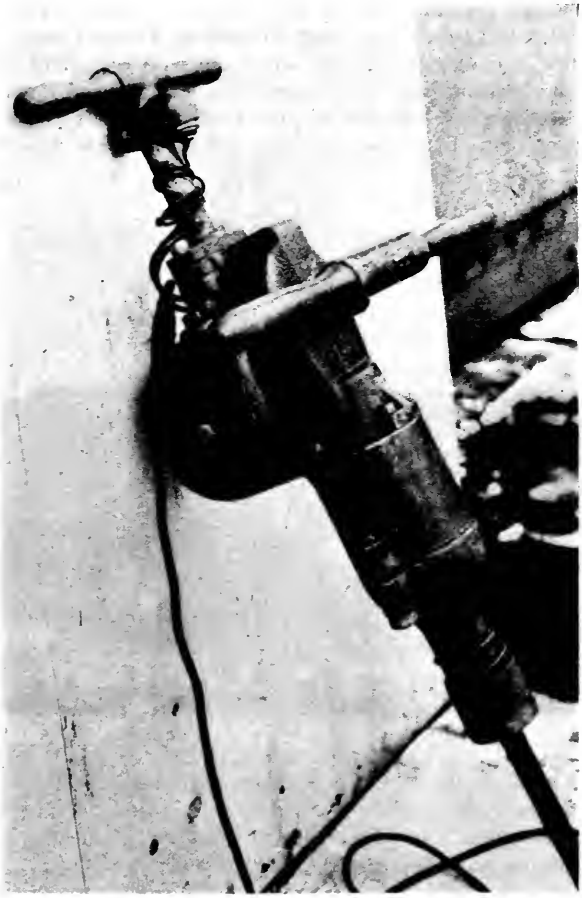
Plate 7 shows a car, upon which is mounted a 12 H.P. gasoline engine directly coupled to an air compressor, with a capacity of 45 cu. ft. of free air per minute at 80 lbs. pressure, also a gasoline tank, with a capacity of 16 gallons, and a water-cooling radiator, with a housing to protect the machinery. The compressor is fitted with an automatic discharge unloader, which maintains a constant pressure without interrupting the continuous operation of the engine, and a receiver of adequate size is mounted under the car deck. This outfit complete weighs, when the radiator and tank are empty, 2,180 lbs., and with the radiator and gasoline tank filled and with hose and tampers, 2,495 lbs. It easily furnishes sufficient air for the operation of two tampers through several hundred feet of ¾-in. hose.

PLATE 6.



Plates 8 and 8-A show a car upon which is mounted a 2-kilowatt dynamo directly coupled to a 4-H.P. gasoline engine which furnishes easily sufficient electric power for the operation of two electric tampers. Such a generating unit weighs about 680 lbs. A car with this unit mounted thereon, including the gasoline reservoir, water radiator and switchboard, weighs about 1,900 lbs. This weight can, however, be considerably reduced.

PLATE 6-A.

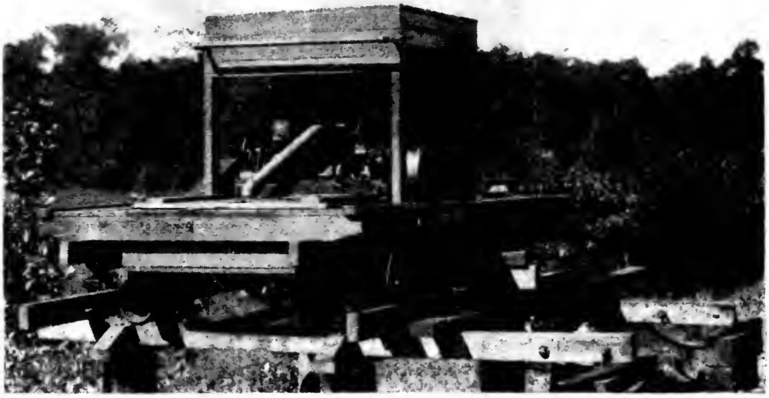


Plates 9 and 10 show the pneumatic tampers and Plate 11 the electric tamper in actual operation.

A test of the automatic tampers was made on the New York Central & Hudson River Railroad during the years 1913 and 1914. The track chosen for the first test was where new rail had been installed, and ties were being spaced, and the track ballasted, the track being lifted from 2 to 4 in. In the second test the track was lifted 3 in. The third test consisted of spacing ties under new rail, raising track on stone, and doing the work with a regular section gang. The fourth test consisted of regular section work, spacing ties, surfacing and dressing track, etc., the work being done by the regular section gang. The fifth test consisted of final surfacing with a regular main-line gang, using the electric tamping outfit, after the track had been raised 12 in. on stone by a special gang.

The first test of tamping ties was made with one unit, which consisted of one machine and two tampers, the machine and tampers being operated in connection with the regular gang of laborers placing ballast, hand tamping, etc. In the second test the tampers were assigned to an extra rail gang, in the third test to a regular gang on the main line, in the fourth test to an ordinary section gang consisting of five men on a double-track section equivalent mileage 11 miles, in the fifth test to a regular gang on main line with the electric tamping outfit.

PLATE 7.



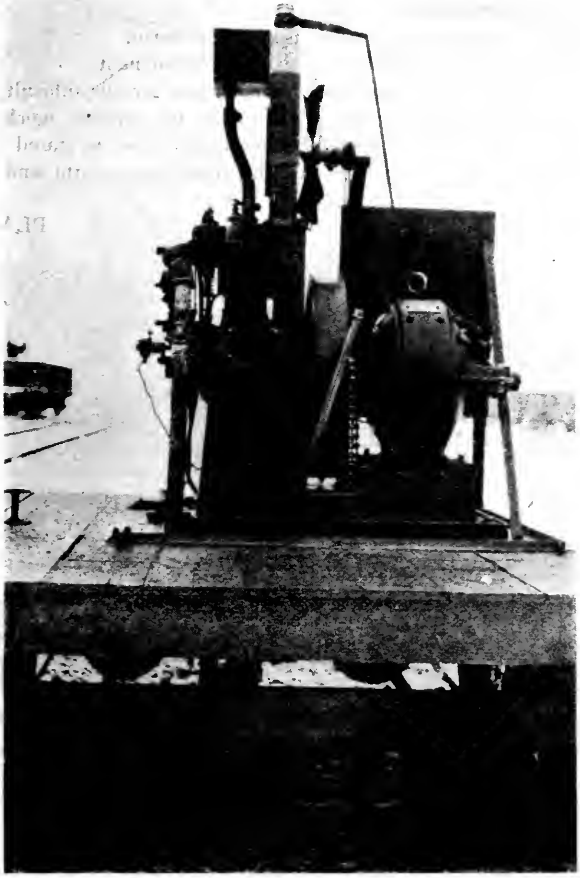
PROGRESS OF THE WORK.

The work at first was very slow, owing to the newness of the machines, the unfamiliarity of the men with their operation, and the training of the men to rapid work. It was found necessary at first to change the men off and put new men on every 2½ hours, although it has since been found unnecessary to make such changes after the men became expert in the use of the tampers.

RESULTS OF THE TESTS.

Considerable trouble was experienced during these tests owing to breakages of various parts of the machine, such as tamping bars, end caps of the tampers, bushings, handle bars, handles, and various parts of the compressor outfit. These breakages, while not serious, caused considerable annoyance and delay. All of these breakages have been reduced to a minimum and very little trouble should be experienced with such breakages from now on. The angle at which the bars were bent enabled the machine to be held in such a position that the ballast could be driven directly under the bottom of the tie, which, when the layer of ballast is thin, avoids forcing the ballast into the sub-ballast. The length of time neces-

PLATE 8.



sary for tamping a tie increases with the thickness of the layer of the ballast to be tamped. With a lift of from 2 to 4 in., by using two machines, we find ordinarily it requires two minutes to tamp a tie. The density of the ballast as obtained with these machines and the uniformity of the tamping was observed during the entire time of the various tests.

The conclusions drawn from observation during these tests were as follows:

(1) The mechanical tamper can raise the track.

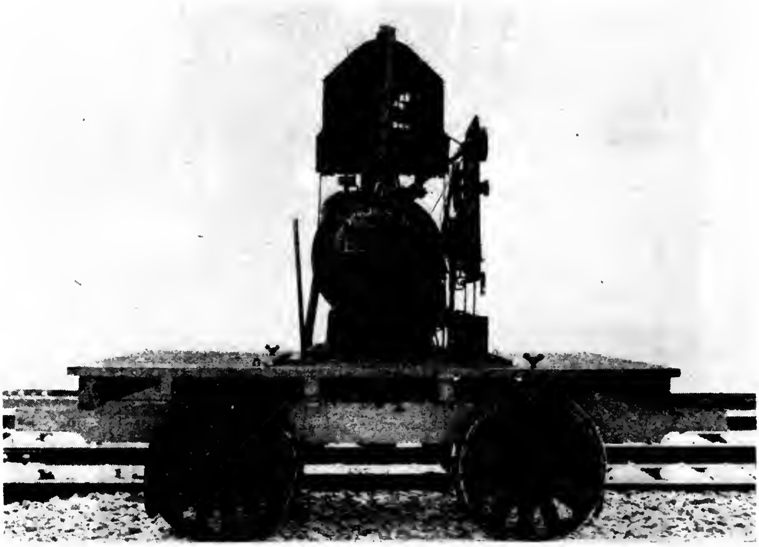
(2) There is less settling of the track observed when tamped by machine than when tamped by hand.

(3) The settling of the track is more uniform.

(4) The machine-tamped track is more permanent.

The pneumatic tampers worked without any serious difficulty, and at no time were difficulties encountered such as to stop the work for any length of time. The only difficulty experienced was, as stated above, in the breakage of the various parts of the compressor outfit and tamping bars.

PLATE 8-A.



COMPRESSOR CAR.

The compressor, which is nominally a 12-H.P. machine mounted on the car, furnished all of the air required to satisfactorily operate two tampers. These tampers seemed to do as efficient work at the end of 600 ft. of hose as at the end of a 50-ft. length of hose. On account of more or less cuts and narrow fills, however, where such machines will be used, it is possible that one would have to use an auxiliary line of iron pipe at such places. This pipe can be drawn along on the ballast as the work progresses, allowing the tampers to work, if necessary, 1,200 or 1,500 ft. from the machine.

COST OF THE APPARATUS.

The cost of the apparatus as compared with the Collet machine is very reasonable. One complete unit consisting of three tampers, 600 ft. of hose and compressor, mounted on a car as illustrated in Plate 7, will cost approximately $1,800, as against $7,800 for the Collet machine.

PLATE 9.

A self-propelled compressor car is illustrated on Plate 7, which is a duplicate of the one used during all the tests except the first. This car is equipped with a clutch with sprocket and chain for driving one pair of the main wheels. The sprocket ratio is such that the speed of the car when being driven is from 12 to 15 miles per hour.

The car can be provided with a galvanized iron cover or wood housing over the machinery to protect it from the weather. A wood housing is shown on Plate 7. The deck of the car is 9 ft. by 5 ft. 5 in. and can accommodate easily 12 men. The engine has ample capacity to haul such a load up the usual grades. The car is provided, as shown in the illustrations, with transverse trucks, the small wheels of which are elevated so that the tread is about 2 in. higher than the tread of the main wheels. To remove the car from the track, it is merely necessary to raise each end of it in turn 2 or 3 in. and slip a 2 in. by 4 in. scantling or a flexible track made of light rails, under the transverse truck at each side, and then push the car off the track transversely over this improvised track.

This car, when fully equipped, weighs:

Car	2,180 lbs.
Gasoline and water	145 lbs.
Hose and tampers	170 lbs.
	2,495 lbs.

but with the above arrangement it can be easily and quickly removed from the track or replaced by four men. This car, besides meeting every requirement for tamping purposes, can take the place of the section motor car that is being used on many sections at the present time.

PLATE 10.

The gasoline-generator car used with the electric tampers in Test 5, is illustrated in Plate 8. It is self-propelled and equipped for removal from track, similarly to the compressor car. The engine is of the so-called "four-cycle" type and therefore not reversible. However, a reversing gear is provided, which permits the operation of the car in either direction. The car is provided with a galvanized iron housing to protect the machinery. The housing can be easily removed when desired.

COST OF OPERATION.

TEST NO. 1.

During this test the track was raised from 2 to 4 in. An average of 26 ties per hour were tamped with the machine, the complete operation being performed by two men. The machine was used an average of 5½ hours per day. This was due partly to delays account of a lack of duplicate parts and partly to the fact the men had other work to do. It has since been demonstrated that the machine can be operated continuously with very little delay. The overhead charges of 0.6 cent per tie includes interest and investment, depreciation and repairs. The interest is at 5 per cent., the repairs the actual amount recorded and the depreciation based on a life of ten seasons. The cost of this test was as follows:

2 men (10 hours each at $0.17)	$ 3.40
16.3 gallons gasoline (for 10 hours), $0.12	1.96
2 pints oil (for 10 hours), $0.05	.10
Total cost per day	$ 5.46

Ties tamped in 10 hours, 260; cost per tie	$0.021
Overhead charges, including repairs	.006
	$0.027

Comparison of cost of tamping one mile of track by hand and by machine:

By Hand.

Gang of 10 men and foreman per day	$ 21.20
They will tamp one mile in 13⅓ days	282.60

By Machine.

3,200 ties, .027	$ 86.40
Saving per mile	196.20

TEST NO. 2.

In Test 2 the automatic tampers were assigned to an extra gang engaged in raising and spacing ties under new rail. The track received an average raise of about 2 to 3 in. on stone ballast. The tampers were started in with an extra gang of 30 men, together with the section gang of seven men; but after working with this number of men for a half day, it was discovered that there were too many men for the capacity of the machines. The sectionmen were sent to do other work, leaving 30 men, or the extra gang; still there were too many men for the machine, so this gang was reduced to 21 men, not including two foremen, distributed as follows: One foreman attended to everything in general, while the other was raising track. There were two men at the jacks, four men putting in new ties and putting on tie plates, five men putting ballast under ties and shovel tamping to hold the track up ahead of the automatic tampers, then eight men followed, gaging all ties, then two men with the automatic tampers, and one man who forked up the stone into the track for the tampers and dressed up ballast. With this organization, it is possible to keep the automatic tampers continuously at work on the track tamping ties.

Under these conditions, 30 ties per hour were tamped, which included tamping the tie outside of the rail after being shovel-tamped, tamping under the rail and inside of the rail 16 in.

The actual cost of tamping per tie, during a nine-hour day, was as follows:

2 men 8 hours per day, 16 hours	17 cents	$2.72
1½ gallons gasoline per hour, 12 gallons	12 cents	1.44
½ pint engine oil, per 8 gallons gasoline, ¾ pint	5 cents	.04
½ pint compressor oil, ½ pint	5 cents	.03
Actual cost tamping ties per day		$4.23
240 ties tamped, $.0177 per tie.		
Total cost, including time the men spent going to and coming from work		.53
		$4.76

240 ties tamped, $0.02 per tie.

The cost of tamping ties with automatic tampers as compared with the cost of tamping by hand, not including foremen, is as follows:

By Hand.

Gang of 40 men, $1.53 per day		$ 61.20
They complete a mile in 9 days		$550.80

By Machine.

Gang of 21 men, $1.53 per day	$32.13	
They complete a mile in 13 days		$417.69
Saving per mile		$133.11

By Hand.

Cost of tamping a tie full	$.065

By Machine.

Cost of tamping a tie full	.02
Difference per tie	$.045
One mile of 3,200 ties	$144.00

TEST NO. 3.

In this test the automatic tampers were assigned to a regular section gang on the main line while spacing ties in a high-speed track. A gang of ten men were employed in the following manner: The stone was first removed from between the ties to within 1½ in. of the bottom of the tie for a distance covering a week's work for the gang. The foreman and six men then raised the track and spaced the ties, put in any new ones required, and put on tie plates, gaged and surfaced the track. These men were followed by three men with the automatic tie tampers who tamped every tie, and backfilled track. The ties were tamped outside of the rail and as far under the rail as the tampers would tamp the ballast. The ties inside of the rail were spade-tamped. Using this method, the daily average was 15 rails, but on account of the automatic tamper being used in a regular section gang, the machine was in use only five days a week, one day being devoted to other section work which had to be taken care of.

In the first part of the test, a light lift was made, which did not require any spade-tamping. In the second part of the test, a lift of 3 in. was made, which required spade-tamping to hold the track up before the automatic tamping machines were used.

The results of Test 3 were as follows:

First Part.

Foreman's supervision, 3 hours	$0.23	$0.69
3 men 9 hours per day, 27 hours	.17	4.59
1 1-9 gallons gasoline per hour, 10 gallons	.12	1.20
2-9 pint engine oil per hour, 2 pints	.05	.10
½ pint compressor oil, ½ pint	.05	.03
Actual cost tamping ties per day		$6.61
300 ties tamped, per tie	$.022	
Total cost, including time of men spent going to and coming from toolhouse		.51
		$7.12
Ties tamped, 300; cost per tie	$.0237	

Tamping by Hand compared with the Automatic Tampers:

By Hand.

Gang 10 men and foreman per day	$ 19.80
Tamp mile in 13⅓ days	$264.00

By Machine.

Gang 3 men and supervision and supplies	$ 7.12
Tamp mile in 10⅔ days	$ 75.95
Difference in favor of machine tamped track, per mile	$188.05

Second Part.

Cost of Tamping Ties, including Spade Tamping and Overhead Charges:

Foreman's supervision, 3 hours	$0.23	$0.69
3 men 9 hours per day, 27 hours	.17	4.59
1 1-9 gallons gasoline per hour, 10 gallons	.12	1.20
2-9 pint engine oil per hour, 2 pints	.05	.10
½ pint compressor oil, ½ pint	.05	.03
Overhead charges (including repairs)		1.80
3 men 2 hours per day spade-tamping, 6 hours	.17	1.02
Cost per day		$9.43
Ties tamped, 300; cost per tie	$.0314	
Total cost, including time crew spent going to and and coming from toolhouse		.51
		$9.94
Ties tamped, 300; cost per tie	$.0331	

Tamping by Hand compared with the Automatic Tampers:

By Hand.

Gang of 10 men and foreman per day	$ 19.80
Tamp 1 mile in 13⅓ days	$264.00

By Machine (including repairs).

Gang 3 men (supervision, supplies and repairs)	$ 9.94
Tamp mile in 10⅔ days	$106.03
Difference in favor of machine-tamped track, per mile	$157.97

TEST NO. 4.

The machine was assigned in this test to a regular section gang on the high-speed tracks of the River Division. The work consisted of spacing ties, surfacing and dressing track. In this test the track was raised quite uniformly 2 in. out of face. For this particular work it was found possible and advisable to reduce the regular section gang one man. The work done by hand with which the above is compared was of a similar nature prosecuted at the same time on the same subdivision. The comparative results were as follows:

By Hand.

Labor (1 foreman and 6 men)		$652.88
Feet of track surfaced	11,530	
Cost per foot surfaced	.0566	
Cost per mile surfaced	298.85	

By Machine.

Labor (1 foreman and 5 men)		$375.75
Gasoline (635 gallons, .12)		76.20
Engine oil (124 pints, .05)		6.20
Compressor oil (30 pints, .05)		1.50
Cup grease (19 lbs., .08)		1.52
		$461.17
Feet track surfaced	13,817	
Cost per foot surfaced	$.0334	
Cost per mile surfaced	176.35	
Cost per mile surfaced—by hand		$298.85
Cost per mile surfaced—by machine		176.35
Difference in favor of machine		$122.50
Average number of ties tamped by hand per day of 10 hours		134
Completing one mile in 24 days.		
Average number of ties tamped by machine per day of 10 hours		238
Completing 1 mile in 13½ days.		
Average cost of surfacing per tie:		
By hand		$.0935
By machine		.0551
Difference in favor of machine work		$.0384
Overhead charges and repairs		.006
Final difference in favor of machine		$.0324

TEST NO. 5.

The electric tampers were used in this test. The outfit was assigned to a regular Main Line gang, which was engaged in final surfacing after the track had been previously raised 12 in., but not yet put into service. The force was organized as follows: One foreman who looked after the work in general, four men doing the tamping (two being required to handle each tamper), and one man digging out stone, feeding ballast to the tampers, dressing up track, etc.

The ties were tamped under the rail, a distance of 16 in. outside and 8 in. inside the rail. The test was made late in the winter season and some of the work done under unfavorable weather conditions. Notwithstanding this, an average of 27 ties tamped per hour was maintained.

The result of the test was as follows:

Foreman, 8 hours	$0.26	$ 2.08
5 men, 8 hours each, 40 hours	.17	6.80
Gasoline, 4 gallons	.12	.48
Engine oil, ⅔ pint	.05	.03
Total cost per day		$ 9.39
216 ties tamped, per tie	$.043	
Time of crew going to and from work		1.11
Total		$10.50
216 ties tamped, per tie	$.049	
Results compared with cost of Hand Work:		
By Hand.		
1 foreman and 6 men, cost per day		$ 11.52
Tamped 1 mile in 26 days		$299.52
By Machine.		
1 foreman and 5 men and supplies per day		$ 10.50
Tamped 1 mile in 15 days		$157.50
By hand		$299.52
By machine		157.50
Difference in favor of machine-tamped track, per mile		$142.02
Cost of tamping per tie:		
By hand		$.094
By machine		.049
Difference		$.045

The comparative stability of the track tamped by hand as compared with the track tamped by the automatic tamper is as follows: At Granton station on the West Shore Railroad in June, 1913, about 800 ft. on the eastbound track was tamped by hand and 800 ft. was tamped by the pneumatic tamper. This track is over the Hackensack Meadows, where the foundation was soft, and for that reason it was not an ideal place for an experiment. This was the only place, however, where air was available at that time on account of the portable compressor not being completed. The results from the tests in feet after six months had elapsed from the time track was tamped were as follows:

Greatest Settlement		Least Settlement		Average Settlement	
Hand	Machine	Hand	Machine	Hand	Machine
.116	.063	.018	.004	.067	.033

With the automatic tampers it is not absolutely necessary to clean the ballast out to the bottom of the tie, as is necessary when tamping by hand, as the tampers will work down through the ballast.

The use of the pneumatic tampers will not always enable one to reduce the number of men on sections, as the track cannot be lined to good advantage with less than six men. When this number of men or less are employed, the advantage resulting from the use of the tampers lies in the relief to the section gang from the work that they now do in tamping ties. This would enable them to devote an additional amount of time to ditching, changing out curve-worn rails, and work of that character that is now done by floating gangs to a great extent. The use of the tampers will also result in giving better riding track.

Results Obtained from the Operation of Twelve Pneumatic Tamping Outfits on the N. Y. C. R. R. During the Year 1914.

Sub-Division	Period of Observations	Days Operated	Hours Operated	Ties Tamped	Single Track Covered, Feet	Gasoline Used, Gallons	Gas Engine Oil Used, Pints	Compressor Oil Used, Pints
3	Aug. 30-Nov. 18	47	284.5	5,974	9,926	453	89.0	19.8
3A	Jul. 29-Nov. 16	57	364	6,734	16,537	503	60.8	25.0
4	Aug. 26-Nov. 21	36	317	6,180	10,194	375	69.0	35.5
5	Aug. 3-Oct. 3	40	295	6,999	13,190	404	86.3	23.0
6	Aug. 4-Oct. 23	46	382	12,148	20,102	501	86.0	43.0
7	Aug. 10-Oct. 19	50	333	8,864	19,225	527	105.0	40.0
10	Aug. 14-Oct. 24	39	307	9.590	15,815	356	51.0	73.0
11	Aug. 17-Oct. 28	32	249	6,040	9,954	362.5	73.0	18.4
23	Aug. 18-Oct. 29	31	204	7,738	12,383	275	54.8	16.0
21	Aug. 17-Oct. 31	30	191	2,880	5,154	167	26.5	14.7
20	Sept. 1-Nov. 16	41	209	5.312	8,770	371.5	74.4	13.2
25 & 27	Jul. 27-Sept. 12	20	112	4,539	7,328	170.5	12.5	7.25
Total	....	469	3,247.5	82,998	148,578	4,465.5	788.3	328.85

Averages.

Hours per day	7.0
Ties tamped per day	177
Ties tamped per hour	26
Single track covered per day	316.8 ft.
Single track covered per hour	45.7 ft.
Gasoline used per hour	1.37 gal.
Gas engine oil used per hour	0.24 pt.
Compressor oil used per hour	0.10 pt.

OPERATION.

COMPRESSOR AND GENERATOR.

Don't attempt to start the motor when the spark is in the early position.

Don't attempt to run without water, oil and gasoline. Lack of either water or oil will quickly ruin the engine.

Don't spend a lot of time cranking the engine if it fails to start after a few turns. Look for the cause of the trouble.

Don't make adjustments unless you know you are right.

Don't forget to drain water in cold weather.

Don't allow a man to tinker with, or to stand around and watch the engine running, as this only increases the cost of the work, and if the motor is properly cared for it does not require this attention.

Last, but not least, use common-sense at all times.

AUTOMATIC TAMPER.

When being used, if the person using the tamper is right-handed, he should take hold of the lower handle with the left hand and the upper handle with the right hand. Using the lower handle as a fulcrum, the tamper can be placed at any angle desired for the purpose of tamping ballast under the tie. If the person using the tamper is left-handed, he should do just the opposite. When tamping, a man should stand, if right-handed, with his left foot on the first tie back of the tie to be tamped; his right foot should be placed on the second tie back, and in such position that if a tamping bar should break, the tamper would not fall against his right foot and injure it.

PLATE 11.

With the tamper held in the proper position, it should be shoved quickly down against the ballast which it is desired to tamp under the tie and held against it with sufficient pressure to keep the tamping bar in position to receive full effect of the blow from the plunger.

The automatic tampers should be moved back and forth along that portion of the tie to be tamped until it is thoroughly tamped. The automatic tampers should not be held in one place any longer than is necessary to thoroughly tamp the tie, as otherwise time will be wasted and ballast crushed.

Ties should be tamped from the rail to the extreme end of the tie on the outside and for a distance from 6 to 12 in. on the inside and under the rail. Ordinarily a tie can be tamped by starting to tamp at the rail, tamping in under the rail as far as can be reached from the outside, and working toward the outside end. If so desired, the tie can be tamped by starting at the outer end of the tie and working toward the center, 12 in. inside of the rail or vice versa. In tamping ties with the automatic tamper, both sides of the tie should be tamped at the same time, and tampers worked opposite each other.

In using the automatic tampers ordinarily, the ties should be tamped after the track has been raised.

When track is in good surface and level and not centerbound, the ties should be spotted in the track, without a lift, and then tamped solid with the automatic tamper.

When surfacing, or making a light lift and ballast is dressed to standard, it should be loosened up and a portion thrown out before ties are tamped. If lifting 1½ in. or more, this is not necessary.

The best methods of procedure formulated from two years' experience with the Automatic Tie Tamper are as follows:

In spotting in ties without raising track, ties should be put in the track and then followed up with the tamper. The foreman of the gang should have general supervision, follow up the routine of the work and protect the men handling the tampers, the noise of which prevents them from hearing the approaching trains.

Force required:—Six men digging out and installing ties.
Two men tamping with automatic tamper.
One foreman supervising the work.

When using the automatic tampers on regular section work, every fourth or fifth tie should be lightly tamped to line and surface and then follow up with the automatic tampers and back-fill, the foreman sighting track and having general supervision of the work.

Force required:—One man with track jack picking up track.
One man forking stone to tampers and back-filling and dressing up.
Two men tamping with automatic tamper.
One foreman sighting track and supervising work.

Before using the tie tampers when putting in ties and raising track, track should be raised, and ties put in and spade-tamped to proper surface in the usual manner, then follow up with the automatic tampers and tamp all ties, after which have gang back-fill and complete the work.

Force required:—Seven men to raise track, install ties, tie plating, gaging and lining track.
Two men tamping with automatic tampers.
One man forking stone to tampers and changing off on tampers if necessary.
One foreman raising and lining track and supervising work.

Before using automatic tie tampers when placing ties, raising track, etc., under new rail, track should be raised, ties renewed where necessary and spade-tamped in the usual manner, and track properly surfaced, then follow up with the automatic tampers and tâmp all ties. We find in doing work of this character, that the work can be expedited by digging out within 1 in. of the bottom of the ties before raising. After track has been spaced and surfaced it is necessary to line and finish the track with the whole gang.

Force required:—Seven men raising track, installing ties, spacing ties, tie plating, gaging and lining track.
Two men tamping ties with automatic tie tamper.
One man forking in stone to tampers and changing off on tampers and back-filling.
One foreman raising and lining track and supervising work.

The above methods cover the operation of one Automatic Tie Tamper Unit. If two units are employed, the force of men should be increased accordingly. However, for large gangs it is possible to obtain a double unit of four, instead of two, automatic tampers.

RISE AND FALL: FUEL AND TIME.

By C. P. Howard, Consulting Engineer.

The Committee on Economics of Railway Location of the American Railway Engineering Association have assembled and presented to the Association a considerable amount of data for the solution of the various problems of grades, including rise and fall, fuel and time. Information as to fuel used in firing up, drifting and standing, has been furnished by A. K. Shurtleff, former Chairman of the Committee, in his article on "Locomotive Fuel Consumption and the Speed Diagram," in Bulletin 148, August, 1912. This serves to make the information in the hands of the Association fairly complete.

This data has been used in the following investigation to determine the variations in time and fuel due to rise and fall, the object being to find, if possible, some handy method of estimating these values, which, for use of the man in the field, should be simple of application, and more accurate than methods heretofore in use.

Many variables enter into calculations as to power and performance of locomotives. Definite values must be taken for some of these variables, and in order to make the results most widely applicable, average conditions must generally be assumed.

The average weight of a freight car in the United States, including load, is about 32 tons; for which the resistance by American Railway Engineering Association formula is 6 lbs. per ton. The typical locomotive first considered in this paper is a consolidation using saturated steam (see Mr. Shurtleff's article, page 8, Part 2, Vol. 14, Proceedings, American Railway Engineering Association, 1913):

Cylinders, 22 by 30 in.
Drivers, 63 in.
Heating surface, 3,300 sq. ft.
Boiler pressure, 200 lbs.
Weight (including tender), 173 tons.

Coal is estimated at 11,000 B. t. u.; consumption, working, 4,000 lbs. per hour; drifting, 789 lbs. per hour (column 4 of table, page 6, Part 2, Vol. 14, Proceedings, American Railway Engineering Association, 1913). Curves of horsepower and tractive power for different speeds calculated from the Manual are shown in Fig. 2.

Table 1 was calculated for this engine loaded for the following maintained speeds on ruling grades:

Ruling grade 1.5 per cent............	5 miles per hour
Ruling grade 1.25 per cent............	5 miles per hour
Ruling grade 1.0 per cent............	5 miles per hour
Ruling grade 0.8 per cent............	5.5 miles per hour
Ruling grade 0.6 per cent............	6.0 miles per hour
Ruling grade 0.4 per cent............	7.0 miles per hour
Ruling grade 0.3 per cent............	7.5 miles per hour

Five miles per hour is the maximum calculated speed at which this engine can supply steam at full cut-off, with the given quantity and quality of coal. It is assumed that for the light trains necessary on heavy grades of 1.0 per cent. and over there will be enough lighter gradients on the rest of the division for the engine to make up time, and permit the use of this low speed on the ruling grade.

As will be further noted, this table may be used for lighter loading and higher speeds. Other conditions being known, the speed, S_2 to be maintained on the ruling grade (S in Fig. 1) determines the weight of train;

$$w = \frac{P_2 - 20\,EG_2}{r + 20\,G_2} \dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where w = weight of train behind tender in tons (2,000 lbs.).

P_2 = available drawbar pull on a level grade at S_2 speed = cylinder tractive power less engine resistance, and must be taken from a table.

G_2 = per cent. of ruling grade (G in Fig. 1).

E = weight of engine and tender in tons.

r = resistance in lbs. per ton of train behind tender.

When the train starts down a grade (see Fig. 1), it will increase its velocity to a speed considered reasonably safe, and hold it to the foot of the grade. This speed may vary considerably, but to simplify calculations, and as conforming reasonably close to good practice, the maximum speed (S_1) attainable on a level grade for the given train is here taken as the limiting speed on descending grades. The same speed (S_1) may then be taken as speed of approach at (a) in Fig. 1, whether the train approaches from a level or descending grade.

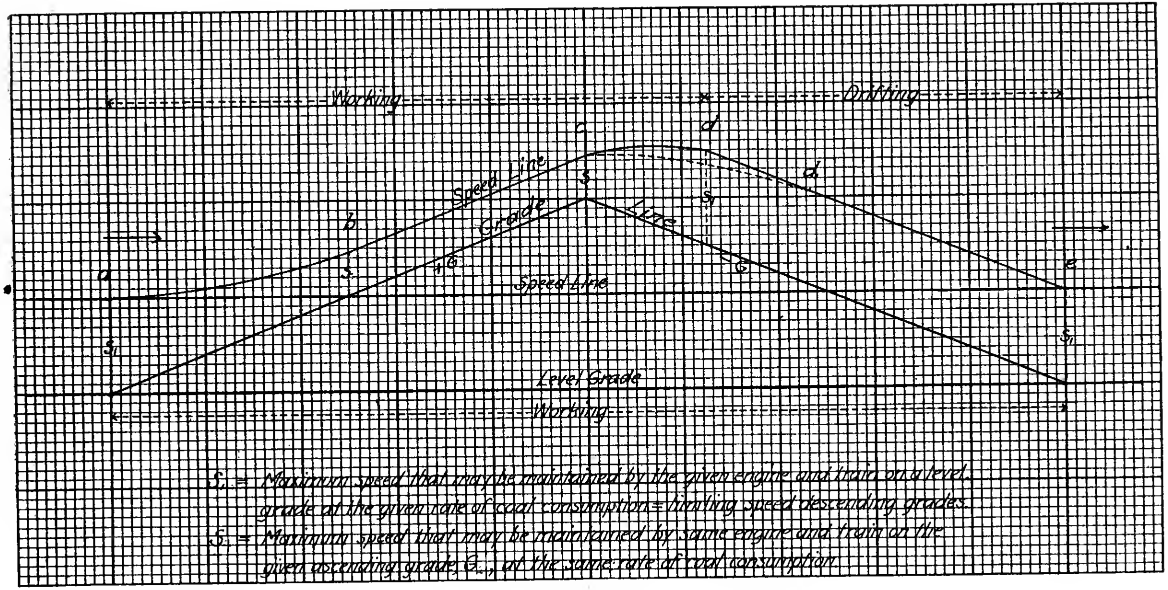
The speed line shown in Fig. 1 is an approximation of average conditions, and greatly simplifies the calculations. With the same speed on the down grade from (d) to (e) as on the level grade, there is no difference in time and, if the grade is steeper than the grade of equilibrium, the saving in fuel consumption is the time from (d) to (e) multiplied by the difference in rate of consumption for the engine working and drifting.

From (a) to (d) the increase in fuel is the difference in time multiplied by the rate of fuel consumption for the engine working. If 1 ft. is added to the height of the hill, the portions of the speed line, ab and cd, will remain unchanged, while bc and de are increased in length.

Let n = time in minutes to travel 100 ft. at S speed $= \frac{1.136}{S}$

Let n_1 = time in minutes to travel 100 ft. at S_1 speed $= \frac{1.136}{S_1}$

Where S and S_1 refer to speed in miles per hour on a given ascending grade and a level grade.



S_1 = Maximum speed that may be maintained by the given engine and train on a level grade at the given rate of coal consumption = limiting speed descending grades.

S = Maximum speed that may be maintained by same engine and train on the given ascending grade, G_+, at the same rate of coal consumption.

FIG. 1.

Then increase of time in minutes, m, due to 1-ft. rise above the point, b (Fig. 1), where momentum gives out is:

$$m = \frac{n - n_1}{G} \quad \text{..........................} \quad (2)$$

where G = per cent. of the given grade.

That is, the increase of time in minutes per foot of rise is the difference between the time required to travel 100 ft. at maintained speed on the given grade and a level grade divided by the per cent. of grade.

The increase of time in hours, M, due to 1 ft. of rise, calculated for 1,000,000 gross tons of 2,000 lbs. (trains plus engines) is:

$$M = km \quad \text{..........................} \quad (3)$$

where $k = \frac{16,667}{W}$, and W = weight of train including engine.

The increase in pounds of coal, c, due to 1 ft. of rise above the limit of momentum is:

$$c = fm \quad \text{..........................} \quad (4)$$

where f = coal consumption in lbs. per minute for engine working.

The tons of coal, C, for 1,000,000 gross tons (trains plus engines) due to 1 ft. of rise is:

$$C = k_1c \quad \text{..........................} \quad (5)$$

$$\text{where } k_1 = \frac{500}{W}$$

For this engine and data the limiting speed (S_1) and weight of train behind the tender are as follows:

Ruling Grade (G_2)	Train Weight (w)	Speed (S_1)
0.3 per cent.	2,360	18.9
0.4 per cent.	2,083	20.8
0.6 per cent.	1,735	23.7
0.8 per cent.	1,461	26.6
1.0 per cent.	1,275	29.1
1.25 per cent.	1,042	33.0
1.50 per cent.	873	36.7

The speed for 0.3 per cent. and 0.4 per cent. ruling grades may seem rather low for the train going down hill, but on the former the train will not drift at all; taking into consideration the resistance of engine. As a matter of fact on a — 0.4 per cent. grade the resistances at 20.8 miles per hour will just about balance the acceleration of the grade on a 1-degree curve, if we take results of tests by Prof. E. C. Schmidt, of the University of Illinois.

The speeds on the 0.6, 0.8 and 1.0 per cent. grades come well within the limits of good practice.

The permissible speed for train loaded for 1.5 per cent. grade may be rather high, as figured by this rule; but the train is light and it makes for uniformity in calculating to apply the same rule to all grades. Moreover, tables for the higher ruling grades can be used for light loading and higher speeds on the lower ruling gradients.

The time on the descending grade being the same as that on the level grade with which it is compared, the lbs. of fuel saved, c_1, for 1 ft.

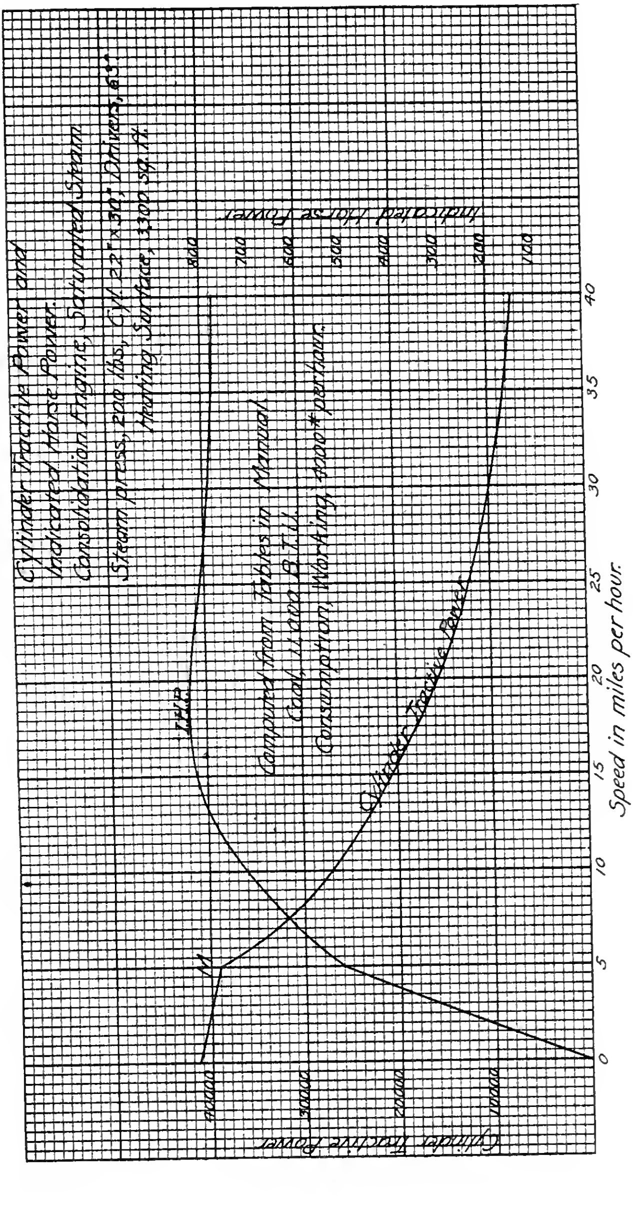

Cylinder Tractive Power and
Indicated Horse Power.
Consolidation Engine, Saturated Steam
Steam press. 200 lbs., Cyl. 22" × 30", Drivers, 63"
Heating Surface, 3300 sq. ft.
Computed from Tables in Manual
Coal, 11,000 B.T.U.
Consumption, Working, 4000# per hour.
Indicated Horse Power
800
700
600
500
400
300
200
100
I.H.P.
Cylinder Tractive Power
Cylinder Tractive Power
40000
30000
20000
10000
0
5
10
15
20
25
30
35
40
Speed in miles per hour.

FIG. 2.

of fall, on any grade, G, steep enough for train to drift at S_1 speed is the time of descent in minutes, $\frac{n_1}{G}$, multiplied by the difference, $f - f_1$, between the fuel consumption per minute of the engine working and drifting; the latter being obtained from Mr. Shurtleff's table (page 6, Part 2, Vol. 14, Proceedings, American Railway Engineering Association, 1913):

$$c_1 = \frac{(f - f_1)\, n_1}{G} \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

When the given grade is so light that the engine cannot maintain speed drifting, but must work part of the time, the engine may be considered, as an approximation, to be alternately working and drifting for short periods, so as to preserve the same average speed of descent. There will be no saving in fuel when working. For the portion of time when the engine is drifting, the saving in fuel is the same rate $(f - f_1)$ as for steeper grades. The total time for 1 ft. of fall is as above, $\frac{n_1}{G}$. To get the proportion of time drifting, we multiply this by $\frac{20\,G}{r_1}$, that is, the accelerating force divided by resistance, where $r_1 =$ total resistance of engine and train at the given speed in lbs. divided by total weight, W, in tons. Therefore, the proportion of time drifting is $\frac{20\,n_1}{r_1}$, and saving in fuel per foot of fall is:

$$c_1 = \frac{20\,n_1 (f - f_1)}{r_1} \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Similarly to equation (5), the saving in coal, for 1,000,000 gross train tons, due to 1 ft. of fall is:

$$C_1 = k_1\, c_1 \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

where $k_1 = \frac{500}{W}$, as in equation (5), and c_1 is to be taken from equation (6) or (7) according, as the given grade is heavier or lighter than the grade of equilibrium.

Table 1 has been calculated from equations (3), (5) and (8), and shows the difference in time and fuel consumption due to 1 ft. of rise or fall, or both combined, beyond the limits of momentum on various ruling and minor gradients for an engine using saturated steam.

It will be noticed that there is much less saving in fuel on ruling than on minor descending gradients—increasing down to the grade of equilibrium, $G = \frac{r_1}{20}$, where the resistance just equals the accelerating force. For any lighter gradients the saving per foot of fall, as above noted, may be taken as approximately the same.

This is readily explained by the fact that on steep grades a large part of the stored energy of the train is destroyed by the brakes. Where

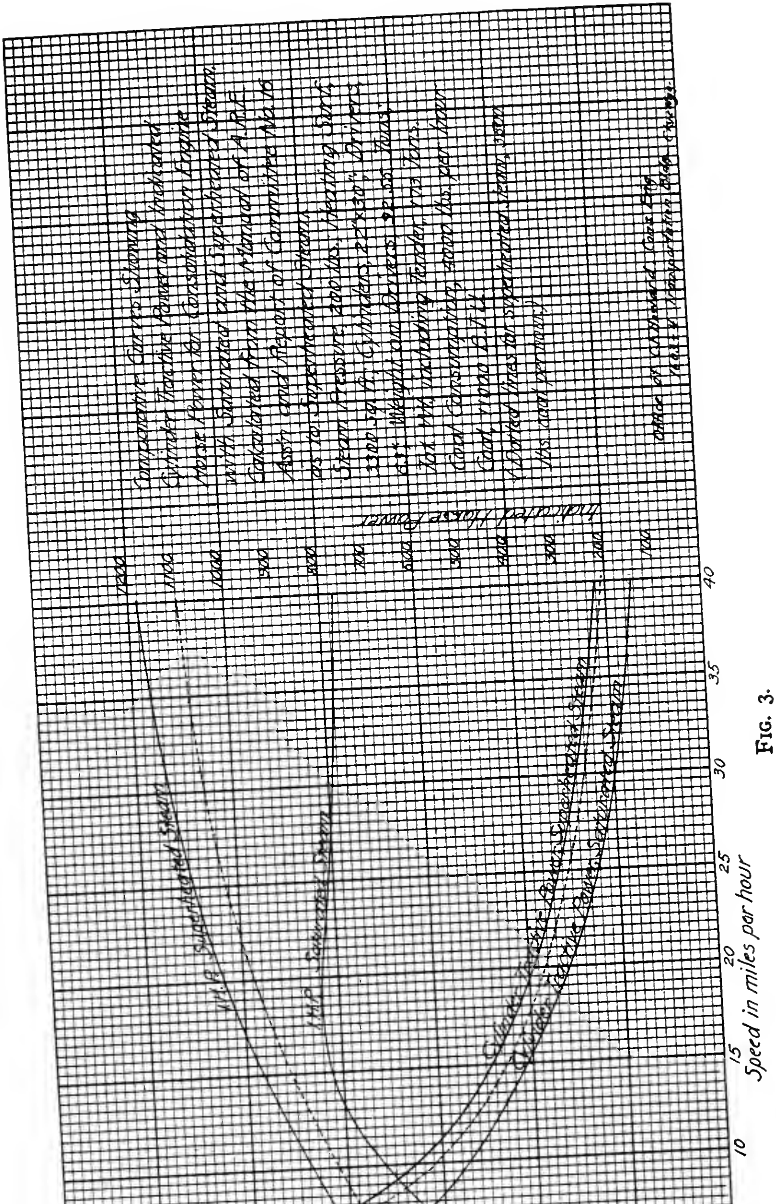

Comparative Curves Showing
Cylinder Tractive Power and Indicated
Horse Power for Consolidation Engine
with Saturated and Superheated Steam.
Calculated from the Manual of A.R.E.
Assn and Report of Committee No. 16
as to Superheated Steam
Steam Pressure 200 lbs. Heating Surf.
3300 sq. ft. Cylinders 22"x30". Drivers
63" Weight on Drivers 92.55 Tons.
Tot. Wt. including Tender 173 Tons.
Coal Consumption 7000 lbs. per hour
Coal 11000 B.T.U.
(Dotted lines for superheated steam, 5800
lbs coal per hour)
Office of [illegible] Cons Eng
1033 Transportation Bldg Chicago
Indicated Horse Power
1200
1100
1000
900
800
700
600
500
400
300
200
100
Cylinder Tractive Power
40000
30000
20000
10000
I.H.P. Superheated Steam
I.H.P. Saturated Steam
Cylinder Tractive Power Superheated Steam
Cylinder Tractive Power Saturated Steam
0
5
10
15
20
25
30
35
40
Speed in miles per hour

FIG. 3.

brakes are not used the full amount of this energy is utilized and represents a saving in fuel.

Trains in each direction should be considered separately. Curvature adds to rise and deducts from fall an amount equal to the proper compensation.

Columns 6 and 7 of Table 1 show the increase in time and fuel due to 1 ft. of rise at maintained speed on various ruling and minor gradients for the given conditions as to power, loading, fuel, etc. Column 8 shows the decrease in fuel for 1 ft. of fall.

If a suitable deduction is made for the saving due to momentum, this or a similar table may be used as a rapid method of approximating the loss of time and fuel due to any height of rise or fall. Momentum may be expressed in terms of velocity head. The saving due to momentum corresponds to the difference in velocity head, modified by the variation in the horsepower of the engine, and the slight variation in head-end resistance.

Neglecting these modifications, we may find the equivalent net rise or fall, by correcting for the difference in velocity head due to change in speed. For instance, if a train approaches an ascending grade at a speed of 30 miles an hour and gradually reduces to a maintained speed of 8 miles per hour, we may deduct from the rise a vertical height of $h_1 - h_2 = 29.3$ feet., where

$h_1 =$ velocity head at 30 miles per hour $= 31.5$ ft.
$h_2 =$ velocity head at 8 miles per hour $= 2.2$ ft.

Column 10 of Table 1 gives these deductions, equivalent to the difference in velocity head for the speeds shown.

The use of the table, however, is not confined to the speeds shown. It is only necessary to correct for the actual difference in velocity heads by the formula:

$$H_1 = H - h_1 + h_2 \quad \text{.......................} \quad (9)$$

where $H =$ rise or fall (plus sign for rise and minus for fall).
$h_1 =$ velocity head at speed of approach.
$h_2 =$ velocity head at maintained or final speed on the grade.
$H_1 =$ equivalent net rise or fall (plus for rise, and minus for fall).

H_1 should never be minus for a rising grade, and if the grade is so short and the final speed that can be maintained on the grade, corresponding to h_2, is so small as to make H_1 minus, then the rise is not sufficient to use up the difference in momentum, and equation (9) should be solved for a proper value of h_2. This is done by making $H_1 = O$ and solving for h_2, or

$$h_2 = h_1 - H \quad \text{........................} \quad (10)$$

This will indicate the final speed on the given grade (corresponding to the velocity head of h_2) and the initial speed on the next grade.

Similarly H_1 should generally be minus on a descending grade. If the limiting speed is so great or the length of grade so short as to make H_1 plus, then the final speed may be taken corresponding to h_2 in equation (10).

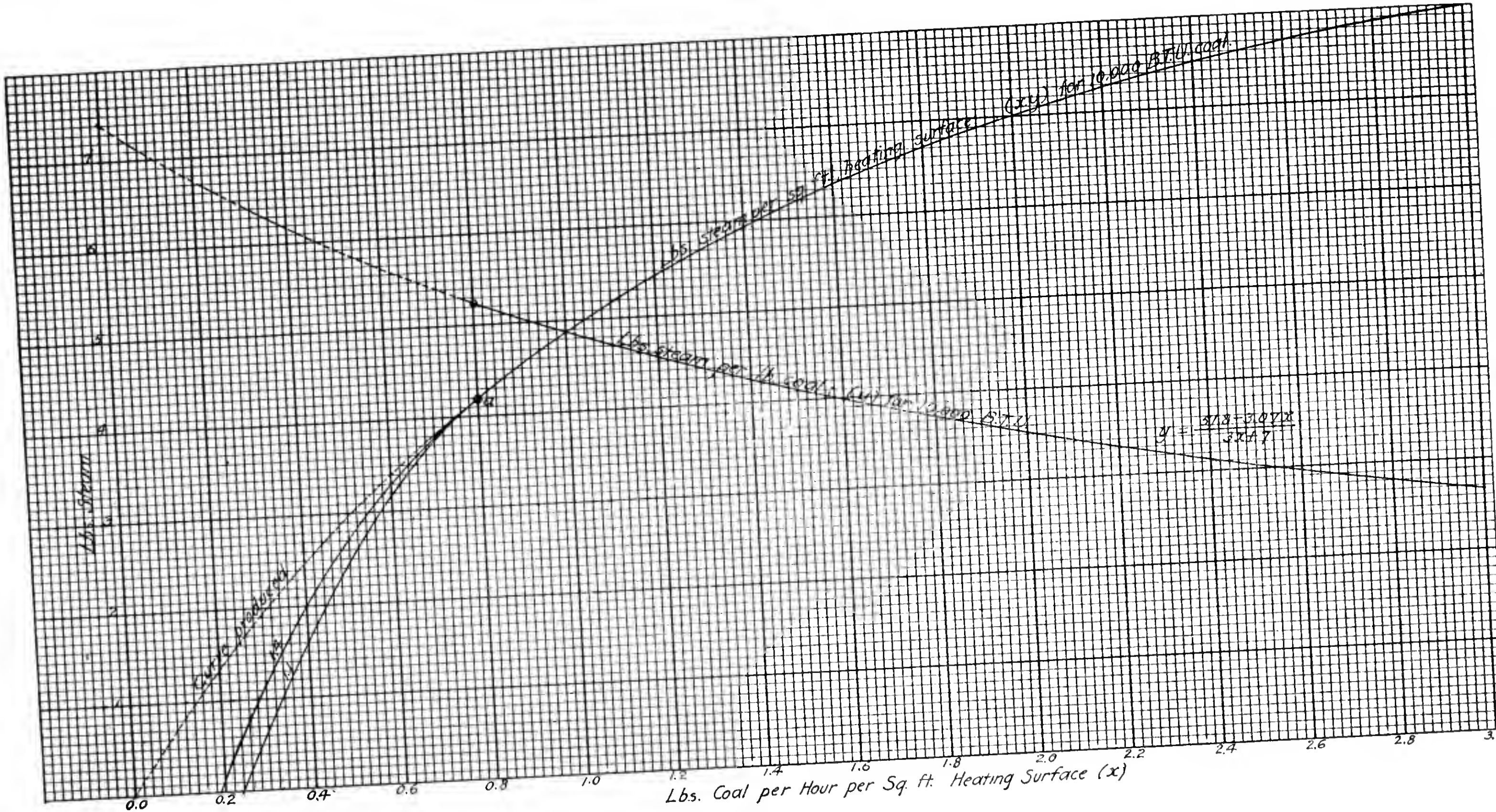

Lbs. steam per sq. ft. heating surface (xy) for 10,000 B.T.U. coal.
Lbs. steam per lb. coal. (y) for 10,000 B.T.U.
y = 31.8-3.07x / 3x+7
a
Curve produced
Lbs. Steam
7
6
5
4
3
2
1
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
Lbs. Coal per Hour per Sq. ft. Heating Surface (x)

FIG. 4.

Table 2 was calculated for superheated steam at 3,500 lbs. coal per hour. It will be noted that the limiting speed on level and descending grades shown in column (S_1) is very high for ordinary freight trains when the ruling grade is 1.0 per cent. or higher.

Table 2a is the same as Table 2, except that the speed is limited to 35 miles per hour on all grades wherever the ruling grade is 1.0 per cent. or more. A train loaded for 0.8 per cent., as shown, would maintain a speed of 35¼ miles per hour on a level grade. This being near the limit, no change was made, and the figures for lower ruling gradients are the same as in Table 2.

While Table 2a is perhaps an improvement on No. 2 for ordinary conditions, it requires considerably more work in the computations. The engine loaded for a 1.5 per cent. ruling grade could maintain a speed of 50.1 miles per hour on a level grade and 36⅔ M. P. H. on a +0.15 per cent. grade, burning 3,500 lbs. coal per hour.

It is necessary to calculate backwards to find the rate of consumption necessary to maintain 35 miles per hour on these grades. It was found that to maintain 35 miles per hour on level and light gradients with trains loaded for heavy ruling grades, as in Table 2a, the following rate of firing would be necessary:

Ruling Grade	Actual Grade	Coal Per Hour
1.5 per cent.	Level	2,097
1.5 per cent.	+0.15 per cent.	3,250
1.25 per cent.	Level	2,366
1.25 per cent.	+0.10 per cent.	3,409
1.0 per cent.	Level	2,897

Of the three tables for general use the writer is inclined to favor Table 2a, superheated steam and restricted speed. The tons of coal per foot of rise, column (C), does not show the wide variations of Table 1, saturated steam. For this quality of coal, 11,000 B. t. u., these values in Table 2a are fairly constant at 2.5 to 2.6 tons coal on ruling grades, running down as low as two tons on a few of the minor gradients, or say an average of 2.4 tons.

Table 2b, similar to Table 2a, is calculated for 14,000 B. t. u. coal. The tons of coal per foot of rise, column (C), is fairly constant at 1.9 to 2 tons on ruling grades, and very little less on minor grades, except where the ruling grade exceeds 1 per cent.

Superheated Steam.—Fig. 3 shows curves of tractive power and horsepower for a similar engine using superheated steam with the same coal and rate of consumption per hour. The heating surface, exclusive of superheating surface is the same, and as to weights, cylinders, drivers, etc., the data is that of the engine using saturated steam. These curves are calculated from the 1915 report of the Committee on Economics of Railway Location. For comparison the curves for saturated steam are reproduced from Fig. 2. The dotted lines show curves for superheated steam using 3,500 lbs. coal per hour.

TABLE 1--Showing Variation in Time and Fuel per Foot of Rise or Fall, or of Rise and Fall Combined; Momentum Excluded. Computed for 1,000,000 Train Tons, including Engine Weights. Car Resistance, 6 lbs. per ton (based on Consolidation Engine, Saturated Steam; Heating Surface, 3000 sq. ft.; Steam Pressure, 200 lbs.; Cylinder, 22X30": Drivers, 63"; Weight, including Tender, 173 Tons; Coal, 11,000 B.t.u.; Consumption--Working, 4000 lbs.; Drifting, 783 lbs.per hour.)

Ruling Grade Percent (G_2)	Actual Grade Percent (G)	Weight of Train behind Tender (w)	Maintained Speed in M.P.H.		Increase for One Foot Rise		Decrease in Coal for 1 ft Fall Tons (C)	Incr. in Coal for 1ft Rise & Fall Tns $(C-C_1)$	Feet of Rise and Fall excluded $(h_1 - h_2)$
			Level Grade (S_1)	On (G) (S)	Time-Hours (M)	Coal-Tons (C)			
1.50	1.50	873	36.67	6.00	2.08	4.17	0.53	3.64	46
	1.25			6.69	1.77	3.53	0.63	2.90	45
	1.00			9.07	1.50	3.00	0.79	2.21	44
	0.75			12.72	1.24	2.47	1.06	1.41	41
	0.50			17.29	1.11	2.21	1.58	0.63	37
	0.25			23.59	1.10	2.19	2.09	0.10	28
	0.15			27.40	1.10	2.21	2.09	0.12	21
1.25	1.25	1042	33.01	5.00	2.12	4.24	0.61	3.63	37
	1.10			6.11	1.89	3.77	0.69	3.08	37
	0.90			8.05	1.62	3.24	0.84	2.40	36
	0.70			10.96	1.36	2.71	1.08	1.63	34
	0.60			14.80	1.16	2.32	1.51	0.81	30
	0.30			19.58	1.08	2.16	2.07	0.08	25
	0.10			26.77	1.10	2.19	2.07	0.12	13
1.00	1.00	1275	29.10	5.00	2.17	4.34	0.72	3.62	29
	0.90			5.88	1.97	3.95	0.80	3.15	28
	0.80			6.90	1.81	3.62	0.90	2.72	28
	0.70			8.16	1.66	3.30	1.03	2.27	27
	0.60			9.78	1.48	2.96	1.20	1.76	26
	0.50			11.80	1.32	2.64	1.44	1.20	25
	0.40			14.08	1.20	2.40	1.80	0.60	23
	0.30			16.66	1.12	2.24	2.04	0.20	20
	0.20			19.70	1.07	2.16	2.04	0.11	16
	0.10			23.49	1.07	2.16	2.04	0.11	10
0.80	0.80	1461	26.61	5.50	2.09	4.18	0.87	3.31	24
	0.70			6.60	1.88	3.76	1.00	2.76	23
	0.60			7.94	1.70	3.40	1.16	2.24	23
	0.50			9.73	1.61	3.02	1.40	1.62	21
	0.40			12.02	1.32	2.63	1.75	0.88	20
	0.30			14.65	1.18	2.36	2.02	0.34	17
	0.20			17.70	1.09	2.18	2.02	0.16	14
	0.10			21.40	1.06	2.12	2.02	0.10	9
0.60	0.60	1736	23.68	6.00	2.06	4.11	1.12	2.99	18
	0.50			7.46	1.82	3.64	1.34	2.30	18
	0.40			9.38	1.60	3.19	1.68	1.51	17
	0.30			12.00	1.36	2.72	1.99	0.73	15
	0.20			15.11	1.19	2.38	1.99	0.39	12
	0.10			18.85	1.08	2.15	1.99	0.16	7
0.40	0.40	2080	20.80	7.00	1.99	3.98	1.62	2.36	13
	0.30			9.16	1.70	3.41	1.95	1.46	12
	0.20			12.26	1.40	2.81	1.95	0.86	10
	0.10			16.02	1.20	2.41	1.95	0.46	6
0.30	0.30	2360	18.90	7.60	2.01	4.01	1.93	2.08	11
	0.20			10.26	1.66	3.33	1.93	1.40	9
	0.10			14.09	1.35	2.69	1.93	0.76	6

Fuel on very light descending grades, less than the grade of equilibrium, except in Table 1, was calculated backwards from the cylinder tractive power. This calculation involves a considerable extension of tables in the Manual, as it deals in very small tractive effort and fuel consumption. It shows in some cases a saving on a —0.1 per cent. grade slightly greater than the increase on a +0.1 per cent. grade, and the accuracy of these figures is a matter of conjecture. However, the amounts and differences are very small and would not seriously affect the value of the tables as a whole.

Resistances and locomotive performance are computed for summer rating, therefore the figures in tables should be corrected for cold weather.

DETAILS OF CALCULATIONS.

The Manual process as applied to simple and four-cylinder compound engines may be formulated as follows:

The tractive power of the locomotive at the maximum speed, S_m (or "M"), at which it can maintain steam at full cut-off is given by the formula:

$$T = \frac{375\,K}{p} \quad \text{(a)}$$

Where $K = \frac{6723\,Ls}{D}$

L = stroke of piston in inches.

D = diameter drivers in inches.

s = pounds of steam per foot of stroke, taken from Table 2 of the Manual.

p = pounds of steam per I. H. P. at "M" velocity, taken from Table 4 of the Manual.

T = cylinder tractive power in lbs. at S_m speed.

Values for s and p for superheated steam (simple engines) are given in extensions of Tables 2 and 4 adopted March, 1915.

Both s and p vary with the boiler pressure, s varies as the square of the diameter of the cylinders, and equation (a) for simple engines is practically identical with the well-known formula:

$$T = \frac{0.85\,PC^2\,L}{D} \quad \text{(b)}$$

where P = boiler pressure in lbs. per square inch.

C = diameter of cylinders in inches.

If equation (a) is used involving a value of K, the speed, S_m in miles per hour may be obtained from:

$$S_m = \frac{Q}{K} \quad \text{(c)}$$

where $Q = Fy_1 = Axy_1$ = pounds steam per hour.

F = pounds coal per hour.

x = pounds coal per hour per square foot of heating surface.

A = square feet of heating surface (excluding superheating surface).

y_1 = pounds of steam per pound of coal and must be taken from Table 1 of the Manual.

TABLE 2--Showing Variation in Time and Fuel per Foot of Rise or Fall or of Rise and Fall Combined; Momentum Excluded. Computed for 1,000,000 Train Tons, including Engine Weights. Car Resistance, 6 lbs. per ton (based on Consolidation Engine, Superheated Steam; Heating Surface, excluding Superheating Surface, 3300 sq.ft.; Boiler Pressure, 200 lbs.; Cylinders, 22x30"; Drivers, 63"; Weight, including Tender, 173 Tons; Coal, 11,000 B.t.u.; Consumption--Working, 3500 lbs. per hour; Drifting, 789 lbs. per hour.)

Ruling Grade Percent	Actual Grade Percent	Weight of Train behind Tender	Maintained Speed in M.P.H.		Increase for One Foot Rise		Decrease in Coal for 1 ft Fall-Tns	Incr. in Coal for 1ft Rise &Fall Tns	Feet of Rise and Fall excluded
			Level Grade	On (G)	Time-Hours	Coal-Tons			
(G_2)	(G)	(w)	(S_1)	(S)	(M)	(C_1)	(C_1)	$(C-C_1)$	(h_1-h_2)
1.50	1.50	882	50.10	7.30	1.40	2.44	0.32	2.12	86.0
	1.25			8.75	1.35	2.37	0.39	1.98	85.2
	1.00			10.91	1.29	2.25	0.49	1.76	83.7
	0.75			14.32	1.19	2.09	0.65	1.44	80.7
	0.50			20.02	1.08	1.89	0.97	0.92	73.8
	0.25			30.22	0.94	1.65	1.51	0.14	55.9
	0.15			35.67	0.87	1.53	1.85	-0.32	40.8
1.25	1.25	1053	45.18	7.30	1.42	2.48	0.37	2.11	69.6
	1.10			8.25	1.39	2.43	0.42	2.01	69.1
	0.90			9.99	1.34	2.34	0.52	1.82	68.0
	0.70			12.60	1.26	2.21	0.65	1.55	65.9
	0.50			15.74	1.15	2.03	0.93	1.10	61.6
	0.30			23.42	1.06	1.85	1.37	0.48	52.2
	0.10			35.62	0.91	1.60	2.09	-0.49	27.0
1.00	1.00	1288	39.34	7.30	1.44	2.53	0.45	2.08	52.8
	0.90			8.02	1.43	2.50	0.50	2.00	51.9
	0.80			8.94	1.40	2.45	0.56	1.89	51.4
	0.70			10.07	1.37	2.40	0.64	1.76	50.6
	0.60			11.52	1.33	2.32	0.74	1.58	49.5
	0.50			13.36	1.28	2.25	0.89	1.36	47.9
	0.40			15.87	1.22	2.14	1.12	1.02	45.3
	0.30			19.13	1.16	2.03	1.35	0.68	41.3
	0.20			23.59	1.10	1.93	1.61	0.32	34.7
	0.10			29.99	1.03	1.80	2.10	-0.30	22.7
0.80	0.80	1480	35.25	7.70	1.45	2.54	0.55	1.99	41.4
	0.70			8.64	1.43	2.50	0.63	1.87	40.9
	0.60			9.85	1.40	2.45	0.73	1.72	40.1
	0.50			11.44	1.35	2.37	0.88	1.49	38.9
	0.40			13.55	1.30	2.28	1.10	1.18	37.1
	0.30			16.51	1.23	2.15	1.35	0.80	33.9
	0.20			20.53	1.16	2.04	1.62	0.42	28.7
	0.10			26.27	1.11	1.94	2.15	-0.21	19.3
0.60	0.60	1742	30.55	8.20	1.47	2.58	0.73	1.85	30.3
	0.50			9.45	1.44	2.53	0.88	1.65	29.5
	0.40			11.24	1.39	2.44	1.10	1.34	28.2
	0.30			13.68	1.33	2.33	1.37	0.96	26.1
	0.20			17.21	1.25	2.20	1.65	0.55	22.3
	0.10			22.44	1.17	2.04	2.24	-0.20	15.0
0.40	0.40	2175	24.54	8.70	1.50	2.62	1.12	1.50	18.4
	0.30			10.56	1.45	2.53	1.41	1.12	17.2
	0.20			13.28	1.40	2.44	1.72	0.72	14.9
	0.10			17.60	1.30	2.27	2.42	-0.15	10.2
0.30	0.30	2492	21.37	9.00	1.52	2.66	1.44	1.22	13.1
	0.20			11.33	1.47	2.57	1.77	0.80	11.5
	0.10			15.05	1.39	2.44	2.49	-0.05	8.1

If equation (b) is used, not involving a value of K, the speed S_m may be obtained from:

$$S_m = \frac{375\,Q}{Tp} \qquad \text{(d)}$$

Cylinder tractive power at any other velocity is obtained from Table 5 of the Manual, and its extension for superheated steam adopted March, 1915.

Engine resistances varying with the speed are calculated from Table 7 of the Manual, which deducted from figures for cylinder tractive power at corresponding speeds gives values of P, the available drawbar pull on a level grade. Tables of T and P for different speeds are then computed.

The weight of train that may be handled on the ruling grade at any given maintained speed, equal to or in excess of "M" velocity, having been obtained from equation (1) above, the speed, S, that may be maintained on any other grade, G, is obtained from the table, corresponding to the value of P in the equation:

$$P = rw + 20\,GW \qquad \text{(11)}$$

where $W = E + w =$ weight of engine and train.

$P =$ drawbar pull on a level grade.

The tractive power at starting and at S_m speed does not vary with the amount of coal consumption, but the speed S_m and the speed at which any given tractive power may be maintained, varies with the coal consumption, F. The formulas so far given are based on a known or assumed value for F. It may happen especially with superheater engines that the possible speed obtained from equation (11) for level and very light grades, based on a given fuel consumption, will exceed the permissible speed. It may then be desirable to estimate coal consumption necessary to maintain a given speed, in other words, to calculate backwards:

$$T_1 = rw + e_1 + 20\,GW \qquad \text{(12)}$$

where $e_1 =$ engine resistance at the given speed (S_1).

$G =$ per cent. of grade (plus for ascending, minus for descending).

$T_1 =$ required cylinder tractive power on the given grade at the given speed.

$$\frac{100\,T_1}{T} = t \qquad \text{(13)}$$

where $t =$ per cent. of cylinder tractive power compared with that at "M" velocity.

From Table 5 of the Manual, or its extension, adopted March, 1915. find velocity, v, in multiples of "M" corresponding to the given per cent., t:

$$xy_1 = \frac{KS_1}{Av} \qquad \text{(14)}$$

or for greater convenience in utilizing Table 1:

$$xy = \frac{KS_1}{Abv} \qquad \text{(15)}$$

ABLE 2-a--Showing Variation in Time and Fuel per Foot of Rise or Fall, or of Rise and Fall Combined; Momentum Excluded. Computed for 1,000,000 Train Tons, including Engine Weights. Car Resistanc 6 lbs. per ton (based on Consolidation Engine, Superheated Steam; Heating Surface, excluding Superheating Surface, 3300 sq.ft.; Boiler Pressure, 200 lbs.; Cylinders, 22X30"; Drivers, 63"; Weight, including Tender, 173 Tons; Coal, 11,000 B.t.u.; Consumption--Working, 3500 lbs., excep where less is required to maintain the Limiting Speed (S_1); Drifting, 789 lbs.per hour.)

Ruling Grade Percent (G_2)	Actual Grade Percent (G)	Weight of Train behind Tender (w)	Maintained Speed in M.P.H.		Increase for One Foot Rise		Decrease in Coal for 1 ft Fall Tons (C_1)	Incr. in Coal for 1ft Rise &Fall Tns ($C-C_1$)	Feet of Rise and Fall excluded (h_1-h_2)
			Level Grade (S_1)	On (G) (S)	Time-Hours (M)	Coal-Tons (C)			
1.50	1.50	882	35.0	7.30	1.30	2.51	0.22	2.29	41.0
	1.25			8.75	1.23	2.44	0.27	2.17	40.2
	1.00			10.91	1.13	2.34	0.34	2.00	38.7
	0.75			14.32	0.99	2.21	0.45	1.76	35.7
	0.50			20.02	0.77	2.08	0.67	1.41	28.8
	0.25			30.22	0.32	2.01	0.97	1.04	10.9
	0.15			35.00	0.00	1.97	1.05	0.92	0.0
1.25	1.25	1053	35.0	7.30	1.34	2.54	0.28	2.26	41.0
	1.10			8.25	1.30	2.50	0.32	2.18	40.5
	0.90			9.99	1.23	2.42	0.39	2.03	39.4
	0.70			12.60	1.12	2.32	0.50	1.82	37.3
	0.50			16.74	0.96	2.19	0.70	1.49	33.1
	0.30			23.42	0.72	2.11	1.00	1.11	23.7
	0.10			35.00	0.00	2.30	1.28	1.02	0.0
1.00	1.00	1288	35.0	7.30	1.40	2.57	0.39	2.18	41.0
	0.90			8.02	1.38	2.54	0.43	2.11	40.6
	0.80			8.94	1.35	2.50	0.49	2.01	40.1
	0.70			10.07	1.31	2.46	0.56	1.90	39.3
	0.60			11.52	1.26	2.39	0.65	1.74	38.2
	0.50			13.36	1.20	2.33	0.78	1.55	36.6
	0.40			15.87	1.12	2.23	0.98	1.25	34.0
	0.30			19.13	1.02	2.16	1.17	0.98	30.1
	0.20			23.59	0.90	2.12	1.34	0.78	23.4
	0.10			29.99	0.62	2.19	1.69	0.50	11.4
0.80	0.80	1480	35.25	7.70	1.45	2.54	0.55	1.99	41.4
	0.70			8.64	1.43	2.50	0.63	1.87	40.9
	0.60			9.85	1.40	2.45	0.73	1.72	40.1
	0.50			11.44	1.35	2.37	0.88	1.49	38.9
	0.40			13.55	1.30	2.28	1.10	1.18	37.1
	0.30			16.51	1.23	2.15	1.35	0.80	33.9
	0.20			20.53	1.16	2.04	1.62	0.42	28.7
	0.10			26.27	1.11	1.94	2.15	-0.21	19.3
0.60	0.60	1742	30.55	8.20	1.47	2.58	0.73	1.85	30.3
	0.50			9.46	1.44	2.53	0.88	1.65	29.5
	0.40			11.24	1.39	2.44	1.10	1.34	28.2
	0.30			13.68	1.33	2.33	1.37	0.96	26.1
	0.20			17.21	1.25	2.20	1.65	0.55	22.3
	0.10			22.44	1.17	2.04	2.24	-0.20	15.0
0.40	0.40	2175	24.54	8.70	1.50	2.62	1.12	1.50	18.4
	0.30			10.56	1.45	2.53	1.41	1.12	17.2
	0.20			13.28	1.40	2.44	1.72	0.72	14.9
	0.10			17.60	1.30	2.27	2.42	-0.15	10.2
0.30	0.30	2492	21.37	9.00	1.52	2.66	1.44	1.28	13.1
	0.20			11.33	1.47	2.57	1.77	0.80	11.5
	0.10			15.05	1.39	2.44	2.49	-0.05	8.1

where y = value in last column of Table 1 of Manual (edition of 1911), under "10,000 B. t. u."

b = heat units in the coal divided by 10,000.

The first and last columns of Table 1 multiplied together give values of xy, or lbs. steam per square foot of heating surface for 10,000 B. t. u. coal, and should be added as another column to Table 1.

From the value of xy obtained from equation (15) take the corresponding value of x, column 1:

$$F = Ax \qquad (16)$$

which is the required coal consumption per hour.

Table 2 of Report on Economics of Railway Location (Vol. 16, No. 172, December, 1914) is to be added to Table 4 of the Manual to provide for superheated steam. It shows 16.62 lbs. of steam per I. H. P. from velocity of 6.5 M to 8.0 M, the last given in the table. Therefore, in default of better information, we can use the same amount of steam per I. H. P. for extending Table 3 of the Bulletin, which is to be added to Table 5 of the Manual, or for values of v greater than 6.5, we have

$$t = \frac{144.4}{v} \qquad (17)$$

To provide for rates of coal consumption less than 0.8 lbs. per square foot of heating surface per hour, Table 1 of the Manual must be extended backwards. Designating the first and last columns of Table 1 by the letters, x and y, as above, and platting the curve (see Fig. 4), it will be found to coincide very closely with the equilateral hyperbola:

$$y = \frac{51.8 - 3.07x}{3x + 7} \qquad (18)$$

The dotted line shows the extension of this curve to the left. Multiplying the values of x and y, we have the curve xy, or pounds of steam per square foot of heating surface for 10,000 B. t. u. coal and different rates of firing. This curve passes through 0.0 at the bottom of the figure. Evidently this is incorrect. A certain amount of coal is consumed while the engine is drifting and maintaining the gage pressure without using any steam in the cylinders.

On page 6 of Bulletin 148, August, 1912, Mr. Shurtleff gives the coal burned in drifting from 0.263 per square foot heating surface for 10,000 B. t. u. coal to 0.175 for 15,000 B. t. u., with corresponding intermediate quantities. It is evident that the curve, xy, should strike the base line at the point indicating the coal consumption for engine drifting.

The curve, xy, gives the quantity of steam for 10,000 B. t. u. The quantity for any other quality of coal and given rate of firing is proportional to the heat units. Therefore we can use the curve for xy, taking note of this proportion as in equation (15), except that when calculating for 11,000 B. t. u., the curve must be bent to strike the base line at 0.239, which is the quantity consumed in drifting, and at 0.188 for 14,000 B. t. u.; as shown by curves marked 1.1 and 1.4, and similarly for other qualities of coal.

TABLE 2-b--Showing Variation in Time and Fuel per Foot of Rise or Fall, or of Rise and Fall Combined; Momentum Excluded. Computed for 1,000,000 Train Tons, including Engine Weights. Car Resistance, 6 lbs. per ton (based on Consolidation Engine, Superheated Steam; Heating Surface, excluding Superheating Surface, 3300 sq. ft.; Boiler Pressure, 200 lbs.; Cylinders, 22x30"; Drivers, 63"; Weight, including Tender, 173 Tons; Coal, 14,000 B.t.u.; Consumption--Working, 3000 lbs. per hour, except where less is required to maintain the Limiting Speed (S_1); Drifting, 620 lbs. per Hr.

Ruling Grade Percent (G_2)	Actual Grade Percent (G)	Weight of Train behind Tender (w)	Maintained Speed in M.P.H.		Increase for One Foot Rise		Decrease in Coal for 1 ft Fall-Ton (C_1)	Incr. in Coal for 1ft Rise &Fall Tns ($C-C_1$)	Feet of Rise and Fall excluded ($h_1 - h_2$)
			Level Grade (S_1)	On (G) (S)	Time-Hours (M)	Coal-Tons (C)			
1.50	1.50	882	35.0	8.40	1.08	1.85	0.17	1.68	40.4
	1.25			10.07	1.02	1.80	0.20	1.60	39.3
	1.00			12.55	0.92	1.73	0.26	1.47	37.3
	0.75			16.47	0.77	1.62	0.34	1.28	33.4
	0.50			22.99	0.53	1.51	0.52	0.99	24.4
	0.25			34.54	0.03	1.44	0.75	0.69	1.1
	0.15			35.00	0.00	1.17	0.81	0.36	0.0
1.25	1.25	1053	35.0	8.40	1.12	1.88	0.21	1.67	40.4
	1.10			9.49	1.08	1.85	0.24	1.61	39.7
	0.90			11.50	1.00	1.80	0.30	1.50	38.2
	0.70			14.50	0.89	1.77	0.38	1.39	35.5
	0.50			19.23	0.72	1.61	0.53	1.08	29.9
	0.30			26.86	0.44	1.54	0.77	0.77	17.6
	0.10			35.00	0.00	1.28	0.94	0.34	0.0
1.00	1.00	1288	35.0	8.40	1.17	1.92	0.28	1.64	40.4
	0.90			9.22	1.15	1.91	0.31	1.60	39.9
	0.80			10.29	1.11	1.87	0.35	1.52	29.2
	0.70			11.59	1.07	1.84	0.40	1.44	38.2
	0.60			13.25	1.01	1.79	0.46	1.33	36.7
	0.50			15.36	0.95	1.75	0.56	1.19	34.6
	0.40			18.24	0.85	1.68	0.69	0.99	31.2
	0.30			21.97	0.73	1.64	0.83	0.81	26.0
	0.20			27.06	0.54	1.62	0.92	0.70	17.2
	0.10			34.28	0.08	1.74	1.05	0.69	1.7
0.80	0.80	1475	35.0	8.90	1.20	1.93	0.37	1.56	40.1
	0.70			9.99	1.17	1.90	0.42	1.48	39.4
	0.60			11.39	1.14	1.86	0.49	1.37	38.3
	0.50			13.22	1.08	1.82	0.59	1.23	36.7
	0.40			15.66	1.01	1.77	0.74	1.03	34.3
	0.30			19.06	0.91	1.70	0.90	0.80	30.1
	0.20			23.68	0.78	1.66	1.02	0.64	23.2
	0.10			30.22	0.52	1.75	1.21	0.54	10.9
0.60	0.60	1762	34.52	9.30	1.28	1.92	0.56	1.36	38.7
	0.50			10.76	1.25	1.88	0.68	1.20	37.7
	0.40			12.75	1.21	1.81	0.84	0.97	36.0
	0.30			15.50	1.16	1.74	1.05	0.69	33.3
	0.20			19.53	1.09	1.63	1.24	0.39	28.4
	0.10			25.45	1.04	1.56	1.62	-0.06	19.0
0.40	0.40	2216	27.63	9.80	1.31	1.96	0.85	1.11	23.4
	0.30			11.88	1.27	1.90	1.08	0.82	21.8
	0.20			14.95	1.22	1.82	1.30	0.52	18.9
	0.10			19.82	1.13	1.69	1.75	-0.06	13.0
0.30	0.30	2568	23.71	10.00	1.33	2.00	1.11	0.89	16.2
	0.20			12.56	1.29	1.94	1.35	0.59	14.2
	0.10			16.68	1.23	1.84	1.81	0.03	10.0

CONCLUSIONS.

The increase or decrease in fuel due to 1 ft. of rise or fall and the increase in time due to 1 ft. of rise may be quickly estimated from Tables 1, 2, 2a, 2b or similar tables.

In using the tables equivalent rise or fall should be considered, the actual rise or fall being corrected for the difference in velocity head.

Trains in each direction should be considered separately.

Rise and fall should be considered separately.

In Tables 1 and 2, where the speed on the level grade is the maximum that may be maintained, the increase of time in hours, M, times the rate of firing in tons, gives the increase in fuel, C, per foot of rise. This relation holds good in Tables 2a and 2b, with ruling gradients not exceeding 0.8 and 0.6 per cent., respectively. For heavier ruling gradients in these two tables the calculations involve different rates of firing due to limitations of speed and the consequent excess of power on level and light minor gradients.

The calculations indicate:

(a) For engines using superheated steam there is little variation in the amount of coal per foot of rise due to difference in gradient.

(b) For any given ruling gradient, character of fuel and steam (saturated or superheated), fuel saved per foot of fall is inversely proportional to the grade down to the grade of equilibrium, where it is the difference between that consumed on a level grade and drifting at the given speed. The grade of equilibrium is the sum of engine and train resistances divided by twenty times the total weight of engine and train, and varies somewhat with the ruling gradient and consequent make-up of train, and slightly with the speed. On gradients less than the grade of equilibrium the fuel saved per foot of fall may be taken as constant as in Table 1, or perhaps more accurately, as shown in succeeding tables, as increasing down to a grade of 0.1 per cent., where, as a general average, it may be considered as about balancing the increase per foot of rise.

AN EXCEPTIONAL FLOOD.

By J. L. Campbell,

Engineer Maintenance of Way, El Paso & Southwestern System.

On the evening of July 19, 1915, 108 feet of bridge 2217 on the El Paso & Southwestern Railroad, near Indiole, New Mexico, were washed out by a flood from a drainage area of 8.87 square miles, as shown on the accompanying map showing the bridge, drainage area and the sectional area of the water.

At 5 p. m. the water service foreman passed over the bridge on a motor car, at which time no rain was falling in the vicinity. At 7 p. m. a westbound freight train plunged into the flood through the washed out section of the bridge. At 9 p. m. the flagman of eastbound passenger train No. 4 crossed the stream on foot from the west to the east end of the bridge around the latter and the wreck. This indicates the short duration and violence of the rainfall and flood. The engineer, fireman, one brakeman and two tramps were drowned, their bodies afterwards being found at points from 12 to 15 miles below the bridge. The train was composed principally of 100,000-lbs. capacity steel coal and coke cars. Several of these cars were washed down the water course to distances varying from 500 to 1500 feet from the bridge. Apparently, the section of washed-out bridge was swept from under the track without breaking the latter. Otherwise, the block signal to the east of the bridge would have stopped the freight train. Evidently, the latter broke the rails and bonding, for passenger train No. 4 coming from the west was stopped by the signal to the west of the bridge. The damming effect on the flood

of the engine and cars, of which ten dropped into the hole, and the equivalent sectional area of the flood in the free channel, are shown on the drawing. The equivalent section is estimated from the three cross-sections of the flood taken below the bridge, as shown on the drawing. The figures around the watershed line and along the ravines within the drainage area are elevations above sea level. Altogether, the form and configuration of the drainage area are such that the flood could reach the bridge rapidly. Rock lies near the surface throughout the area, the slopes are generally steep, and little water would be absorbed by the ground. The accompanying photographs of the wreck indicate the nature of the waterway channel.

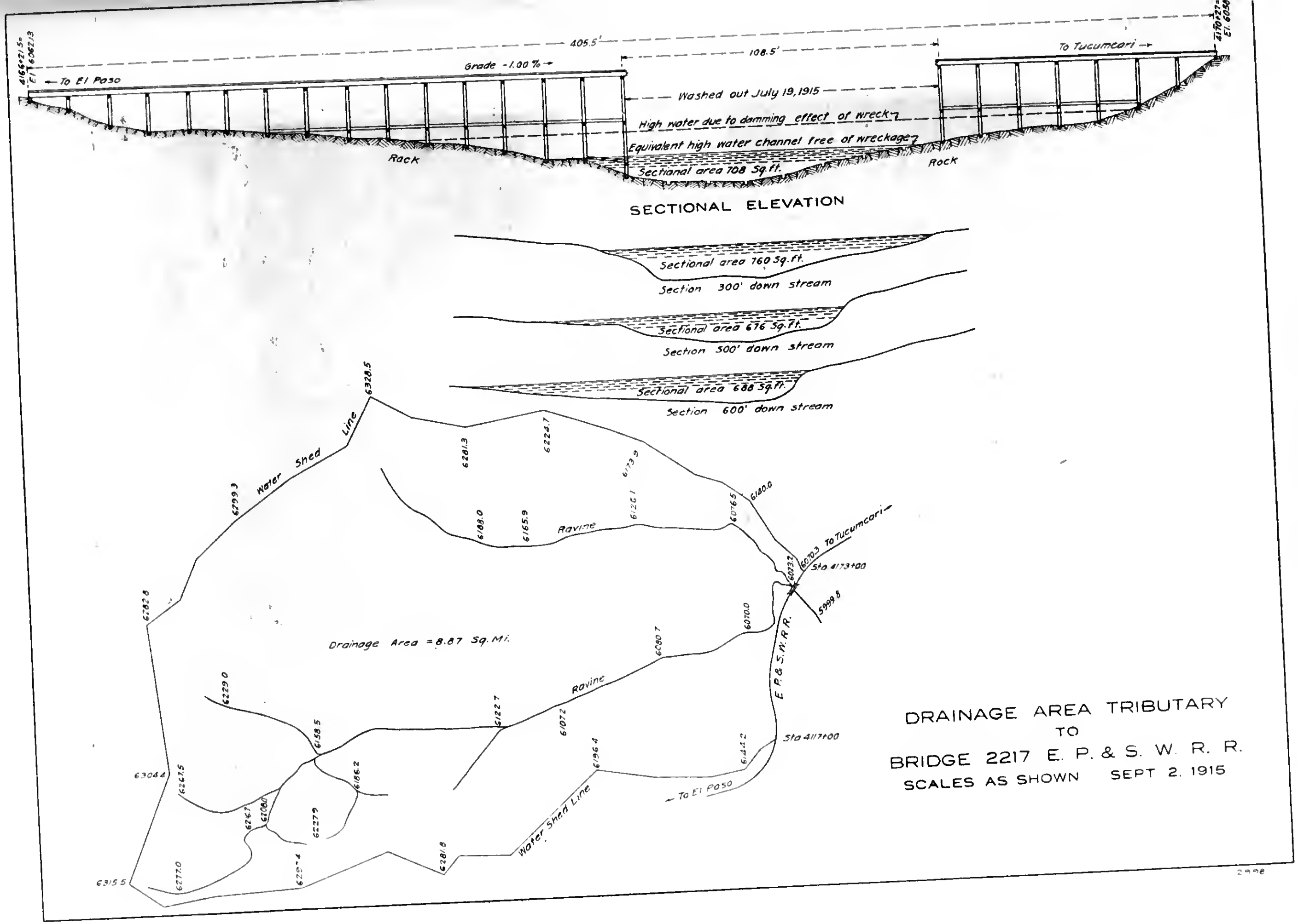
Computing the probable rate of runoff from the survey made of the flood and application of Kutter's formula, we have the following:

Sectional area	700
Wetted perimeter	140
Hydraulic mean radius	5
Slope	.0125
Coefficient of roughness	.035
Coefficient of velocity	57.
Mean velocity	14.2 ft. per sec.
Discharge	9840 sec. ft.

Referring to Appendix A of the report of the Roadway Committee of the American Railway Engineering Association beginning on page 490 of the 1911 Proceedings, Vol. 2, Part 3, and selecting the formulas for runoff in second feet applicable to the case, we have rates of runoff by the several authorities, as follows:

Cooley	859 sec. ft.
Fanning	1236 sec. ft.
Murphy	1399 sec. ft.
C., B. & Q. Railway	2977 sec. ft.
Kuichling	3049 sec. ft.
Kutter	3839 sec. ft.
E. P. & S. W. Railway	4539 sec. ft.
Dredge	4592 sec. ft.
Dickens	11337 sec. ft.

In the above the coefficient giving the maximum runoff for the several formulas was selected. The Dickens formula has five coefficients ranging from 200 to 2200 giving discharges varying from 1031 to 11,337 second feet. This formula was developed in India to fit five different provinces. The Gray formula, on page 499 of the report above specified, is not included for the reason that the discharge Q is given in second feet per acre and the drainage area A in square miles, giving a discharge of 172,874 second feet. If the drainage area A is taken in acres instead of square miles, the formula would give a discharge of 3862 second feet. With the exception of the Dickens formula, all the above give results less than one-half the actual discharge of the flood herein described. Some of the formulas appear seriously inadequate even for ordinary floods.



DRAINAGE AREA TRIBUTARY
TO
BRIDGE 2217 E. P. & S. W. R. R.
SCALES AS SHOWN SEPT 2. 1915


290

*A SYSTEM FOR STANDARDIZING MAINTENANCE OF WAY WORK.

By Earl Stimson,

Engineer Maintenance of Way, Baltimore & Ohio Railroad.

In the spring of 1911 a movement was started on the Baltimore & Ohio Railroad to standardize maintenance of way work. From that time the work has been steadily carried forward, resulting in the development of a system of handling maintenance of way track work, which has produced more uniform practices and increased the efficiency of the organization.

This has been accomplished by the establishment of standard schedules indicating the unit performance of the various items of track work and by keeping a daily record of the performance of each gang. The ratio of the actual performance to the standard schedule is the measure of each gang's effectiveness. By the use of the information thus derived and through the establishment of standard methods, the supervisors have, month by month, increased the output of the gangs on their territories.

In the beginning the principles of efficiency, as outlined by various authors and experts on shop practice, were used in the formation of a system which would be applicable to maintenance of way work. It was at once seen that several main features must be developed in order to secure the expected benefits:

(1) A method of equitably distributing the available force.

(2) Standards for each item of maintenance work.

(3) Instructions to foremen to enable them to submit accurate reports of performances.

(4) Closer supervision by means of planning and dispatching the work in advance.

(5) Simple forms for the notation of records and performances, and for comparison of results.

(6) A reward in the form of a bonus as an incentive to the worker to increase his output.

The Philadelphia Division was selected as the division best suited for making the necessary studies and working out the system. It was manifestly impossible for the supervisors to handle special work of this kind together with their regular duties; therefore, each supervisor was given an assistant, who is required to devote practically his entire time to the study of standard schedules and methods, to the recording and study of performances and to personal instruction of the foremen in regard to standard practice, etc., but not in regard to the conduct of the work.

The assistant supervisors are all graduates of technical schools, selected from transitmen on the engineering corps, and are eligible for promotion to the position of supervisor or Assistant Division Engineer.

For the first two years the work was confined to the Philadelphia Division. By the spring of 1913 a system had been worked out which was giving results warranting its further extension. This was done, and at the present time the Standard Track Work System is in operation on four divisions. On two of these, however, it is applied to only one subdivision.

The forms, charts, etc., which are shown in the following illustrations, and the methods of applying them, are those now in use and have been developed from investigation and trial, some of them being very different from those first tried.

While the development of this system has been mainly along the line of track work, its principles are equally applicable and readily adaptable to bridge, building and signal maintenance and renewal work.

FORCE DISTRIBUTION.

One of the many features contributing to uniform maintenance conditions is an equitable distribution of the available force to the various sections. This has been arrived at by accurately computing the equivalent mileage of each section, and from a monthly inspection of the territory to determine the condition per cent. of the principal items of maintenance work. From this percentage and the equivalent mileage the equated mileage is computed for each section, and this is directly proportional to the number of men required. For this purpose two forms are used:

Fig. 1—"Record of Track and Roadbed Features."
Fig. 2—"Track Condition Sheet."

The track and roadbed feature sheet has a number of blank columns at the right for recording the monthly condition per cent., equated mileage and force allotment. In this way one sheet will serve for a period of six months, provided there are no changes in the physical characteristics of the sections.

The relative values assigned to various track and roadbed features have been arrived at from records of past charges to these features, extending over a period of years.

The column headed "Arbitrary Mileage" is provided to cover unusual conditions not elsewhere provided for. For instance, on a section having track pans, the track at the pans requires additional work, which is a constant factor and may be equivalent to an additional 0.5 mile of main track. In this case 0.5 mile would be allowed as arbitrary mileage. Likewise, arbitrary mileage is allowed to cover special maintenance due to poor subgrade until such conditions can be permanently corrected.

The Track Condition Sheet is prepared monthly and is based on a careful inspection of the road, the condition per cent. being the estimate of the existing condition as compared with the standard of maintenance at which it is desired to maintain the line of road under consideration.

In order to arrive at a more nearly correct result than would be obtained by an estimate of the condition of the entire section, six divisions of the general maintenance work have been made and each given a relative value based on the charges to these accounts for a number of years. An estimate is made of the condition of each of these items on each section, and this, multiplied by the relative value, gives a calculated per cent., the total of which is the condition per cent. of the section. The equivalent mileage divided by the condition per cent. gives the equated mileage, which directly represents the required force.

STANDARD SCHEDULES.

Standard schedules, or units of performance, are established with great care, as it is essential that they be correct and that the organization of the gang and method of doing the work is the best that can be worked out.

The standard performance, or 100 per cent. efficiency, is the output of a first-class gang working at a speed which can be continuously maintained without physical harm to the men, following an approved method of doing the work and consisting of the most economical number of men for the kind of work to be done.

To arrive at the 100 per cent. standard, first-class gangs are selected and detail time studies made of the performance, the time studies being divided into as many moves and as much detail as possible in order that the various studies may be compared in detail and a standard method worked out which will eliminate all unnecessary moves. If it appears that an improvement can be made, the organization of the gang and the method of doing the work is altered and new studies made. When the most satisfactory organization and method has been found, a final detail study is made of the performance of the gang and this is established as 100 per cent. efficiency and issued as a standard schedule.

In this way schedules have been established for all of the more important items of maintenance work and many of the minor items are now being studied with a view to standardizing practically every item of maintenance work.

For uniformity, all the schedules are reduced to a unit of performance per ten hours, and all represent a performance which has been attained.

It was at first thought that, owing to the wide variation in conditions, there would be a number of items of work for which it would be impossible to work out standard schedules, but the study of performances has developed a remarkable uniformity in the output of gangs working under apparently widely varying conditions, and there are relatively few items of maintenance work which cannot be standardized. In cases where one standard schedule cannot be made to apply, as, for example, in ditching, a schedule is made for the individual job and is based either on previous records, performances under similar conditions, or observations after the work is started. For individual pieces of work of this kind the supervisor, after careful consideration and planning of a method to be followed, establishes a schedule or standard of output for 100 per cent. efficiency, and the foremen's reports are graded on this basis.

Going to and from work and clearing the track for passing trains represents considerable lost time which is beyond the control of the foreman and men. This lost time is classed as *detention*, and studies made to determine the amount of detention show that road sections average about 10 per cent. Therefore, in grading the foreman's reports for comparison with the standard schedule, a credit of 10 per cent. is allowed for detention. On terminal and yard sections the detention is usually much more; in some cases 25 per cent. Sections of this character are treated individually and a study of the detention on each section made.

Figs. 3 and 4 are a reproduction of pp. 107 and 109 of the book of Standard Schedules. Page 107 gives the standard method of tie renewals when track is not raised; page 109 shows the detail time distribution and the unit rate per ten hours.

TIES. Page 107.

METHOD OF RENEWAL.

TRACK NOT RAISED.

Men work in pairs, each starting at end of cribs and digging ballast out of cribs adjacent to ties to be renewed. Spikes are then drawn and old tie is worked into open crib and pulled out of track. New bed is prepared and new tie slipped into place with tie tongs. One man then holds tie close up to rail by means of bar, and other spikes; each thoroughly tamp both sides each end of tie outside of rail and 18 in. inside. Ballast is cleaned and returned to cribs, dressing shoulder.

Not less than two weeks after renewal, tie should be thoroughly retamped.

In pulling new ties into place, the practice of digging picks into face of tie and so working it into place must not be allowed. Tie tongs are provided for this purpose.

FIG. 3.

TIES. Page 109.

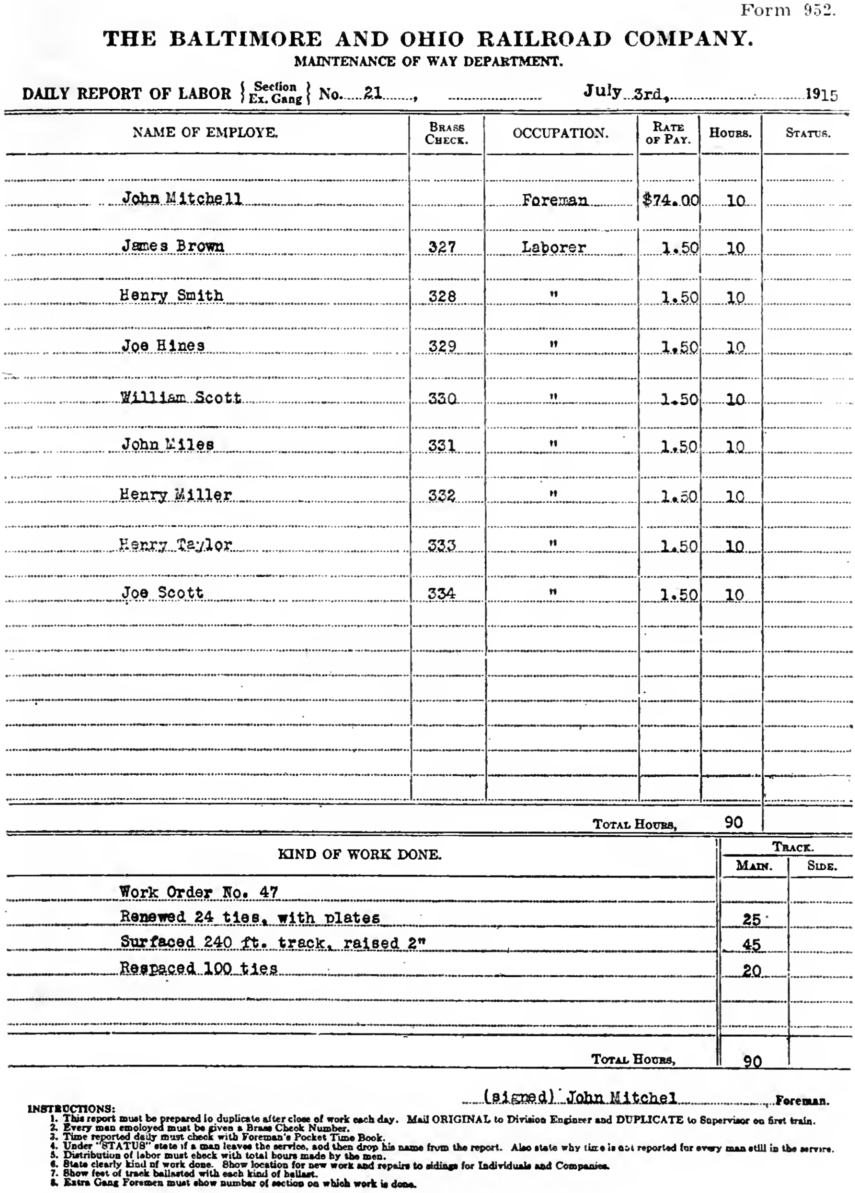
TIME DISTRIBUTION OF RENEWALS.

TRACK NOT RAISED.

	Stone Ballast Minutes.	Gravel Ballast Minutes.	Cinder Ballast Minutes.
Cribbing out	18	10	10
Drawing spikes	3	3	3
Removing old tie	2	2	2
Preparing new beds	3	3	3
Carrying tie 100 ft	2	2	2
Placing new tie	2	2	2
Spiking to gage	4	4	4
Tamping	13	8	8
Cleaning ballast and redressing cribs and shoulder (very dirty)	20	3	3
Carrying old ties 50 ft. and piling for burning	2	2	2
Foreman	6	4	4
Total minutes for one tie	75	43	43
Rate, ties per 10 hours	8	14	14

If any of the above items are not performed subtract corresponding time with an allowance for supervision from totals and figure rate per 10 hours.

FIG. 4.



Form 952.

THE BALTIMORE AND OHIO RAILROAD COMPANY.

MAINTENANCE OF WAY DEPARTMENT.

DAILY REPORT OF LABOR {Section / Ex. Gang} No. 21, July 3rd, 1915

NAME OF EMPLOYE.	BRASS CHECK.	OCCUPATION.	RATE OF PAY.	HOURS.	STATUS.
John Mitchell		Foreman	$74.00	10	
James Brown	327	Laborer	1.50	10	
Henry Smith	328	"	1.50	10	
Joe Hines	329	"	1.50	10	
William Scott	330	"	1.50	10	
John Miles	331	"	1.50	10	
Henry Miller	332	"	1.50	10	
Henry Taylor	333	"	1.50	10	
Joe Scott	334	"	1.50	10	
			TOTAL HOURS,	90	

KIND OF WORK DONE.	TRACK.	
	MAIN.	SIDE.
Work Order No. 47		
Renewed 24 ties, with plates	25	
Surfaced 240 ft. track, raised 2"	45	
Respaced 100 ties	20	
TOTAL HOURS,	90	

(signed) John Mitchel Foreman.

INSTRUCTIONS:

1. This report must be prepared in duplicate after close of work each day. Mail ORIGINAL to Division Engineer and DUPLICATE to Supervisor on first train.
2. Every man employed must be given a Brass Check Number.
3. Time reported daily must check with Foreman's Pocket Time Book.
4. Under "STATUS" state if a man leaves the service, and then drop his name from the report. Also state why time is not reported for every man still in the service.
5. Distribution of labor must check with total hours made by the men.
6. State clearly kind of work done. Show location for new work and repairs to sidings for Individuals and Companies.
7. Show feet of track ballasted with each kind of ballast.
8. Extra Gang Foremen must show number of section on which work is done.

FIG. 5.

The detail time distribution is essential for correctly grading the foreman's daily reports. If all of the details of work shown are performed, then the unit performance for 100 per cent. efficiency for tie renewals in stone ballast is eight ties per ten hours. If, however, some of the items are omitted, as is the case when a gang cleaning ballast immediately follows the tie renewal gang, then the work of cleaning ballast, filling the cribs and dressing the shoulder is performed by the following gang, in which case the tie schedule is corrected by omitting this item, which makes the unit rate 11 ties per 10 hours, instead of 8 ties per 10 hours.

It will be noted from Fig. 4 that the new tie may be carried 100 ft. and the old tie 50 ft. If ties are moved more than this distance, they must be trucked, in which case the foreman makes a separate distribution of the time so consumed, charging it to "trucking," which is covered by another schedule.

As stated above, all of the principal items of track work, and most minor items, have been covered by detail time distribution schedules as illustrated by page 109 (Fig. 4).

INSTRUCTIONS TO FOREMEN.

To form an accurate comparison of the performance of various gangs, absolute uniformity in the reports submitted by the foremen is necessary. Owing to the difficulty experienced by foremen in preparing reports, it is desirable to make all forms used by them as simple as possible.

Form 952, illustrated by Fig. 5, is a daily labor report which has been in use over the Baltimore & Ohio System for a number of years. This form proved to be well suited to the reports required in connection with the Standard Track Work System, no change being necessary and no additional report required of the foremen.

It is, however, necessary that the distribution shown on the daily labor report be made with considerable care, so that each item of work may be correctly graded. To secure this result detail instructions governing the distribution and reporting of time charges are issued. To insure a correct understanding of the instructions, each supervisor called a special meeting of his foremen, at which time the instructions were explained and discussed item by item. In addition to this, the assistant supervisor, as he goes over his territory, personally instructs the foremen and sees that the reports are correctly prepared.

Following are the instructions above referred to:

The Baltimore and Ohio Railroad Company—Maintenance of Way Department.

Instructions for Reporting and Distributing Track Work Time Charges.

To be used in connection with the Standard Track Work System.

Kind of Work.	Manner of Reporting.	Items to be Included.
	SINGLE OPERATIONS.	
Lining (Acct. 220-e)	State feet of track lined and whether main or side track.	Breaking down shoulder, lining track, replacing and dressing ballast.
Surfacing (Acct. 220-e)	State total number of ties tamped and feet of track surfaced, whether tamping one or both ends of ties, and if main or side track.	Cribbing out, tamping, replacing and dressing ballast.
Gaging (Acct. 220-e)	State number of ties gaged, whether with or without adzing, and if main or side track.	Pulling spikes, adzing and respiking to gage.
Laying Rail (Acct. 220-c)	State amount laid in feet whether new or repair and if laid in Main Track or Siding. State time placing plates and number of plates. Make separate report of time distributing rail, new or repair and loading rail removed.	Pulling spikes, lining out old rail, adzing, lining in new rail, putting on rail joints, full bolting, full spiking to gage, uncoupling old rail, trucking material, flagmen and water boy. Time consumed removing old plates and placing new plates to be reported separately. Separate report to be made of time consumed unloading.
Replacing Broken and Defective Rail. (Acct. 220-c)	State number of rails and length and whether new or repair. Show time trucking and distance trucked.	Pulling spikes, lining out old rail, adzing, lining in rail, new or repair, putting on rail joints, full bolting, full spiking to gage and flagmen. If plates are changed make separate charge, also separate time consumed loading, unloading and trucking rail.
Replacing Rail Joints. (Acct. 220-d)	State number, kind of joint and number of holes.	Removing old bolts and joint; placing new joint and full bolting.
Tightening and Replacing Bolts. (Tightening bolts Acct. 220-e) Replacing bolts, (Acct. 220-d)	State number of bolts tightened, number renewed and on which track.	Removing old bolts, putting in and tightening new bolts and tightening old bolts.
Renewing Cross Ties (Digging in) (Acct. 220-b)	State number of ties; with or without plates; kind of ballast and whether main or side tracks. If trucking show number of ties and distance trucked.	Carrying new tie if less than 100 feet, cribbing out, removing plates, removing old tie, placing new tie, replacing plates, tamping, cleaning ballast and refilling cribs, dressing ballast, carrying and piling old tie for burning if less than 50 feet. If new tie is moved more than 100 feet or old tie is moved more than 50 feet, separate time consumed loading, unloading and trucking.
Respacing Ties (Acct. 220-e)	State number of ties and kind of ballast.	Cribbing out, driving tie to place, tamping, replacing and dressing ballast.
Renewing Switch Ties (Acct. 220-b)	State number, length, kind of ballast and whether main or side track.	Carrying new tie if less than 100 feet, cribbing out, removing plates, removing old tie, placing new tie, replacing plates, tamping, cleaning ballast and refilling cribs, dressing ballast carrying and piling old tie for burning if less than 50 feet. If new tie is moved more than 100 feet or old tie moved more than 50 feet, separate time consumed loading, unloading and trucking.
Replacing Frog (Acct. 220-d)	State weight of rail, frog number and location. Show time trucking and distance trucked.	Removing old frog and plates, placing new frog and plates, full spiking, and flagging. Separate time consumed loading, unloading and trucking.
Replacing Switch (Acct. 220-d)	State weight of rail, length of points and location. Show time trucking and distance trucked.	Removing old switch, placing and bolting new switch, adjusting and flagging. Separate time consumed loading, unloading and trucking.

Kind of Work.	Manner of Reporting.	Items to be Included.
	SINGLE OPERATIONS.	
Replacing Guard Rails (Acct. 220-d)	State weight of rail, length of guard rail, number of clamps, whether plated or un-plated and location. Show time trucking and distance trucked.	Removing clamps, removing old guard rail, placing new guard rail, replacing clamps and flagging. Separate time consumed loading, unloading and trucking.
Replacing or Installing Guard Rail Clamps (Acct. 220-d)	State whether replacing or installing, number of clamps and make. Show time trucking and distance trucked.	Removing old clamps and placing new.
Installing Tie Plates (Acct. 220-d)	State number of plates. Show number of plates and distance trucked.	Pulling spikes, adzing, placing plates and spiking to gage. Separate time consumed loading, unloading and trucking.
Installing Anti-Creepers (Acct. 220-d)	State number and kind. Show number of anti-creepers and distance trucked.	Moving ballast, installing anti-creeper and tightening. Separate time consumed loading, unloading and trucking.
Replacing Other Track Material not Specified above (Acct. 220-d)	State amount and kind. If trucking show amount of material and distance trucked.	All operations required to remove old material and install new. Separate time consumed loading, unloading and trucking.
Cleaning Switches (Acct. 220-b)	State number cleaned.	Include time cleaning frog, switch and derail.
Cleaning Snow and Ice (Acct. 272)	State number of switches cleaned. Make separate report for cleaning platforms.	Include time cleaning frog, switch and derail.
Cleaning Weeds. (Acct. 202-b)	State number of feet cleaned and kind of ballast.	Removing weeds from ballast and scuffing shoulder.
Cleaning Right of Way (Acct. 202-b)	State amount cleaned by feet of track and give location.	Removing miscellaneous scrap, drift, dirt and other material from tracks and right of way.
Mowing (Acct. 202-b)	State amount mowed by feet of track and give location.	Cutting and disposing of brush, grass, weeds, etc.
Ditching (Acct. 202-d)	State location, amount in feet and method.	Constructing or cleaning tile or open ditches. Include time placing and removing plank for trucking, laying and removing track for ditching cars, loading, trucking and unloading dirt. If steam ditcher is used special report to be made.
Patrolling (Acct. 202-c)	State distance covered in miles.	When track walker is tightening bolts or doing other work while patrolling make separate charge.
Trucking (Acct. 220)	State amount and kind of material and distance trucked.	Loading, unloading, trucking and flagging. (Any material handled on hand, push or motor cars.)
Loading and Unloading (Acct. 220)	State amount and kind of material and kind of car whether box, flat or gondola.	Unloading, carrying and piling material or carrying and loading material.
Wasting Slag and Refuse (Acct. 202-g)	State kind of car, number of cars unloaded and location.	Unloading and spreading slag and refuse. If tracks are thrown or raised in connection with unloading make separate distribution of time.
Cleaning Ballast (Screens or Forks) (Acct. 202-b)	State number of cribs, feet of shoulder and feet of center ditch cleaned.	Removing ballast from shoulder, cribs and center ditch, cleaning with forks or screens, replacing cleaned stone, dressing ballast and disposing of refuse.

Kind of Work.	Manner of Reporting.	Items to be Included.
COMBINED OPERATIONS.		
Ballasting (Preparing roadbed and applying ballast Acct. 220-a Applying ties Acct. 220-b)	Distribute time to the following items: Feet of track stripped. Feet of roadbed prepared, number of ties renewed, number of ties respaced, feet of track ballast unloaded and number of cars, feet of first raise, feet of second raise, feet lined, feet of track dressed, quantity, kind of material and distance trucked.	Stripping track:—Digging out and disposing of old ballast from cribs, center ditch and shoulders (If old ballast is used to build standard roadbed section, charge second handling to (Preparing Roadbed). Preparing Roadbed:—Widening and preparing subgrade to receive ballast. Renewing Ties:—Carrying new tie if less than 100 feet, removing old tie, carrying 50 feet, and piling for burning, placing new tie, placing plates, spiking to gage, temporary surface and flagging. Respacing:—Cracking up spikes driving ties to place and driving down spikes. Unloading Ballast:—Releasing ballast cars. First Raise:—Jacking up track 4" to 6" tamping and flagging. Second Raise:—Jacking up track 4" to 6" tamping to final surface and flagging. Lining:—Throwing to standard centers and detail lining. Dressing:—Dressing center ditch and shoulders to standard section.
Surface and Raise Out of Face and Renewing Ties (Applying ties Acct. 220-b Surfacing track Acct. 220-c)	State number ties renewed, number of ties respaced, feet of track surfaced, feet of track lined and feet of track dressed. If ties are trucked state number and distance trucked.	Renewing Ties:—Carrying new tie if less than 100 feet, cribbing out, removing plates, removing old tie, placing new tie, replacing plates, carrying and piling old tie for burning if less than 50 feet. Respacing:—Driving tie to place. Surfacing:—Cribbing, jacking up track, tamping and flagging. Lining:—Breaking down shoulder, lining track, replacing and dressing ballast. Dressing Ballast:—Unloading ballast to refill cribs, dressing cribs, shoulder and center ditch.

Separate distribution of time must be made for any items of work not covered by the above list.

Time charges for one item must not run over into the charge for another item.

For instance, in surfacing if there is any lining or gaging, a careful separation must be made to each class of work and not lumped as surfacing.

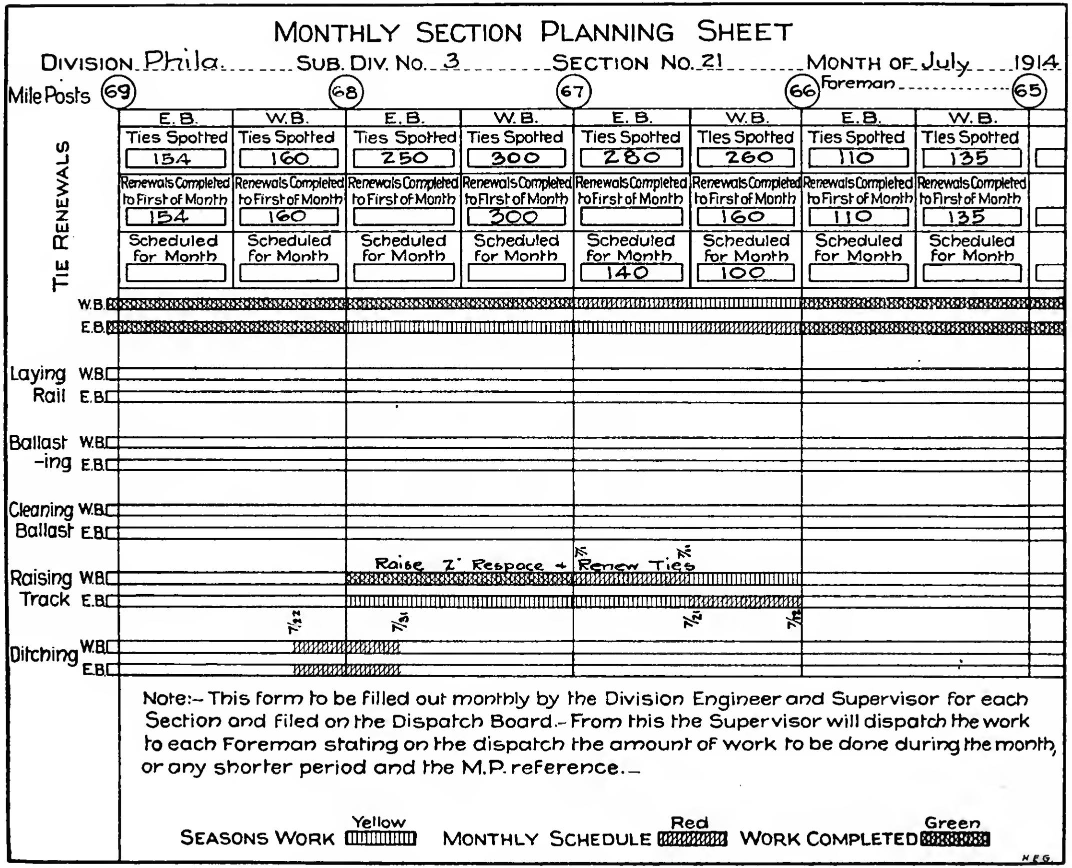
The time consumed loading, unloading and trucking material is in all cases included in the cost of applying the material, but a separate distribution of the time consumed on this work must be made.

The time flagging must in all cases be charged to the work being protected.

PLANNING AND DISPATCHING.

In order to outline the order of the work and to assign it to the gangs to follow in sequence, so as to reduce the loss of time consumed by unnecessary movement of the gangs from place to place, a system of planning and dispatching the work has been devised.

The Planning sheet is shown by Fig. 6, one sheet being used for each section.



MONTHLY SECTION PLANNING SHEET

DIVISION Phila. SUB. DIV. NO. 3 SECTION NO. 21 MONTH OF July 1914

Foreman

Mile Posts ⑲ ⑱ ⑰ ⑯ ⑮

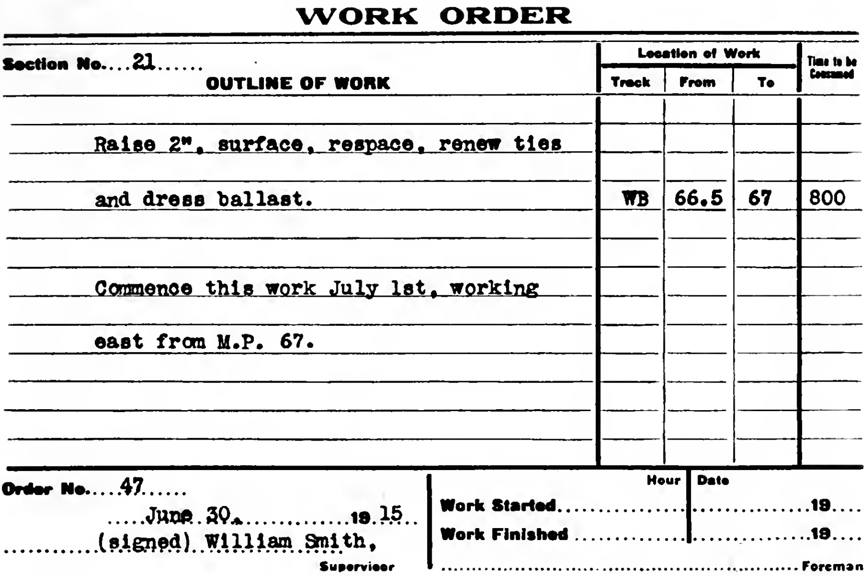
Mile Posts	69		68		67		66		65
TIE RENEWALS	E. B.	W. B.	E. B.	W. B.	E. B.	W. B.	E. B.	W. B.	
Ties Spotted	154	160	250	300	280	260	110	135	
Renewals Completed to First of Month	154	160		300		160	110	135	
Scheduled for Month					140	100			

Note:—This form to be filled out monthly by the Division Engineer and Supervisor for each Section and filed on the Dispatch Board.—From this the Supervisor will dispatch the work to each Foreman stating on the dispatch the amount of work to be done during the month, or any shorter period and the M.P. reference.—

SEASONS WORK Yellow ▥ MONTHLY SCHEDULE Red ▨ WORK COMPLETED Green ▩

H.E.G.

FIG. 6.



WORK ORDER

Section No.....21......

OUTLINE OF WORK	**Location of Work** **Track**	 **From**	 **To**	**Time to be Consumed**
Raise 2", surface, respace, renew ties				
and dress ballast.	WB	66.5	67	800
Commence this work July 1st, working				
east from M.P. 67.				

Order No.....47.....

.....June 30,.............19.15..

...........(signed) William Smith,

Supervisor

	Hour	**Date**
Work Started	....	...............19....
Work Finished	....	...............19....

.... **Foreman**

FIG. 7.

Early in the spring the program of work for the season is decided upon and charted in yellow. Thereafter, as the work progresses and new monthly sheets are prepared, the completed work is shown in green and the monthly program shown in red. A few days before the close of the month the Division Engineer calls a meeting of the supervisors for the purpose of planning the work of the coming month. The work to be done, the location and the relative order in which it is to be undertaken is decided upon and shown in red on the chart. The quantity of work to be accomplished is computed from the standard schedules and the force allotted for the month. The direction in which the work is to progress, the date on which it is to be commenced and the calculated date of completion are shown on the chart.

The chart is prepared in duplicate, one copy to be retained by the Division Engineer and the other for the use of the supervisor. Upon his return to headquarters, the supervisor transmits the program to the foreman by means of work orders, giving him the program for the entire month, or any part of it, as he may see fit. For this purpose a work order, or dispatch book, is provided. This is illustrated by Fig. 7. The book is bound in stiff-back, notebook form, and contains 100 perforated leaves.

The work order is made out in duplicate, the carbon copy being filed on the dispatch board, which will be described later. The work order states the kind, location, amount of work to be done and the time to be consumed. Upon completion of the work the foreman dates and signs the order and returns same to the supervisor. The foreman is given a work order for all work to be done. This, however, does not relieve him from the responsibility of making unforeseen and emergency repairs.

The percentage of efficiency of a gang is not measured by the time reported on the work order, as this is not in sufficient detail, but is obtained from the foreman's daily labor report.

By reference to Fig. 6, the planning sheet, it will be seen that it is proposed to raise the westbound track 2 in., surface and renew ties from M.P. 66.5 to 67.0. The order transmitting these instructions to the foreman is shown on the work order, Fig. 7, and the foreman's daily labor report covering the work accomplished on July 3 is shown by Fig. 5.

FORMS, FILING CASE AND DISPATCH BOARD.

For the purpose of recording the performance of gangs two forms are in use: Fig. 8, Daily Record of Track Work Performance, and Fig. 9, Monthly Record Track Work Efficiency. As stated above, the foremen submit to the Division Engineer and supervisor, on Form 952 (Fig. 5), a daily report of work done. The original, which is forwarded to the Division Engineer, is for the use of the clerical force in making the proper distribution of charges. The carbon copy is used by the assistant supervisor in posting the daily record sheet. For instance, suppose the gang on Section 10 consists of foreman and 9 men, working 10 hours per day, and the foreman has a work order to renew ties without raising track; then the schedule under which he is working will be that shown by Fig. 4, or 8 ties per 10 hours. The foreman's daily report on Form 952, July 3d (Fig. 5), shows that he renewed a total of 64 ties, working 100 hours. The standard time required to renew 64 ties in stone ballast, track not raised, is 80 hours, whereas the actual time consumed was 100 hours. However, 10 per cent. of this is consumed by unavoidable delays, passing trains, etc., and is charged to "Detention," leaving 90 hours actually devoted to effective work. Under the heading of "Renewing Cross-Ties," 80 is recorded as "Standard Time," and 90 as "Actual Time," which indicates an efficiency of 89 per cent.

All other work is recorded in the same way. The column headed "General Miscellaneous" is for recording work which has not been covered by standard schedules, and such work is given an arbitrary rating of 67 per cent., for investigation has shown that work which has not been standardized is being performed at an efficiency of about two-thirds of what can be accomplished after standardizing.

In order to intelligently record and grade the foreman's daily reports it is essential that the assistant supervisor be familiar with the work being done by every section and extra gang on his territory, and this can only be accomplished by constant visits to the gangs and inspection of the work, as many gangs as possible being visited every day.

Although entries of the standard and actual hours are made of every gang every day, the efficiency per cent. of the gangs is worked up only twice a month, that is, the close of the semi-monthly pay-roll period. The efficiency per cent. is arrived at by totaling the standard and actual hours for every class of work, including "General Miscellaneous," but excluding "Detention," and dividing the standard by the actual.

For information and study a separation is made of the total scheduled hours, which is the work covered by the standard schedules, as the effect produced by the inclusion of the "General Miscellaneous" with the arbitrary efficiency of 67 per cent. is to lower the total efficiency. For this reason an effort is being made to work out standards for every possible item of work.

At the close of the month the "Monthly Record Track Work Efficiency" sheet, shown by Fig. 9, is compiled from the totals on the "Daily Record" sheet, Fig. 8. The monthly record shows the percentage of efficiency made by every gang on each class of work, the average of every gang on all work and the averages for the subdivision—in other words, an accurate measure of the performance of every gang.

When it is seen that some gang is making an exceptionally good record, or an unusually poor one, it is the duty of the assistant supervisor to immediately visit that gang and make a study of its work; if an exceptionally good record is being made, to ascertain how the work is being handled, with a view to further improvement of the standard method, and if a poor record is being made, to locate the trouble and instruct and assist the foreman in following the standard method.

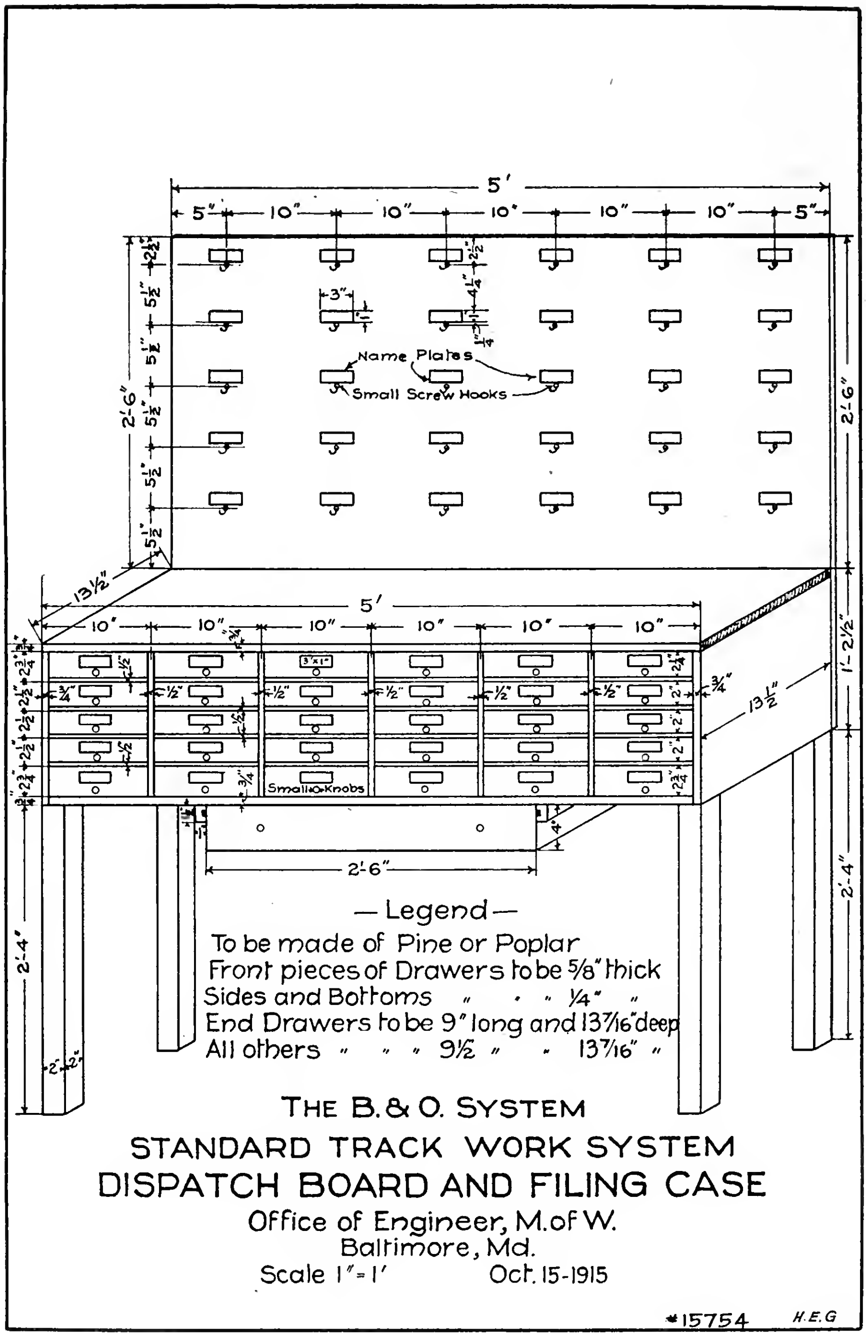

5'
5" 10" 10" 10" 10" 10" 5"
2'-6"
2½"
5½"
4¼"
3"
Name Plates
Small Screw Hooks
13½"
10" 10" 10" 10" 10" 10"
3"×1"
¾"
½"
2¾"
2½"
2"
Small Knobs
1'-2½"
2'-4"
4"
2'-6"
2"
— Legend —
To be made of Pine or Poplar
Front pieces of Drawers to be ⅝" thick
Sides and Bottoms " " " ¼" "
End Drawers to be 9" long and 13 7/16" deep
All others " " " 9½ " " 13 7/16" "
THE B. & O. SYSTEM
STANDARD TRACK WORK SYSTEM
DISPATCH BOARD AND FILING CASE
Office of Engineer, M. of W.
Baltimore, Md.
Scale 1" = 1'
Oct. 15-1915
#15754
H.E.G

FIG. 10.

Fig. 10 shows the standard dispatch board and filing case which has been installed in the office of every supervisor on whose territory the Standard Track Work System is in operation. Each drawer of the filing case is equipped with a name plate, for posting the section number and foreman's name. In the drawers are filed the daily labor sheets, Form 952.

The upright board is the dispatch board, and, corresponding to the name plate on the drawer, there is a similar name plate on the board with a hook directly beneath it, on which the carbon copy of the work order is filed.

An inspection of the work orders on the board shows the location of every gang on the subdivision, and the work being done. A further inspection of the daily labor sheet file shows the progress being made on the work covered by the orders on file above.

The long drawer at the bottom of the case is for the purpose of filing the daily record sheets. The planning chart for each section is kept on file in the drawer with the daily labor distribution sheets.

THE BONUS FEATURE.

A great deal can be accomplished by means of the standard gang organizations and methods, and much more by an effective appeal to the individual effort. Such an appeal may be in the form of a published rating of the foremen and gangs according to the per cent. efficiency attained, which for a time incites a spirit of competition, the natural desire to excel, but effort based on this alone is not long sustained.

It therefore is necessary that the appeal for increased effort be backed with some material reward. This reward is offered in the form of a bonus, or premium, which is the employé's share of the value of the result of his increased effort over the average which experience has set at 67 per cent. of the standard.

The regular daily or hourly rate for the actual time worked is paid, and in addition a bonus graded according to the per cent. efficiency from 67 per cent. upward. No bonus is paid for less than 67 per cent. efficiency.

The bonus is a percentage of the wages earned and increases gradually from 67 per cent. to 100 per cent., and above 100 per cent. at the rate of 1 per cent. for each 1 per cent. increase in the efficiency percentage.

Owing to the nature of maintenance of way track work, it is necessary to consider the gang as a unit rather than the individual, therefore the foreman and each man in the gang receives the bonus based on the efficiency of the entire gang.

The following bonus table has been adopted as standard:

STANDARD BONUS TABLE.

Efficiency per cent.	Bonus per $1.00 Wages	Efficiency per cent.	Bonus per $1.00 Wages	Efficiency per cent.	Bonus per $1.00 Wages	Efficiency per cent.	Bonus per $1.00 Wages
67	.0001	78	.0238	88	.0832	99	.1881
68	.0004	79	.0280	89	.0911	100	.20
69	.0011	80	.0327	90	.0991	101	.21
70	.0022	81	.0378	91	.1074	102	.22
71	.0037	82	.0433	92	.1162	103	.23
72	.0055	83	.0492	93	.1256	105	.25
73	.0076	84	.0553	94	.1352	110	.30
74	.0102	85	.0617	95	.1453	120	.40
75	.0131	86	.0684	96	.1557	130	.50
76	.0164	87	.0756	97	.1662	135	.55
77	.0199	87.5	.0794	98	.1770	140	.60

Example.—The efficiency of the gang for the month is 85 per cent. The table shows 85 per cent. entitles each man of the gang to a bonus of $0.0617 for each $1.00 earned. Hence, the foreman, at $70.00 per month, earns a bonus of $4.32 and receives a total for the month of $74.32.

The men earning $42.90 per month each receive a bonus of $2.65, or a total for the month of $45.55.

SUMMARY.

The benefits to be derived from the Standard Track Work System are both direct and indirect, and may be stated as follows:

1. The roadbed and track feature and track condition sheets provide for a more effective distribution of the forces, resulting in more uniform track conditions.

2. The standard schedules furnish an accurate unit for the measure and comparison of the performance of gangs and an accurate basis for estimating and planning the work to be done.

3. The instructions to foremen provide for a correct and uniform distribution of the time for the purpose of comparing the performance of gangs, which in turn results in a more correct distribution of charges to the proper accounts, thus furnishing reliable cost data.

4. The system of planning and dispatching the work requires that more attention be given this important feature, and results in a more intelligent direction and intensive supervision of the work.

5. The daily and monthly record sheets place the results obtained in a form for ready comparison, the study of which leads to improvements in methods and points out the weak places in the organization.

6. The increase in efficiency which can be accurately measured by means of the standard schedules and is rewarded by the bonus payment, results in a direct financial gain, both to the employé and the employer.

7. By no means the least of the benefits to be derived from this system is that of the development of the young engineer from an inexperienced transitman or draftsman from the engineer's office into a well-qualified candidate for the position of supervisor or Assistant Division Engineer, from which position he will later qualify for that of Division Engineer.

TEST OF TRACK BOLTS AND WRENCHES.

By Earl Stimson,

Engineer Maintenance of Way, Baltimore & Ohio Railroad.

With the introduction and extensive use of track bolts of larger diameter, and of bolts made of high tensile steels, the necessity of a greater length of track wrench became apparent. This led to some experiments to develop the maximum length of wrench for practical and safe use with bolts of different diameters and of different tensile strengths.

Two tests were made: First, using standard 1 in. by 4¾ in. carbon steel bolts with Harvey grip thread and hexagonal nuts, and second, using 1 in. by 4¾ in. heat-treated alloy steel bolts with U. S. standard thread and hexagonal nuts. The bolts were tested in a Rhiele screw gear 100,000-lb. machine with the use of apparatus designed especially for testing bolts, as shown in Figs. 1 and 2. After placing the bolt in the loop, the movable head of the machine was run up far enough to permit placing the bearing plate and spring washer and getting a full thread in the nut. The nut was then at a height to enable a man to get a horizontal pull at his waist line. After measuring each bolt and recording its dimensions, a trackman weighing 150 lbs. was given a wrench and directed to tighten the nut as he would in track, the loads being observed on the scale beam. After he had drawn the nut tight, the load on the bolt as registered on the beam was recorded. The machine was then started on slow motion, about ½-in. per minute, until the elastic limit was reached. This being read and recorded, the machine was run to the ultimate strength of the bolt. A repetition of this test was made, using wrenches 30, 36, 42 and 48 in. in length, of the same design as shown on Drawing 42811, excepting length. The results were then tabulated to show the relation between the load on the bolt when pulled tight with the different wrenches and the load at the elastic limit of the bolt.

It was intended to make the conditions of the test as nearly as possible identical with actual conditions met with in maintaining track. It was difficult, however, to arrange the apparatus so as to get a pull on the wrench in a vertical plane and at the same time measure the loads accurately. The arrangement enabled the trackman to throw his entire weight on the wrench, giving it about the same jerk or impulse it receives in actual practice. No attempt was made to obtain uniformity of load with the same length of wrench; the trackman used his own judgment in determining when the nuts were tight. The loads on the bolts, therefore, when the nuts were pulled up tight, were shown to vary as much as 8,000 lbs. for the same length of wrench.

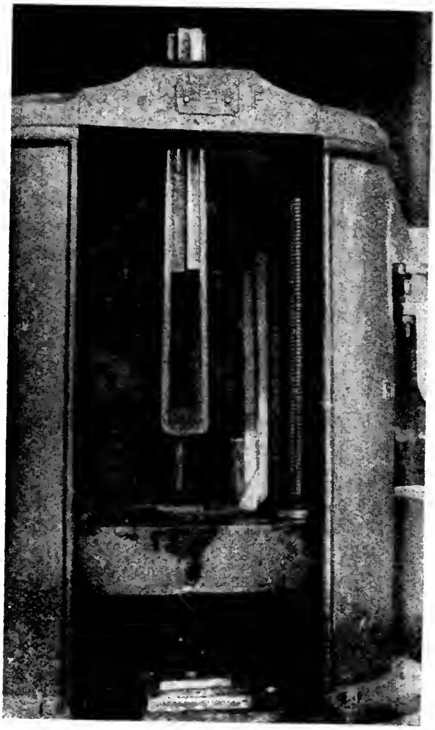


FIG. 1.

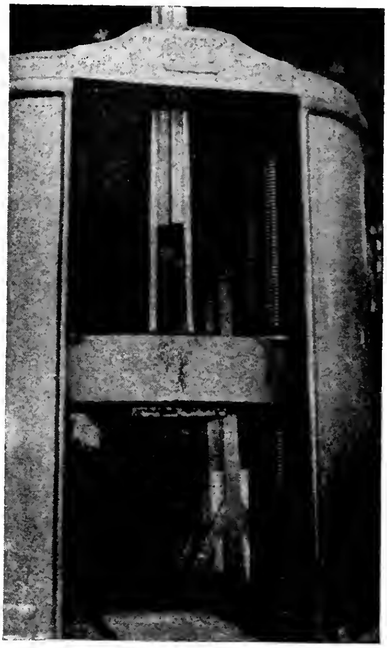


FIG. 2.

APPARATUS USED FOR TESTING BOLTS.

Figs. 3 and 4 give the dimensions of the bolts. In the run of the kegs the carbon steel bolts averaged 0.995 in. in diameter, while the heat-treated alloy steel bolts ran about 0.933 in. in diameter. The threads of the carbon bolts were of the Harvey grip pattern, while those of the heat-treated alloy bolts were U. S. standard, both being rolled.

A comparison of the chemical and physical properties of the two bolts is given in Tables 1 and 2. The trouble that has been had with the corners of hexagonal nuts rounding while being tightened gave rise to an examination of the nuts, as well as the bolts. While this phase of the subject will be discussed later, it might be noted here that the analysis of both kinds of steel showed higher carbon and manganese in the bolt than in the nut, while the sulphur and phosphorus ran lower in the bolt than in the nut. In the analysis of the alloy steel it is also important to note that some nickel and chromium was contained in the nut. This nut was intended to be made of straight open-hearth steel; however, as both the nickel chrome steel and the straight open-hearth steel are produced from the same blast furnaces, a small amount of the nickel and chromium elements contained in the burden of the furnaces creeps into the open-hearth steel. The function of these elements in the bolts is to bring up the tensile strength of a comparatively low-carbon steel. Their presence in the nut likewise improves the quality of the metal.

The object of the tests was to show the relation between the loads on the bolts when drawn up tight with various length wrenches and the elastic limit of the bolts. The averages of a series of tests with carbon steel bolts given in Table 3 shows the loads pulled with 30 and 36 in. wrenches well within the elastic limit of the bolt, while the load pulled with the 42-in. wrench exceeds the elastic limit. The load pulled with the 48-in. wrench is less than that pulled with the 42-in. wrench, and is also less than the elastic limit of the bolt. The increment of load should be expected to vary with the length of wrench. In running this test, however, the jaws of the 42-in. and 48-in. wrenches became so badly sprung that the nuts rounded so as to prevent pulling them up tight.

TABLE 1.—COMPARATIVE CHEMICAL ANALYSIS.

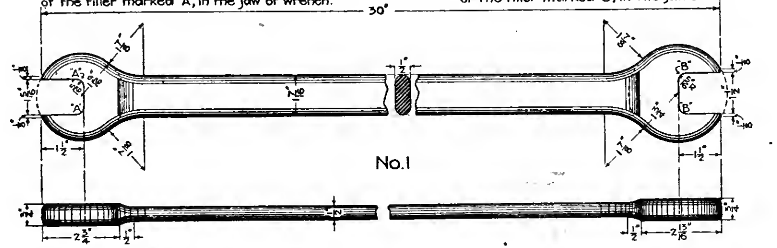
	Carbon Steel.		Alloy Steel.	
Elements.	Bolts. Per Cent.	Nuts. Per Cent.	Bolts. Per Cent.	Nuts. Per Cent.
Carbon	0.20	0.12	0.19	0.17
Sulphur	0.031	0.09	0.037	0.08
Phosphorus	0.008	0.110	0.01	0.073
Manganese	0.50	0.37	0.71	0.60
Chromium	...	....	0.14	0.08
Nickel	...	....	1.09	0.41

TABLE 2.—COMPARATIVE PHYSICAL PROPERTIES OF BOLTS TESTED.

	Carbon Steel.	Alloy Steel.
Reduction, per cent	46.7	30.5
Elongation, per cent. in 4¾ in.	15.3	7.8
Elastic limit, lbs. per sq. in.	49,109	93,225
Ultimate strength per sq. in.	59,704	104,793

No point on the side of the wrench shall be closer than 1" to the center point of the fillet marked "A", in the jaw of wrench.

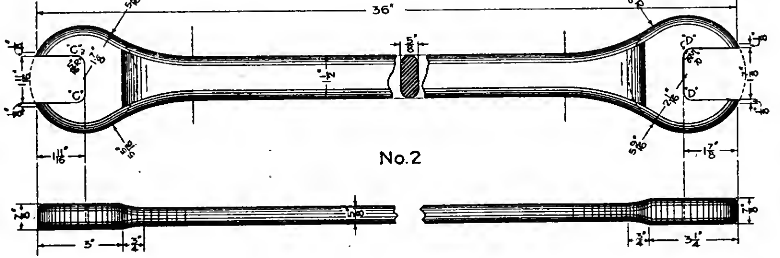
No point on the side of the wrench shall be closer than $1\frac{1}{16}''$ to the center point of the fillet marked "B", in the jaw of wrench.



No.1

No point on the side of the wrench shall be closer than $1\frac{1}{8}''$ to the center point of the fillet marked "C", in the jaw of wrench

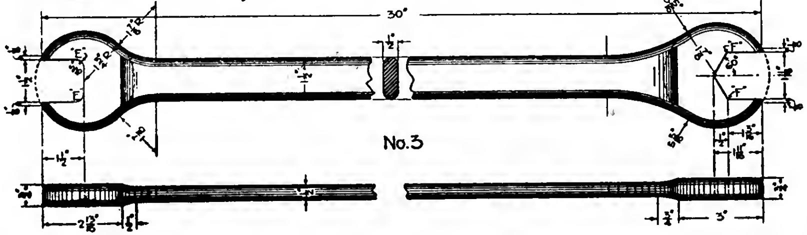
No point on the side of the wrench shall be closer than $1\frac{3}{16}''$ to the center point of the fillet marked "D" in the jaw of wrench.



No.2

No point on the side of the wrench shall be closer than $1\frac{1}{16}''$ to the center point of the fillet marked "E" in the jaw of the wrench.

No point on the side of the wrench shall be closer than $\frac{15}{16}''$ to the point marked "F" in the jaw of wrench.



No.3

Specifications:-

These wrenches to be made of "Open Hearth Steel" having carbon running between 0.40% and 0.55%, sulphur not over 0.03% and phosphorus not over 0.05%.

The jaws of the wrenches to be hardened so that a new fine file will not cut into the face of the jaws — the hardening of the jaws to extend $\frac{3}{4}''$ from end of wrench.

The number of the wrench, B.& O R.R Co., manufacturers name and trade mark to be plainly stamped on the side of the handle near the center.

No.1 wrench is for all track work where $\frac{3}{4}''$ or $\frac{7}{8}''$ bolts are used.

No.2 wrench is a frog wrench for 1" and $1\frac{1}{8}''$ bolts

No.3 wrench is for all track work where $\frac{7}{8}''$ or 1" bolts are used.

Approved:- D. D. Carothers
Chief Engineer.

Approved:-
General Manager. B.&O.R.R.

Approved:- C. C. F. Bent.
General Mgr. B. & O.S.W.R.R.

B. & O.R.R.CO.

TRACK WRENCHES.

Office of Chief Engineer,
Baltimore Md.

May 1907.

4381

TABLE 6.—SHOWING LOAD REGISTERED WITH NUTS PULLED TIGHT.

Length of Wrench.	Harvey Grip Thread.	U. S. Standard Thread.
30 in.	26,850 lbs.	27,300 lbs.
	23,600 lbs.	27,770 lbs.
	26,900 lbs.	31,200 lbs.
	Maximum 31,200 lbs.	
36 in.	31,600 lbs.	34,360 lbs.
	23,500 lbs.	29,700 lbs.
	29,850 lbs.	28,450 lbs.
	Maximum 34,360 lbs.	
42 in.	42,600 lbs.	34,920 lbs.
	38,650 lbs.	33,100 lbs.
	34,600 lbs.	33,000 lbs.
	Maximum 42,600 lbs.	
48 in.	35,700 lbs.	46,350 lbs.
	25,690 lbs.	44,100 lbs.
	33,200 lbs.	38,700 lbs.
	Maximum 46,350 lbs.	

TABLE 7.—CALCULATED STRENGTH OF BOLTS BASED ON MINIMUM ELASTIC LIMIT OF 48,000 LBS. PER SQ. IN. FOR CARBON STEEL AND 75,000 LBS. PER SQ. IN. FOR ALLOY STEEL.

		Strength in Pounds. (Elastic limit)	
Diameter of Bolts.	Area.	Carbon Steel.	Alloy Steel.
¾ in.	.4417	21,201 lbs.	33,127 lbs.
⅞ in.	.6013	28,862 lbs.	45,097 lbs.
1 in.	.7854	37,699 lbs.	58,905 lbs.
1⅛ in.	.9940	47,712 lbs.	74,550 lbs.
1¼ in.	1.2272	58,905 lbs.	92,040 lbs.

The 48-in. wrench was redressed and tempered and another series of tests made. Again its jaws sprung, and so damaged the nut that further tightening was impossible.

With the carbon steel bolts and hexagonal nuts, therefore, the use of a wrench greater than 36 in. in length not only involves the risk of stretching the bolts beyond their elastic limit, but so injures the nuts as to necessitate cutting them in order that they might be removed.

Trouble with the wrenches spreading was not experienced with the alloy steel bolts. After a second dressing and tempering of the same wrenches used with the carbon steel bolts, a much greater load was pulled, using alloy steel bolts, without injuring the nuts. (See Table 4.)

Here it should be remembered that the nickel and chromium elements in the alloy steel produce a much harder steel than the mild open-hearth carbon steel, without raising the carbon. The need of a harder steel nut is emphasized by the damage done with long wrenches while tightening the carbon steel bolts. It will be seen from the following statement (Table 5, taken from Tables 3 and 4) that slightly greater loads were pulled with the same length of wrench with the alloy bolts than with the carbon bolts, while the damage done to the nuts (see Figs. 5 and 6) was much less with the alloy steel than with the carbon steel.

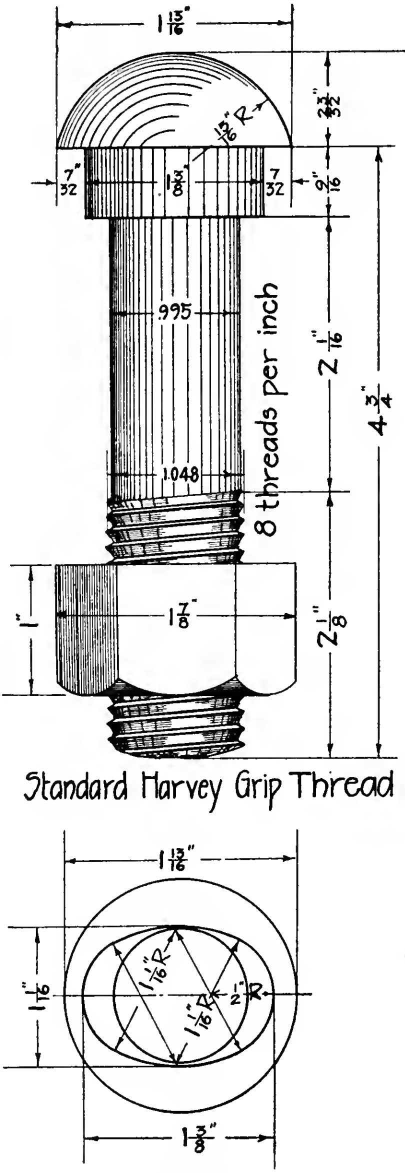

1 13/16"
23/32"
15/16" R
7/32"
1 3/8"
7/32"
9/16"
.995
8 threads per inch
2 1/16"
4 3/4
1.048
1"
1 7/8"
2 1/8"
Standard Harvey Grip Thread
1 13/16"
1 1/16"
1 1/16" R
1/2" R
1 1/16" R
1 3/8"

Fig. 3

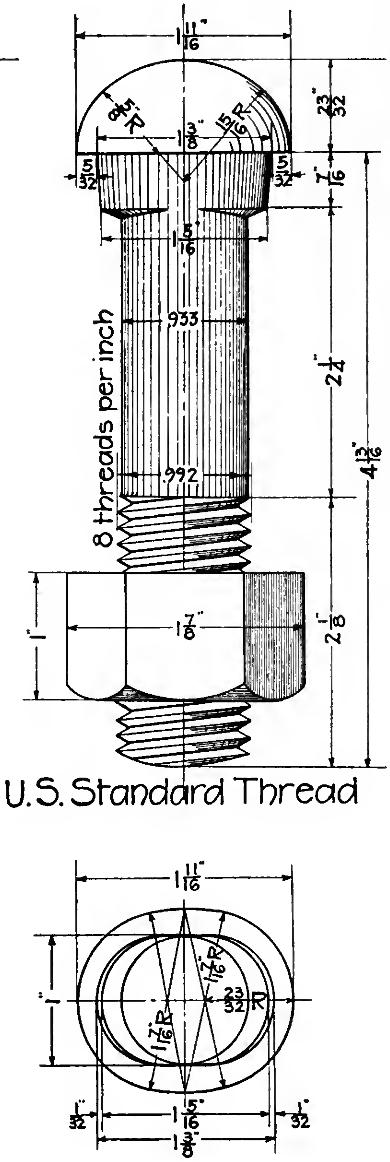

1 11/16"
15/16 R
15/16 R
1 3/8"
23/32"
5/32
5/32
7/16"
1 5/16"
.933
8 threads per inch
2 1/4"
4 13/16"
.992
1"
1 7/8"
2 1/8"
U.S. Standard Thread
1 11/16"
1"
1 7/16" R
23/32 R
1 7/16" R
1/32"
1 5/16"
1/32"
1 3/8"

Fig. 4

Fig. 5. Carbon Steel Bolts.

Fig. 6. Alloy Steel (Nickel Chrome) Bolts.

Photographs showing greater damage done by the wrench to the carbon steel nuts than to the alloy nuts. Also showing carbon steel bolts breaking in the shank and alloy bolts breaking at the root of the thread.

TABLE 5.

Length of Wrench.	Load when pulled tight. Carbon Bolt.	Alloy Bolt.
30-in	25,783	28,757
36-in	28,333	30,837
42-in	38,617	33,673
48-in	31,530	43,050

Referring again to Tables 3 and 4, it will be seen that the loads which were registered when the nuts were pulled up tight vary considerably. Several factors account for this variation. In the first place, it was left entirely to the trackman pulling the wrench to determine when he had the nuts tight; second, the damage done by the wrench to some of the nuts was greater than to others, making it impossible for the trackman to draw all of them up the full amount; third, the Harvey grip thread on the carbon bolts pulled much harder than the U. S. standard thread on the alloy bolts. The Harvey grip threads on the bolts run eight to the inch, while those in the nut run about 7.8 to the inch. They are rolled to fit loosely enough, so that the first three turns of the nut can be made with the fingers. The difference in pitch of the threads then takes effect, giving a much tighter nut than when threaded with the same pitch as the bolt. Furthermore, the Harvey grip threads pulled much more irregular than the U. S. standard threads, as in some cases the nuts with the Harvey grip threads could be turned down the full length of the thread with a 12-in. wrench, while others required a 30-in. wrench with considerable pull to screw them down when the bolt was clamped in a vise.

Even with such irregularities in results, the data obtained enables the establishment of a safe limit to the length of wrenches for use with bolts having different tensile strengths. Diagram 1 gives the average load in pounds pulled by the 150-lb. trackman, using four wrenches varying in length from 30 in. to 48 in., together with the actual strength in pounds of both carbon steel and alloy steel bolts varying in diameter from ¾-in. to 1¼ in. The "Wrench-pull" curve is the maximum load registered when the nuts were pulled tight with each wrench (see Table 6). The strength of the bolts is calculated (see Table 7) on the basis of minimum allowable elastic limit of the steel, namely, 48,000 lbs. per square inch for carbon and 75,000 lbs. per square inch for alloy steel. In the case of a 1-in. carbon steel bolt, for instance, the diagram shows the strength line (horizontal) crossing the "Wrench-pull" line about halfway between the 36-in. and 42-in. wrench ordinates, indicating that the 1-in. carbon steel bolt can be "wrenched up" to its elastic limit with, say, a 40-in. wrench. In the case of alloy steel it will be seen that the 1-in. bolt cannot be "wrenched up" to its elastic limit even with a 48-in. wrench, as the "Wrench-pull" line is far below the strength line along the 48-in. ordinate.

Thus the diagram indicates the length of wrench required to tighten the various bolts to their capacity. It should be remembered, however, that the "Wrench-pull" curve represents the loads that can be brought to the bolts by a 150-lb. man and not the maximum loads that can be pull and thus raise the curve. It is felt, however, since the curve represents the maximum pull registered where both the Harvey grip and U. S. standard threads were tested, that the loads would seldom be exceeded in actual track maintenance, and could, therefore, be used with safety as a guide in determining the practical length of wrench to be used with bolts of any tensile strength.

Having found the amount of strain that can be brought to a bolt with the different lengths of wrenches, the question arises as to the limit in length of wrenches for practical use. In setting the maximum limit, two questions should be considered, namely, size and weight for convenient handling by one man, and length giving sufficient leverage to permit a man of average strength to properly tighten track bolts. A 40-in. wrench weighs 8½ lbs. and, for 1-in. bolts, seems to meet with universal favor among trackmen. Anything longer is usually too heavy and too cumbersome to handle conveniently. Whether 40 in. gives sufficient leverage requires the determination of the load transmitted through the rail joint into the bolts. To secure the greatest efficiency in the rail joint, it is essential that the splices be held together rigidly. This is the primary function of the bolts and, to obtain proper rigidity, sufficient tension must be put into them so that there will be no separation of the splices under load. It seldom happens that all bolts are tightened the same amount, consequently a large percentage of the load transmitted through the joint comes in tension upon the bolts that are tightest. Undoubtedly the maximum condition is when the two middle bolts are the tightest. Taking for eample an axle load of 64,000 lbs., one wheel would impart to the rail joint a static load of 32,000 lbs. Assuming that the effect of impact adds 200 per cent. to the static load, there would be 96,000 lbs. coming to the rail joint. Each of these two middle bolts would then receive one-half the horizontal component of 96,000 lbs. acting upon the wedging surface of the splice bars (26°), namely, 21,043 lbs.

$$\begin{aligned}\tfrac{1}{2}\text{ horizontal component, }96{,}000\text{ lbs.} &= \frac{96{,}000 \times \sin 26^\circ}{2}\\ &= \frac{96{,}000 \times .4384}{2}\\ &= \frac{42.086}{2}\\ &= 21{,}043\text{ lbs.}\end{aligned}$$

Therefore, to take care of the loads coming to a joint, the bolts should be tightened at least to a tension of 21,043 lbs. But, in practice, face between the splices and rail, so that it becomes desirable to bring faces and insure maintaining 21,000 lbs. as a minimum stress in the bolt. much greater tension in the bolts to take care of the ununiform bearing faces and insure maintaining 21,000 lbs. as a minimum stress in the bolt.

When a bolt has been wrenched up to 21,000-lb. tension and subsequently receives a strain of 21,000 lbs. from rolling loads, it must withstand a total of 42,000 lbs. tension.

A 1-in. bolt of 75,000 lbs. per square inch elastic limit withstands only, say, 59,000 lbs. (Table 7), so that the difference, namely, 17,000 lbs., represents the allowable greater tension that can be wrenched into the 1-in. bolt, making a total of 21,000 lbs. plus 17,000, or 38,000 lbs.

Referring now to the "Wrench-pull" curve, Diagram 1, it will be seen that 38,000 lbs. can be pulled with a 40-in. wrench, so that it seems advisable to set the maximum allowable length of track wrench for 1-in. high-tension bolts at 40 in.

On the basis of this assumption, namely, that the permissible amount of tightening depends on the elastic limit of the bolt in question, and the tension brought to the bolt by the load and impact of a maximum axle loading, Diagram 2 has been prepared giving the safe length of track wrench for use with bolts having a known minimum elastic limit per square inch. In other words, it gives the length of wrench required to bring a tension to each sized bolt not to exceed the actual elastic limit of the bolt less the load or strain brought to the bolt by the rolling load. For example, in the case of the 1-in. alloy steel bolt considered above, we have:

Actual elastic limit	59,000 lbs.
Rolling load and impact	21,000 lbs.
Permissible tension that can be wrenched into the bolt	38,000 lbs.

It is then found by use of the "Wrench-pull" curve that 38,000 lbs. can be pulled with a 40-in. wrench, so that Diagram 2 being calculated in this way, is felt to represent safe practical conditions.

The lengths derived in this way appear to be less than the lengths commonly used for track wrenches, yet the results of the experiment are considered with the belief that much of the unsatisfactory service of track bolts comes from overtaxing their strength, turning them up so tight that they stretch under the combined rolling loads and wrench loads. It seems advisable, therefore, to so regulate the length of wrenches that such injury cannot be done to the bolts under normal working conditions, and Diagram 2 is exhibited as a guide in determining the safe and practical lengths to be used.

Many complaints have been made that the metal in the jaws of some wrenches is too soft, which permits the jaws to spread, rendering them useless. This trouble has been found largely where hexagonal nuts were used. In making the bolt test, it was observed that, unless the wrench was given a full bite on the nut each time, it slipped and the nut gradually rounded and acted as a wedge to open up the jaws of the wrench. A repetition of this slipping soon damaged the wrench beyond further use. As previously stated, one of the long wrenches which spread was redressed and tempered, yet after tightening about half a dozen more nuts the jaws again spread in the same way. When again dressed and tempered, and used with the hexagonal nuts on the alloy steel bolts, there was little trouble with the jaws spreading. These nuts ran a little higher in carbon and contained some nickel and chromium which made them harder. It is believed, therefore, that a great deal of the trouble which is ordinarily attributed to the wrench is due as well to the soft metal in the nut. It is also due to the shape of the nut. Square nuts made of the same quality of steel seldom become so rounded that they cannot be turned, even after the jaws of the wrench have been slightly sprung. The use of hexagonal nuts became necessary in the development of heavy, reinforced splice bars, as the reinforcing ribs so diminished the clearance on the outside surface of the bars that square nuts could not be used. This is now being overcome by the use of thicker spring-washer nutlocks and chamfered nuts.

B.&O. R.R.CO.

TEST OF TRACK BOLTS & WRENCHES

CARBON STEEL BOLTS

An Experiment to Determine the Safe Length of Wrench for Use with 1 Inch Track Bolts

Office of Engr. M. of W. Balto. Md. March 1914.

TABLE NO. 3.

Length of Wrench	Bolt No.	Diam. of Thrd		% Re-duct.	Diam. of Bolt		% Re-duct.	Length of Bolt			% Elong.	Load to Pull Tight	Stress per Sq. In.	Load at Elastic Limit	Stress per Sq. In.	Load at Failure	Stress per Sq. In.	Remarks
		Before Test	After Test		Before Test	After Test		Before Test	At Elastic Limit	After Test								
30"	1	1.046	1.046	0.0	0.990	0.818	31.8	4.900		5.500	12.2	26,850	34,900	40,000	52,000	49,450	64,400	Max. reduction in body of bolt No twisting in bolt.
	5	1.050	1.045	0.0	0.991	0.778	38.4	4.889		5.516	14.8	23,600	30,600	41,500	53,900	48,150	62,400	Nut badly rounded by wrench No twisting.
	9	1.045	1.045	0.0	0.996	0.815	33.1	4.902		5.570	13.6	26,900	34,600	35,000	44,900	47,100	60,500	Nut slightly rounded by wrench No twisting
	Total	3.141	3.136	0.0	2.977	2.411	103.3	14.691		16.586	40.6	77,350	100,100	116,500	150,800	144,700	187,300	
	Aver.	1.047	1.045	0.0	0.992	0.804	34.4	4.897		5.529	13.5	25,783	33366	38,833	50266	48,233	62433	
36"	2	1.046	1.046	0.0	0.980	0.635	58.1	4.900		5.760	17.5	31,600	41,900	37,750	48,800	43,500	56,200	Nut slightly rounded by wrench. No twisting of bolt.
	6	1.052	1.046	0.0	0.992	0.742	44.1	4.890		5.581	14.1	23,550	30,400	40,400	52,300	48,000	62,200	Nut rounded by wrench prevented pulling up tight. No twisting of bolt.
	10	1.050	1.046	0.0	0.995	0.684	52.8	4.905		5.725	16.7	29,850	38,400	36,200	46,500	46,400	59,700	Nut badly rounded by wrench. No twisting of bolt.
	Total	3.148	3.148	0.0	2.967	2.061	155.0	14.695		17.066	48.3	85,000	112700	114,350	147,600	137,900	174,100	
	Aver.	1.048	1.049	0.0	0.989	0.687	51.7	4.898		5.689	16.1	28,333	37,566	38,117	49,200	45,967	58,033	
42"	3	1.045	1.045	0.0	0.990	0.800	34.8	4.950		5.610	13.3	42,600	55,400	41,500	53,800	51,100	66,400	Nut badly rounded Bolt twisted thru 20°
	7	1.047	1.045	0.0	0.996	0.645	58.1	4.947		5.808	17.4	38,650	49,600	37,150	47,600	47,350	60,800	Nut slightly rounded Slight tortion
	11	1.045	1.045	0.0	0.992	0.667	54.8	4.918		5.742	16.7	34,600	44,800	36,250	47,200	45,800	59,400	Nut slightly rounded No perceptible tortion
	Total	3.137	3.125	0.0	2.978	2.112	147.7	14.815		17.160	46.4	115,850	149,800	114,900	148600	144,250	186,600	
	Aver.	1.046	1.043	0.0	0.993	0.704	49.2	4.938		5.720	15.5	38,617	49933	38,300	49533	48,083	62,200	
48"	4	1.050	1.050	0.0	0.999	0.706	50.1	4.889		5.662	15.8	35,700	45,600	40,970	52,200	46,750	59,750	Nut badly rounded Bolt twisted 25°
	8	1.055	1.055	0.0	1.011	0.644	58.4	4.880		5.755	17.9	25,690	32,800	32,480	41,400	45,500	57,800	Nut rounded at 31,550° preventing Furthur tightening.
	12	1.047	1.047	0.0	1.009	0.734	46.1	4.865		5.599	15.1	33,200	42,300	38,200	48,700	47,800	60,900	Nut rounded at 35,650° preventing Furthur tightening. Bolt twisted 20°
	Total	3.152	3.152	0.0	3.019	2.084	154.6	14.634		17.016	48.8	94,590	120,700	111,650	142,300	140,050	168,450	
	Aver.	1.051	1.051	0.0	1.009	0.695	51.5	4.878		5.673	16.3	31,530	40,233	37,217	47466	46,683	56150	

TABLE No. 3.

J.G.P.

B.&O. R.R. CO.

TEST OF TRACK BOLTS & WRENCHES

ALLOY STEEL BOLTS

An Experiment to Determine the Safe Length of Wrench for Use with 1 Inch Track Bolts.

Office of Engr. M. of W. Balto. Md. March 1914.

TABLE NO. 4.

Length of Wrench	Bolt No.	Diam. of Thrd		%	Diam. of Bolt		%	Length of Bolt			%	Load	Stress	Load	Stress	Load	Stress	Remarks
		Before Test	After Test	Re-duct	Before Test	After Test	Re-duct	Before Test	At Elastic Limit	After Test	E-long	to Pull Tight	per Sq. In.	at Elastic Limit	per Sq. In.	at Failure	per Sq. In.	
30"	1	0.992	0.826	25.4	0.935	0.911	5.1	4.800	4.800	5.185	8.0	27,300	39,700	6,9000	100,400	72,900	106,000	Broke in thread.
	2	0.990	0.862	24.2	0.918	0.918	0.0	4.800	4.802	5.135	7.0	27,770	41,800	56,076	84,900	60,950	92,200	" " "
	3	0.990	0.783	37.5	0.932	0.932	0.0	4.835	4.847	5.206	6.7	31,200	45,700	59,850	87,800	73,270	107,000	" " "
	Total	2.972	2.471	87.1	2.785	2.761	5.1	14.435	14.449	15.516	21.7	86,270	127,200	184,926	283,100	207,120	305,200	
	Aver.	0.991	0.824	29.0	0.928	0.920	1.7	4.812	4.816	5.172	7.4	28,757	42,400	61,642	94,366	69,040	101,733	
36"	4	0.980	0.820	30.0	0.935	0.928	1.5	4.825	4.826	5.219	8.2	34,360	50,000	62,000	90,300	72,720	105,000	" " "
	5	0.985	0.855	24.6	0.935	0.916	4.0	4.810	4.830	5.164	7.5	29,700	43,200	62,200	90,500	71,100	103,000	" " "
	6	0.990	0.839	28.2	0.930	0.925	1.1	4.809	4.819	5.159	7.3	28,450	41,900	63,730	93,900	75,000	110,000	" " "
	Total	2.955	2.514	82.8	2.800	2.769	6.6	14.444	14.475	15.562	23.0	92,510	135,100	187,930	274,700	218,820	318,000	
	Aver.	0.918	0.838	27.6	0.933	0.923	3.3	4.815	4.825	5.187	7.7	30,837	45,033	62,643	91,567	72,940	106,000	
42"	7	1.000	0.825	31.9	0.933	0.912	4.4	4.805	4.863	5.268	9.7	34,920	51,000	56,000	82,000	60,000	88,000	" " "
	8	0.990	0.775	38.8	0.932	0.915	3.5	4.807	4.832	5.294	10.1	33,100	48,500	59,650	87,700	67,500	99,100	" " "
	9	1.000	0.785	38.3	0.935	0.935	0.0	4.804	4.809	5.209	8.5	33,000	48,000	61,600	89,900	72,200	104,000	" " "
	Total	2.990	2.385	109.0	2.800	2.762	7.9	14.416	14.504	15.771	28.3	101,020	147,500	177,250	259,600	199,700	291,100	
	Aver.	0.997	0.795	36.3	0.933	0.921	3.6	4.805	4.835	5.257	9.4	33,673	49,167	59,083	86,533	66,567	97,033	
48"	10	1.000	0.848	28.1	0.927	0.922	1.1	4.845	4.845	5.198	7.3	46,350	68,700	75,800	112,000	80,000	118,000	" " "
	11	1.001	0.899	20.9	0.938	0.935	0.0	4.770	4.801	4.885	2.4	44,100	63,800	71,950	104,000	88,880	128,000	" " "
	12	0.990	0.780	38.0	0.940	0.917	4.9	4.810	4.829	5.310	10.4	38,700	55,800	58,400	84,500	67,300	97,200	" " "
	Total	2.991	2.527	87.0	2.805	2.774	6.0	14.425	14.475	15.393	20.1	129,150	188,300	206,150	301,300	236,180	343,200	
	Aver.	0.997	0.842	29.0	0.935	0.925	3.0	4.808	4.825	5.131	6.7	43,050	62,767	68,717	100,467	78,727	114,400	

TABLE No. 4.

J.G.B.

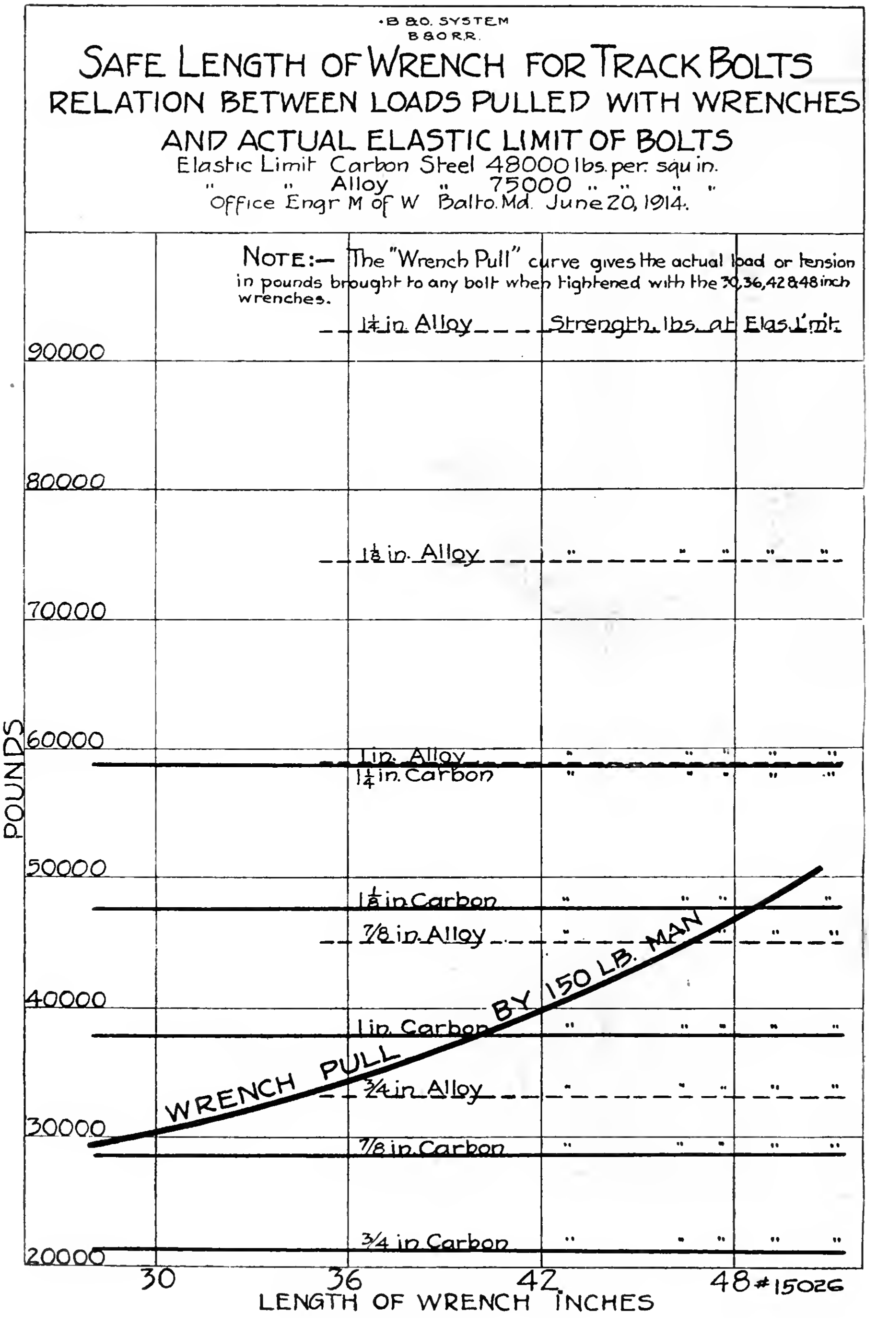
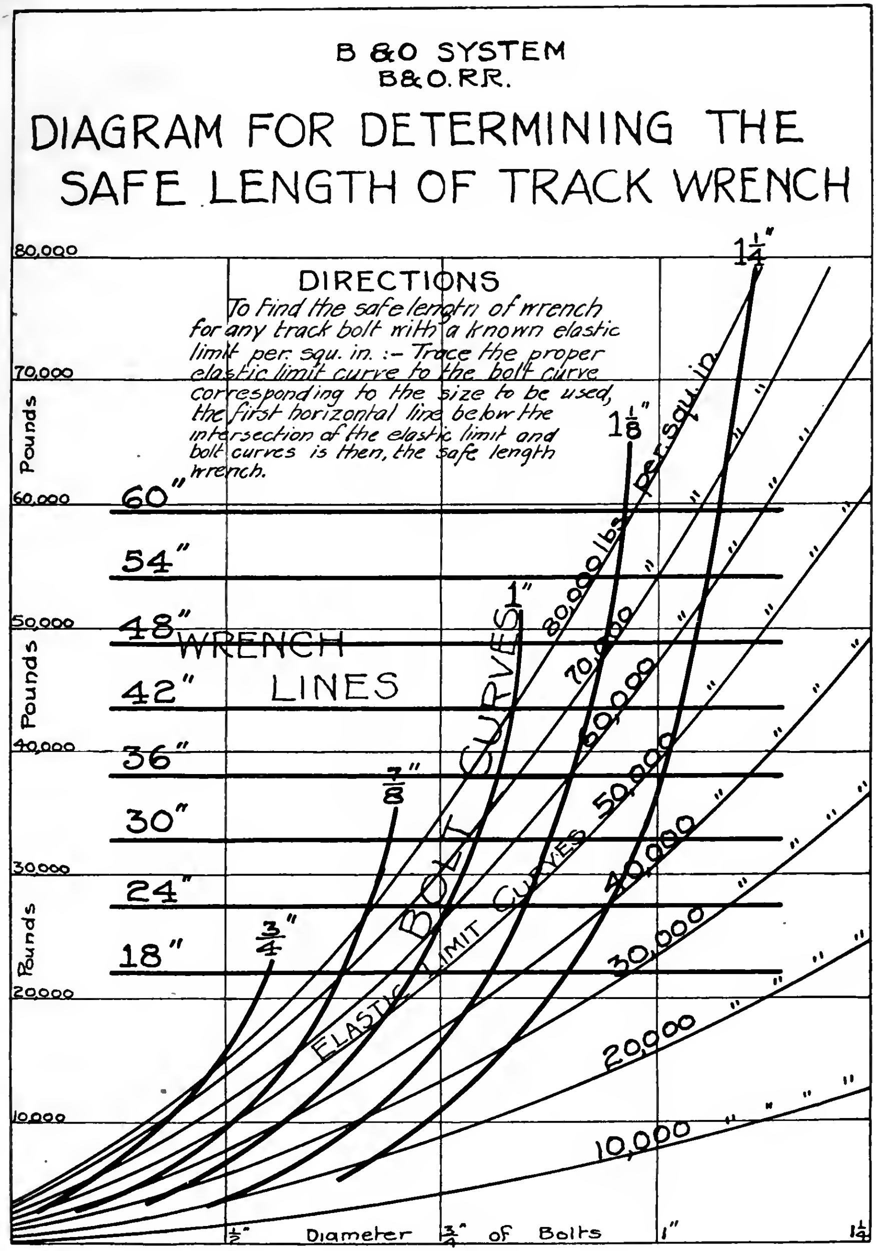

·B &O. SYSTEM
B&O R.R.
SAFE LENGTH OF WRENCH FOR TRACK BOLTS
RELATION BETWEEN LOADS PULLED WITH WRENCHES
AND ACTUAL ELASTIC LIMIT OF BOLTS
Elastic Limit Carbon Steel 48000 lbs. per squ in.
" " Alloy " 75000 " " " "
Office Engr M of W Balto. Md. June 20, 1914.
NOTE:— The "Wrench Pull" curve gives the actual load or tension in pounds brought to any bolt when tightened with the 30, 36, 42 & 48 inch wrenches.
1¼ in. Alloy Strength lbs. at Elas. Limit
1⅛ in. Alloy
1 in. Alloy
1¼ in. Carbon
1⅛ in. Carbon
7/8 in. Alloy
1 in. Carbon
3/4 in. Alloy
7/8 in. Carbon
3/4 in. Carbon
WRENCH PULL BY 150 LB. MAN
POUNDS
90000
80000
70000
60000
50000
40000
30000
20000
30
36
42
48
LENGTH OF WRENCH INCHES
#15026

DIAGRAM No. 1.



B & O SYSTEM
B & O. R.R.

DIAGRAM FOR DETERMINING THE SAFE LENGTH OF TRACK WRENCH

DIRECTIONS

To find the safe length of wrench for any track bolt with a known elastic limit per squ. in. :— Trace the proper elastic limit curve to the bolt curve corresponding to the size to be used, the first horizontal line below the intersection of the elastic limit and bolt curves is then, the safe length wrench.

Diagram No. 2.

TEST OF DOUGLAS FIR BRIDGE STRINGERS.

By H. B. MacFarland,
Engineer Tests, the Atchison, Topeka & Santa Fe Railway System.

COMPARATIVE TEST OF TREATED AND UNTREATED DOUGLAS FIR STRINGERS TO DETERMINE THE EFFECT OF TREATMENT ON PHYSICAL PROPERTIES.

OBJECT.

The object of this test was to determine whether the moisture could be properly removed from Douglas Fir stringers by a process of creosoting involving boiling under vacuum, and to determine whether this method of treatment had a detrimental effect upon the physical properties of the material.

Former tests have demonstrated that the strength of Douglas Fir is decreased approximately one-third when the material is subjected to any process of creosoting involving high temperatures during treatment.

The St. Helens Creosoting Company, St. Helens, Ore., submitted some experimental data on small specimens showing that the strength of Douglas Fir is not appreciably affected when the moisture is removed by boiling under vacuum, preliminary to creosoting.

ARRANGEMENTS FOR TESTS.

Arrangements were made with the St. Helens Creosoting Company to treat a test lot of 100,000 feet of 7 in. by 16 in. by 30 ft. commercial bridge stringers by the process of removing the moisture by boiling under vacuum, and at a temperature of from 180 to 190 degrees Fahrenheit.

Selection of the material for treatment and for physical tests was made under the personal supervision of Messrs. G. E. Rex, Manager Treating Plants, Santa Fe System; A. F. Robinson, Bridge Engineer, Santa Fe System; E. O. Faulkner, Manager Tie and Timber Department, Santa Fe System; O. P. M. Goss, Consulting Engineer for the Pacific Coast creosoting and timber interests, and the writer. All were present during the treatment, and others representing railway and creosoting interests.

The work at the treating plant was conducted from November 1 to 10, 1915, actual treating taking place from November 4 to 8, 1915. The regular plant equipment was used, care being exercised to check all gages and thermometers by calibrated instruments taken from the Topeka Laboratory.

MATERIAL.

From the lot of 356 stringers in this order, 61 were selected for test purposes. Fifty-two of these stringers were cut in two, the two halves given corresponding test numbers, one-half being treated and the other half held as a control, to determine the effect of the treatment on the wood. Nine stringers were selected after treatment for special tests. All specimens selected for test were representative of the entire lot, as to physical structure and prevailing defects.

TREATMENT.

In the boiling under vacuum process of creosoting as practiced by the St. Helens Creosoting Company, the charge of green or water-soaked timber is placed in the retort, which is then filled with creosote oil at a temperature of from 150 to 180 degrees Fahrenheit. The temperature of the oil is gradually increased to 190 degrees Fahrenheit, and then held at that temperature, under atmospheric pressure, until the timber is uniformly heated. A vacuum is then drawn and the temperature maintained at 190 degrees Fahrenheit to remove moisture. In treating this material the preliminary heating period was 5 hours after the charge had attained the desired temperature. The boiling under vacuum was continued until the average condensation for two consecutive hours was less than one-tenth of a pound of water per cubic foot of timber per hour; this required from 14 to 15½ hours, at the end of which period additional oil was added and 5 to 10 lbs. pressure applied to insure the retort being full of oil before the pressure pumps were started.

The steam in the heating coils was then turned off and oil pumped from the measuring tanks into the retort. The pumping was continued and the pressure in the retort was increased until the desired treatment of twelve pounds per cubic foot was forced into the timber. This operation required from four and one-half to six hours and the pressure reached a maximum of 132 lbs. per square inch. The oil was then forced back into the high tank with air pressure, and a vacuum drawn on the retort for thirty minutes to surface dry the charge.

Specimens for physical tests were distributed as follows in the four charges necessary for treating the entire lot:

Charge No.	Plant Run.	Retort.	Test Specimens.
1	172	E	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12 and 13.
2	173	F	10, 16, 17, 19, 22, 23, 25, 26, 27, 30, 31, 32 and 33.
3	174	F	14, 15, 18, 20, 21, 24, 28, 29, 34, 35, 36, 37, 38, 39 and 40.
4	175	E	41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51 and 52.

Following is a summary of treating plant logs for each of the above charges:

	Charge Number.			
Preliminary Warming Period.	1	2	3	4
Time—hr. min.	2–00	2–20	3–30	4–30
Temp. deg. F.:				
Start	....	165	155	128
Final	190	179	191	190
Heating Period.				
Time—hr. min.	5–00	5–00	5–00	5–00
Temp. deg. F.:				
Maximum	191	181	191	192
Minimum	189	179	190	188
Boiling Period.				
Time—hr. min.	14–00	15–30	15–30	14–00
Temp. deg. F.:				
Maximum	191	181	191	191
Minimum	188½	177	187½	189
Vacuum—Inches of mercury:				
Maximum	28¼	28¼	28¼	28½
Condensation—Water lb. per hr.:				
Maximum	2090	867	1020	790
Minimum	236	153	153	77
Pressure Period.				
Time—hr. min.	4–45	5–52	5–30	5–35
Temp. deg. F.:				
Start	189	180	191	190
Final	174	176	178	175
Pressure—lbs. per sq. in. gage, maximum	127	130	132	130
Oil from measuring tanks, gallons:				
Total	3850	3350	2625	2650
Rebound	775	800	835	650
Net	3075	2550	1790	2000
Blowing Back Period.				
Time—hr. min.	0–35	0–38	0–45	0–50
Drying Period.				
Time—hr. min.	0–30	0–30	0–30	0–30
Temp. deg. F.:				
Start	153	176	156	154
Final	150	147	148	150
Vacuum—Inches of mercury:				
Maximum	28	27½	26	26
Condensation—Water, lbs.	26	51	..	..
Total Time in Retort.				
Hr. min.	26–50	29–50	30–45	30–25

Plant log for charge No. 1, plant run No. 172, Retort E, started November 4, 1915, showing a typical detailed data sheet, as kept for each of the four runs, follows:

Time.	Temp. deg. F. Thermometer Working.	Test.	Vacuum in. of Mercury.	Condensation Inches.	Remarks.
12:30 P. M.	..	..	..	..	Load in 12:30 P. M.
2:30	180	..	..	..	
3:00	190	..	..	..	Water in condenser, 51 lbs. per in.; measuring tanks hold 25 gals. per in.; oil in sump, 16½ in.
3:30	188	191	..	..	
4:00	189	192	..	..	
4:30	189½	193	..	..	
5:00	190	193½	..	..	
5:30	190	193	..	..	
6:00	190	193	..	..	
6:30	190	194	..	..	
7:00	191	195	..	..	
7:30	190½	194	..	..	Vacuum started.
8:00	189	192	18	36½	Mostly oil, no sample.
8:30	190	192	18½	41	Oil, sample taken.
9:00	189	192	21	25½	Some oil, sample taken.
9:30	190	193	21½	..	
10:00	190	193½	22	15¼	Water clear, sample taken.
10:30	190½	194	23¾	..	
11:00	191½	195	24½	14	Clear water.
11:30	191	194½	25	..	
12:00	189½	193	25	11¾	Clear water, sample.
12:30 A. M.	188½	192½	26	..	
1:00	191	193	26	10	Clear water.
1:30	190	193	26½	..	
2:00	190½	194	27	9	Clear water, sample.
2:30	190	193	27	..	Clear water, sample.
3:00	190	193	27½	10	Clear water.
3:30	190	193½	27¾	..	
4:00	190	192	27¾	8¼	Clear water.
4:30	189½	192	27½	..	
5:00	189½	191½	27½	6¼	Clear water.
5:30	191	192	27¾	..	
6:00	189½	191	27¾	6¾	Clear water.
6:30	191	192	28	..	
7:00	190	191	28	6¼	
7:30	189	192	28	..	
8:00	189	192	28	5½	
8:30	190	192	28	..	19 in. in sump tank.
9:00	190	192½	28	4¾	Supt. advises ½-hour longer.
9:30	189	193	27¼	..	Pressure started 9:30 a. m. Retort filled for pressure.

Time.	Temp deg. F. Thermometer Working.	Test.	Pressure Lbs. Per Sq. In.	Oil Measuring Tank Gage, In.	
9:43 A. M.	190½	192½	5	3	Retort filled for pressure.
10:00	188½	191	17	28	
10:30	187	189½	35	50½	
11:00	184½	187	60	69½	
11:30	182	184½	95	82	At 83 in., changed to tank No. 2, with 2½-in. readings.
12:00	181	183	105	10½	
12:30 P. M.	179	181	115	24	
1:00	177	179	120	35½	
1:30	175	176½	124	51	
2:00	174	175½	127	66	
2:15	174½	163½	..	72½	Pressure removed, 2:20, started to blow with 26 lbs. air, 31-in. rebound.
2:30	174½	163½	..	..	

Time.	Temp. deg. F. Thermometer Working.	Test.	Vacuum in. of Mercury.	Condensation Inches.	Remarks.
2:50 P. M.	..	..	..	..	Final Vacuum started.
3:00	153	163	19	..	
3:20	150	160	28	½	Vacuum broken, end of treatment.

Charge was removed from cylinders about 4:00 p. m., November 5, 1915, and left on trucks over night. Maximum thermometer inserted at center of load, not ventilated, read 181 deg. F., both top and bottom, and checked O. K. to standard. No rain over night. Charge warm in morning.

PROGRAM OF TESTS.

In order to establish the effect of the treatment and to make allowance for changes in moisture content during the lapse of time between treatment at St. Helens and tests at Topeka, proper records of weights and moisture content of all specimens were taken at St. Helens and again at Topeka. The test material was shipped to the Topeka laboratory via boat and rail, arriving December 20, 1915. On arrival it was piled outdoors until tested. Complete laboratory tests were made to determine the strength of the material. Tests on this material were started on January 17, 1916. These tests were as follows:

TESTS.

Transverse.—Full size specimens 7 in. by 16 in. by 15 ft. Specimens were supported on two I-beams, placed on the table of a 200,000-lb. Olsen testing machine. A span of fourteen feet was used with the specimen mounted on rocking knife edges to allow movement on the I-beams. The load was applied at third points through knife edges. Steel plates six inches wide were used between the knife edges and the specimen to prevent damage to the wood fiber during application of the load. Rollers were used between the top knife edges and the plate to allow movement in a horizontal plane. These details are shown by photograph, Fig. 1. Deflections were measured for the fourteen-foot span by means of a fine steel wire and scale graduated to hundredths inch. The wire was stretched over two nails driven on the neutral axis vertically above the knife edge supports. It was placed so that it did not touch the face of the beam and was kept taut by means of a weight attached to one end. Deflections were read on a mirror scale fixed back of the wire on the neutral axis of the beam at the center. The speed of the machine was regulated to conform as nearly as possible to recommended practice as outlined in the government's instructions to engineers of timber tests.

On this basis the rate of load application was maintained to give a fiber strain at the rate of 0.0010 inch per inch of outer fiber length per minute. Deflection readings were taken while the machine was in motion.

Prior to transverse tests, the specimens were weighed and a sketch made showing the exact dimensions, location of knots, shakes, checks, pith center, etc., as well as notes relative to structure and general characteristics of the individual specimen. The edge of the stringer on which the load would ordinarily be applied in bridge construction had been marked in selecting the stringers for test, and care was taken to conform to this position when placing both treated and untreated specimens in the testing machine. After placing each specimen in position, an initial load of 2,000 lbs. was applied to give a firm bearing on the supports and the deflection scale then set at zero. The load was then uniformly applied and measured at increments of 5,000 lbs. The weighing beam of the machine was kept floating after the elastic limit had been passed to record the maximum load. A description and sketch of failure for each specimen was made at the time of test.

Compression Parallel to Grain.—Specimens, 5 by 5 by 12 inches. These were cut from the full-size specimens after transverse tests, care being taken to select them from the sound material. The ends of the specimens were accurately finished parallel and perpendicular to the axis to prevent lateral distortion of the fiber during test. Each specimen was weighed, measured and sketched before it was placed in the machine. An initial load of 2,000 lbs. was then applied and the deflectometer set at zero. The load was then applied at a uniform rate and deflectometer readings taken at increments of 5,000 lbs. to the elastic limit, the deflections being read while the machine was in motion. The machine was operated at a speed to produce a fiber strain of 0.0036 inch per inch of length per minute. The weighing beam of the machine was kept balanced after the elastic limit had been passed and until the maximum load was reached. A description and sketch of the specimen showing general characteristics and location of the failure were recorded on the log sheet. The method of setting up the apparatus for this test is shown by photograph, Fig. 2.

Compression Perpendicular to Grain.—Specimens, 6 by 6 by 30 inches. These specimens were also cut from material used in transverse tests. In order to get comparable data, the load was applied through a plate 6 inches wide, on the convex side of the growth rings. The specimens were weighed, measured and sketched and all defects described before being placed in the machine. An initial load of 500 lbs. was applied and the deflectometers set at zero. The load was then applied in increments of 2,500 lbs. to the elastic limit, the machine being stopped at each load increment to take the deflectometer readings. After passing the elastic limit, only loads corresponding to deflections of one-tenth, three-sixteenths, and three-eighths inch were recorded. The average of the two deflectometer readings was taken as the true deflection. A description of the failure for each specimen was noted on the sketch made on the log sheet. The method of setting up the apparatus for this test is shown by photograph, Fig. 3.

MOISTURE.

Both the amount and distribution of moisture in the timber were obtained from borings from the end of a newly sawed section. Seven

1-inch holes two inches deep were bored as shown by photograph, Fig. 42. Borings from the four holes near the surface were kept separate from the three near the center in these determinations. A section 1 inch thick was also cut from each of the test stringers and dried to give the average moisture through the timber.

The percentage of moisture in all determinations was computed on a dry basis, i. e., weight of the dry wood was considered 100 per cent.

The method used for determination of moisture in untreated specimens is not applicable to the determination of moisture in treated specimens. The discrepancies are due to volatilization of certain constituents in the creosote at a temperature below 220 deg. F. The method of moisture determination for treated specimens was that described on page 52, Volume 16, Bulletin 168 of the American Railway Engineering Association. The method used was as follows:

The apparatus for determining the moisture for treated specimens consisted of an oil bath prepared in a galvanized iron vessel 6 inches in diameter, and 18 inches high, using lubricating oil. The chips on which the moisture was to be determined were previously weighed and placed in a side neck distilling flask. The flask was then immersed in the oil bath. The exit tube of the distilling flask extended through the galvanized can. An oil-tight joint between the exit tube and the can was made by means of a wood cork. A thermometer, graduated in Fahrenheit degrees, was placed in the neck of the flask through a wood cork. The entire flask, including the neck, was surrounded by the lubricating oil and the bath carefully heated to 250 degrees Fahrenheit from 8 to 12 hours. Care was taken not to exceed a temperature of 250 degrees Fahrenheit in order to prevent charring of the wood chips, which gives high results, due to volatilization of water of constitution in the cell structure of the wood.

The volatile oils and water expelled by the heat were condensed in the body of the pipette. A graduated cylinder under the mouth of the pipette received the products of the distillation. When it was seen that no more volatile products were being expelled, the flame from a Bunsen burner was applied to the pipette and all condensed moisture and volatile oils driven into the graduated cylinder.

The exact volume of water was easily determined by reading off the number of cubic centimeters. This represented the weight of moisture in original specimen.

ABSORPTION OF CREOSOTE.

The weight of creosote per cubic foot for the treated specimens was determined as follows:

The weight per cubic foot of dry wood in each treated specimen was assumed as being that of the corresponding untreated specimen from the same stringer. The actual weight for each untreated specimen was obtained and using the dry weight of the untreated specimen as above outlined and making moisture correction in the treated specimen, the weight of creosote absorbed per unit of volume was determined by difference. The creosote per square foot of area for each stringer was also computed from these data.

The maximum, minimum and average penetration of creosote was obtained from a newly sawed section 48 inches from the end of the specimen.

FORMULAE.

The following formulæ were used in computing the strength of specimens in the transverse and compression tests:

TRANSVERSE TEST.

$$S = \frac{P}{A} \qquad E.L. = \frac{P'}{A} \qquad J = \frac{0.75 \times P}{b \times d}$$

$$R = \frac{L \times (P + 0.75 \times W)}{b \times d^2} \qquad E = \frac{P' \times L^3}{4.7 \times b \times d^3 \times D}$$

COMPRESSION TEST.

Parallel to Grain. Perpendicular to Grain.

$$J = C.S. = \frac{P}{A} \qquad E.L. = \frac{P'}{A} \qquad C = \frac{P}{A} \qquad E.L. = \frac{P'}{A}$$

$$E = \frac{P' \times d}{A \times D}$$

P = Maximum load, pounds.
S = Stress, pounds per square inch.
C = Crushing stress at 0.5-inch compression, pounds per sq in.
$C.S.$ = Crushing stress, pounds per square inch.
J = Shearing stress, pounds per square inch.
P' = Load at elastic limit, pounds.
$E.L.$ = Stress at elastic limit, pounds per square inch.
E = Modulus of elasticity, pounds per square inch.
R = Modulus of rupture, pounds per square inch.
W = Weight of specimen, pounds.
A = Cross sectional area, square inches.
L = Length of span, inches.
D = Deflection or compression at elastic limit, inches.
d = Depth or vertical length of specimen, inches.
b = Breadth of specimen, inches.

PHOTOGRAPHS.

The photographs presented by Figs. 1 to 43, inclusive, show the methods of making tests, cross-sections of each stringer, representative specimens after test showing typical failures, penetration of creosote in typical specimens and location of borings for moisture determination. The cross-sections of specimens 53 and 55, which were used for special test, are shown by Fig. 43. The photographs of the cross-sections were taken at the ends of the untreated specimens, nearest the center of the original stringer, and consequently may be considered as also representing the structure of the treated specimens.

GRAPHS.

Results of laboratory tests for each specimen are graphically presented by Figs. 44 to 151, inclusive. On each sheet results of transverse and compression tests are plotted. The curve for the transverse test shows the relation of fiber stress in pounds per square inch in the outermost fiber to the deflection in inches. The curves for the compression tests show the relation of load in pounds per square inch to the deflection in inches. The elastic limit was taken at the point on the curves where the relation of stress to strain ceased to be proportional.

Diagrams are also presented on each sheet showing the dimensions and characteristics of the individual specimens and the point at which load was applied. Composite graphs showing results of transverse test for each of the four charges, superimposed to facilitate the study of the effect of treatment and variation in individual specimens tested, are shown in Figs. 152 and 153,

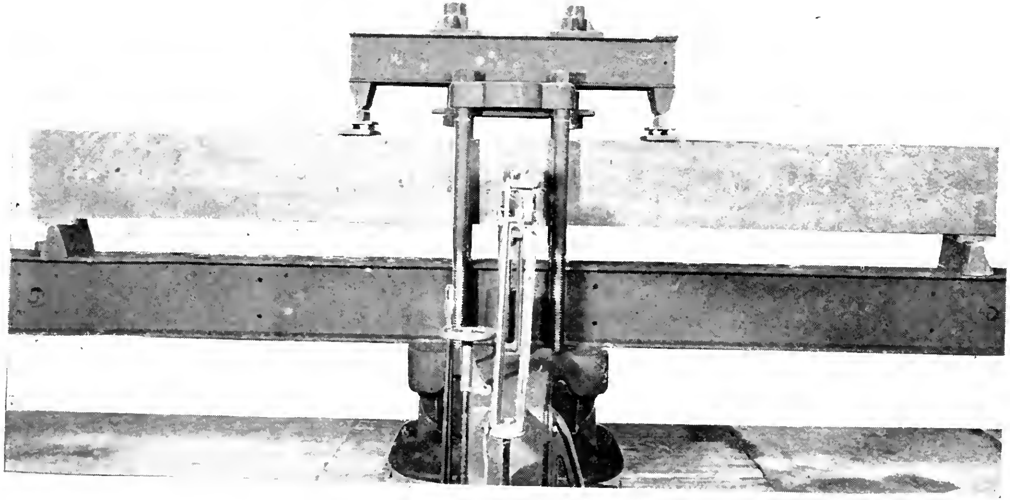


FIG. 1.

Method of making transverse tests with 200,000-lb. Olsen machine, showing extension I-beam base on platform, and method of applying two point loading with test specimen in position.

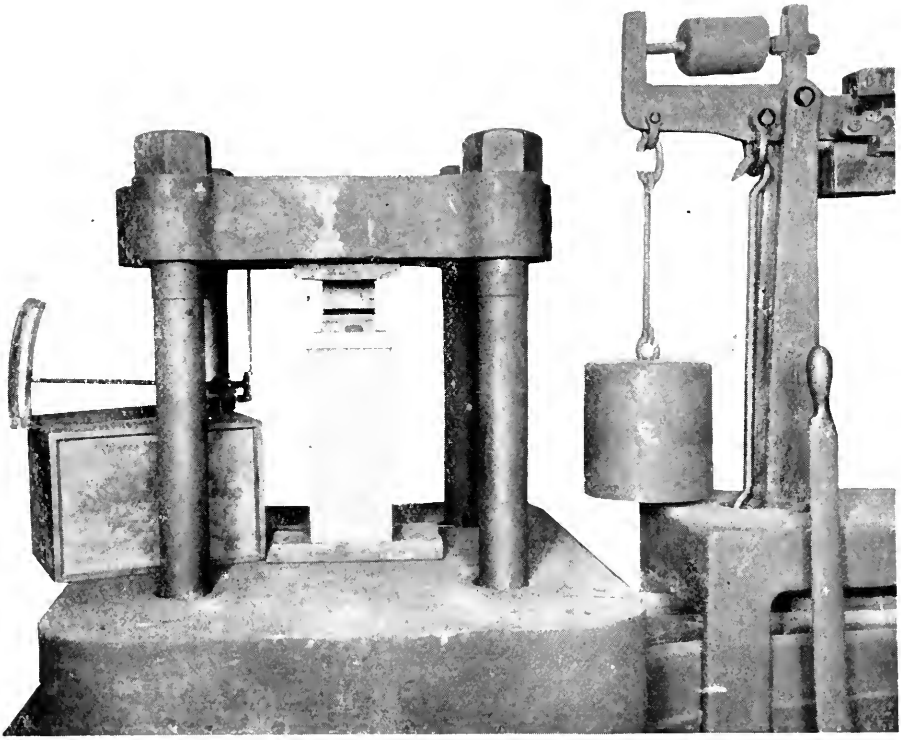


Fig. 2.

Method of making compression test parallel to grain in 200,000-lb. Olsen machine. Specimens 5x5x12 inches, with load applied through ball and socket joint under head of machine.

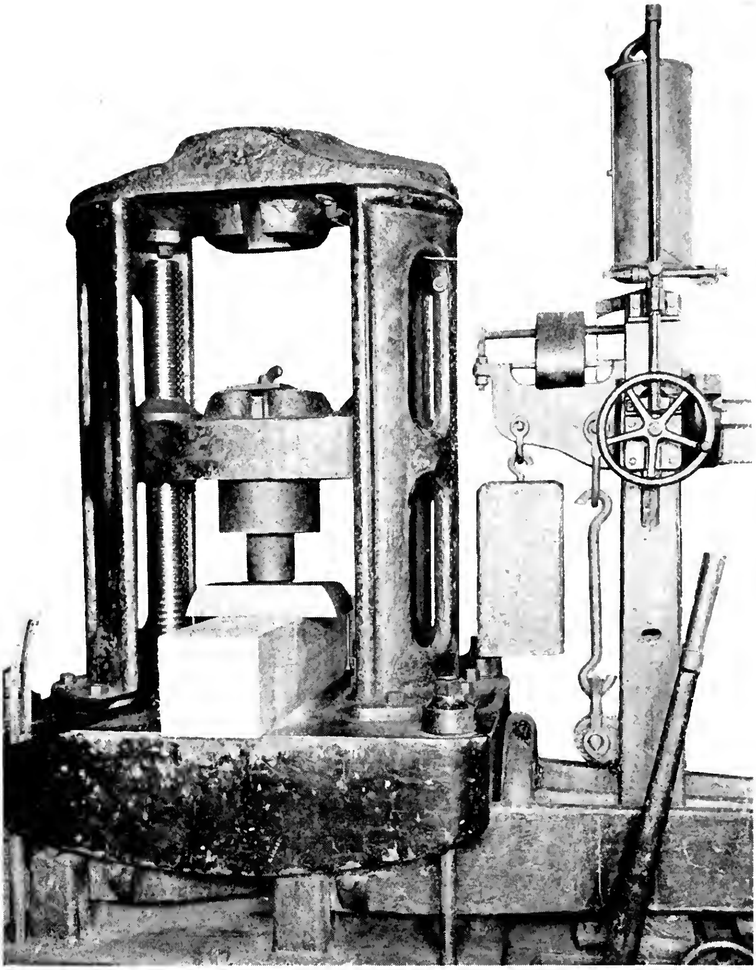


Fig. 3.

Method of making compression test perpendicular to grain in 100,000-lb. Riehle machine. Load applied through plate 6 inches wide with slightly rounded edges. Deflection measured by means of two deflectometers—one on either side.

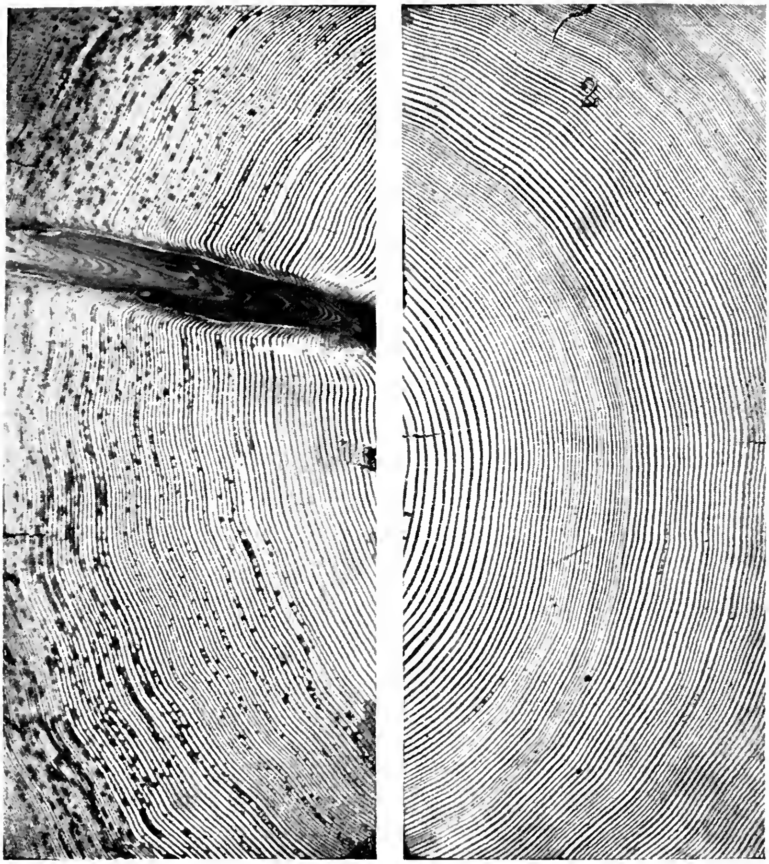


FIG. 4.

Cross-section at center of stringers 1 and 2. Stringer 1 shows side cut averaging 11 growth rings per inch, with average growth structure, and pith center, 9½ inches from center of specimen. Stringer 2 shows side cut, averaging 9 growth rings per inch, showing irregular growth and a large percentage of spring wood; pith center 7 inches from center of specimen.

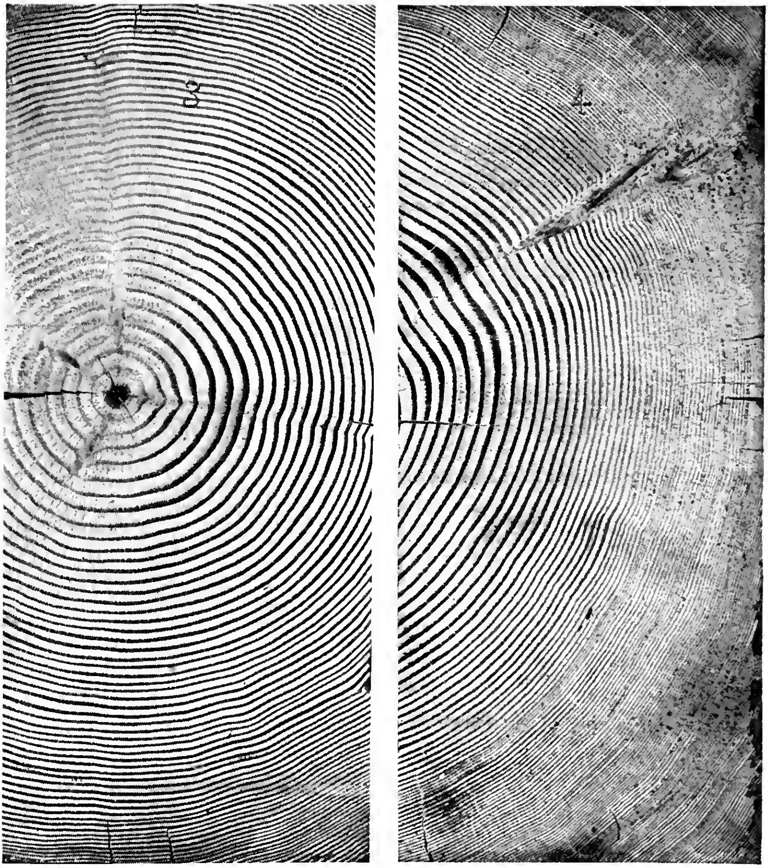


FIG. 5.

Cross-section at center of stringers 3 and 4. Stringer 3 shows box heart cut, averaging 7 growth rings per inch, with large percentage of spring wood, and pith center 2 inches from center of specimen. Stringer 4 shows side cut averaging 12 growth rings per inch, and pith center 5¾ inches from center of specimen, with large percentage of spring wood.

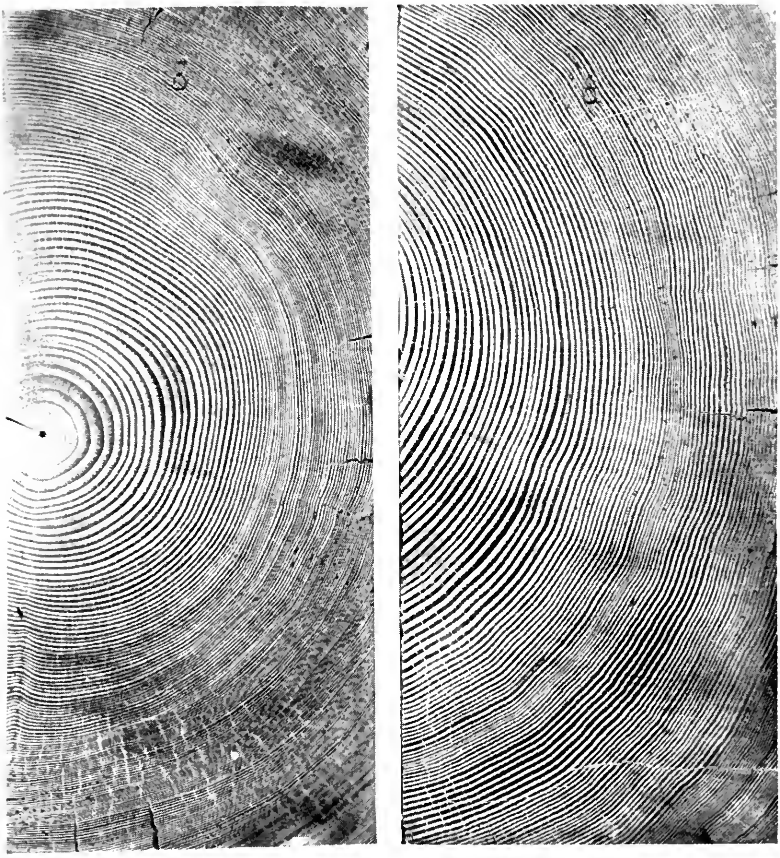


Fig. 6.

Cross-section at center of stringers 5 and 6. Stringer 5 shows box heart cut averaging 20 growth rings per inch, with small percentage of spring wood, and pith center 3 inches from center of specimen. Stringer 6 shows side cut averaging 10 growth rings per inch, and abnormal growth with small percentage of spring wood; pith center 6¼ inches from center of specimen.

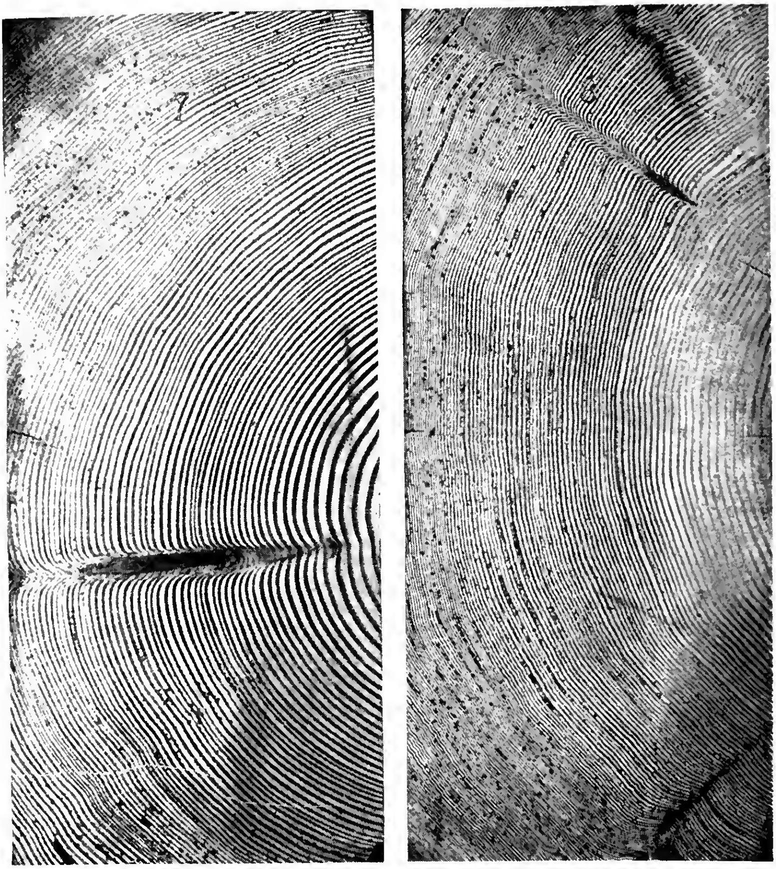


Fig. 7.

Cross-section at center of stringers 7 and 8. Stringer 7 shows side cut averaging 10 growth rings per inch, with average percentage of spring and summer wood and pith center 6¼ inches from center of specimen. Stringer 8 shows side cut averaging 12 growth rings per inch, with fairly large percentage of spring wood, and pith center 8½ inches from center of specimen.

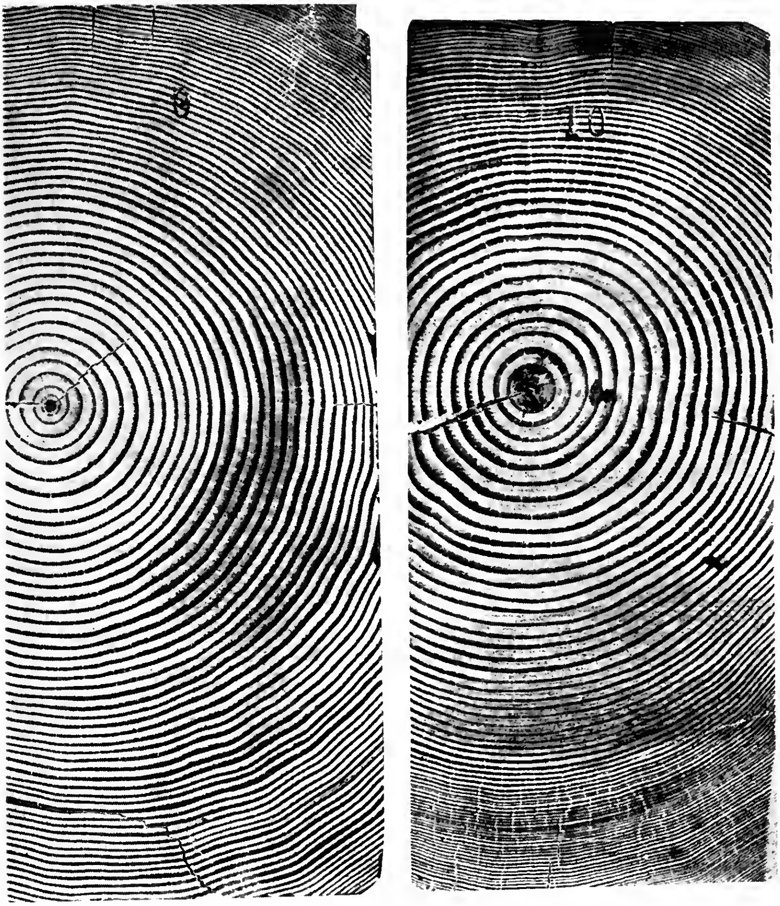


Fig. 8.

Cross-section at center of stringers 9 and 10. Stringer 9 shows box heart cut averaging 6 growth rings per inch, with rank growth and large percentage of spring wood, and pith center 3 inches from center of specimen. Stringer 10 shows box heart cut averaging 9 growth rings per inch, with small percentage of spring wood, away from pith center and pith center 1¾ inches from center of specimen.

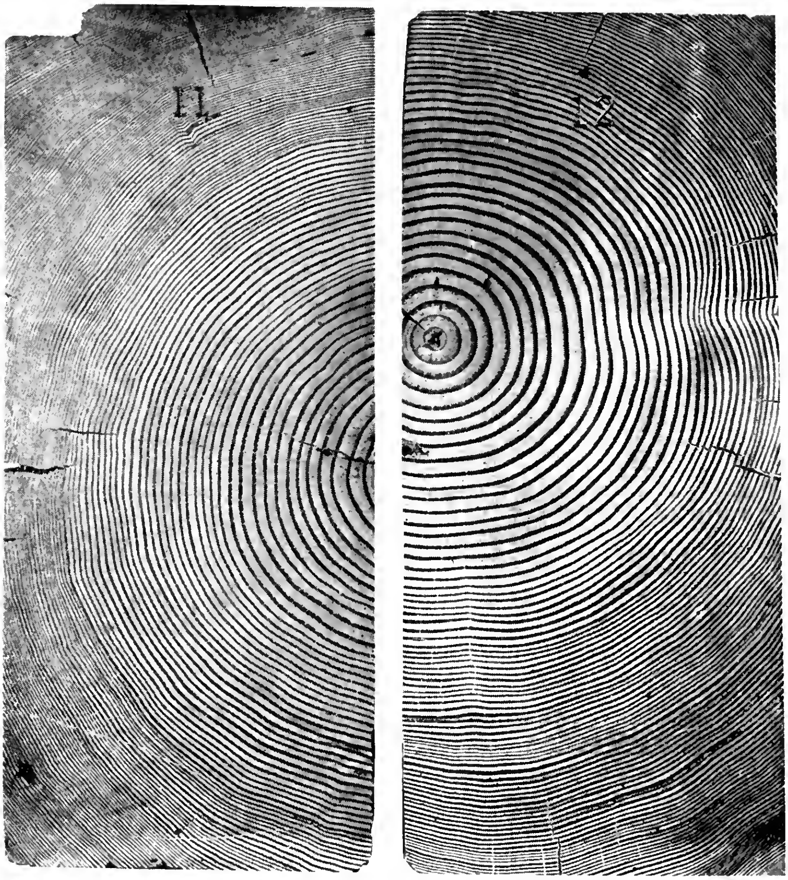


FIG. 9.

Cross-section at center of stringers 11 and 12. Stringer 11 shows side cut averaging 11 growth rings per inch, with irregular growth and large percentage of spring wood; pith center 4¾ inches from center of specimen. Stringer 12 shows box heart cut averaging 8 growth rings per inch, with large percentage of spring wood and pith center 3 inches from center of specimen.

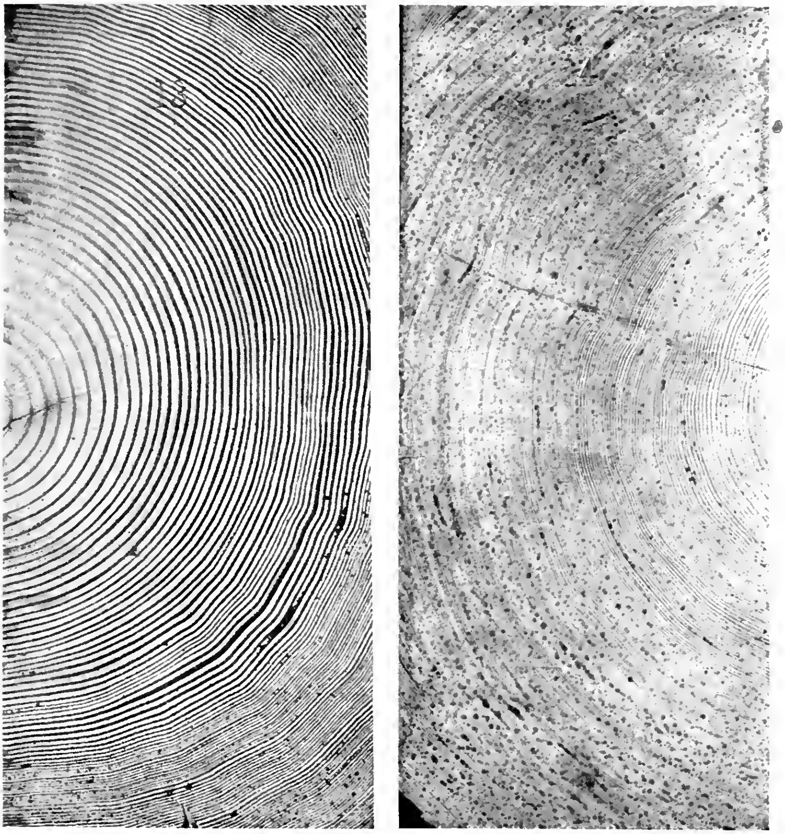


FIG. 10.

Cross-section at center of stringers 13 and 14. Stringer 13 shows side cut averaging 9 growth rings per inch, with large percentage of spring wood, average growth structure, and pith center 4¼ inches from center of specimen. Stringer 14 shows side cut averaging 27 growth rings per inch, very close growth, and pith center 5¾ inches from center of specimen.

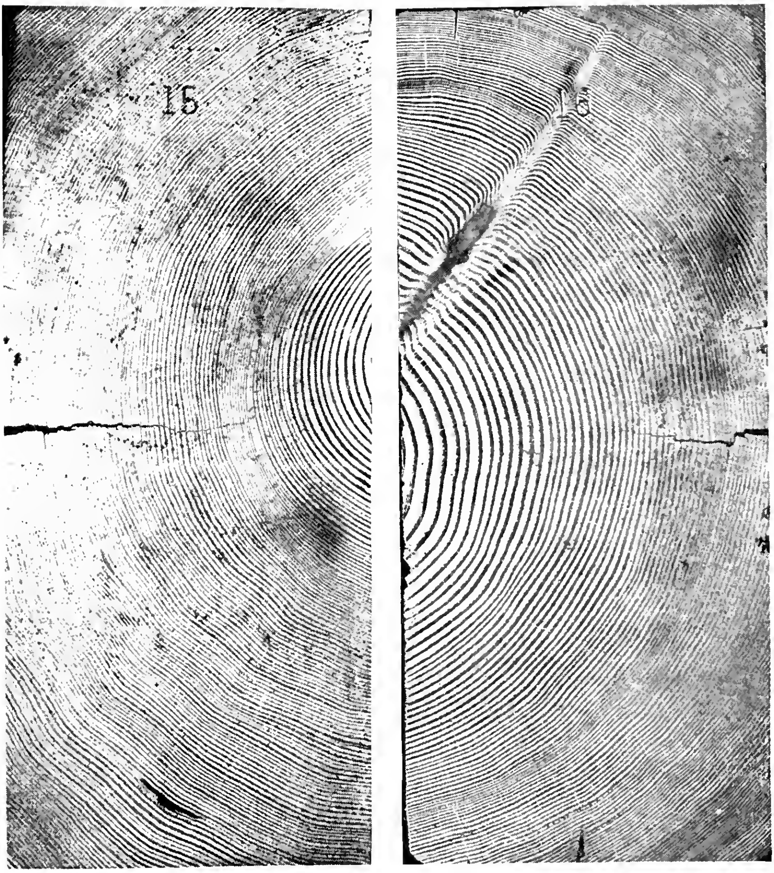


FIG. 11.

Cross-section at center of stringers 15 and 16. Stringer 15 shows side cut averaging 14 growth rings per inch, with average percentage of spring and summer wood, and pith center 5¼ inches from center of specimen. Stringer 16 shows side cut averaging 11 growth rings per inch, with heavy summer growth, and pith center 5 inches from center of specimen.

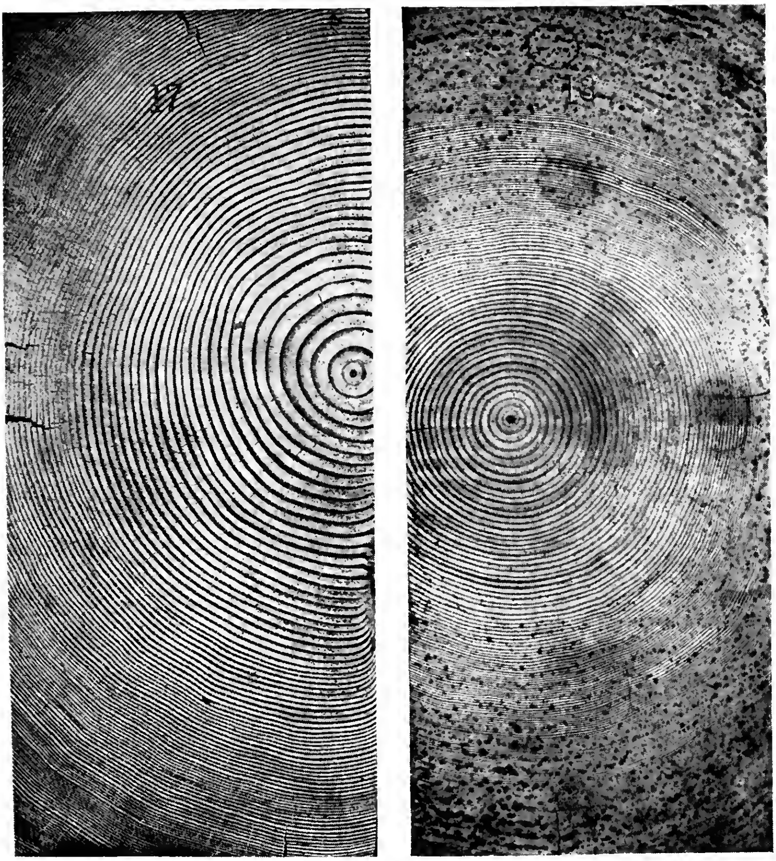


FIG. 12.

Cross-section at center of stringers 17 and 18. Stringer 17 shows box heart cut averaging 10 growth rings per inch, with a large percentage of spring wood, and pith center 3¼ inches from center of specimen. Stringer 18 shows box heart cut averaging 21 growth rings per inch, with close growth rings, and a large percentage of spring wood around pith center, which is 1½ inches from center of specimen.

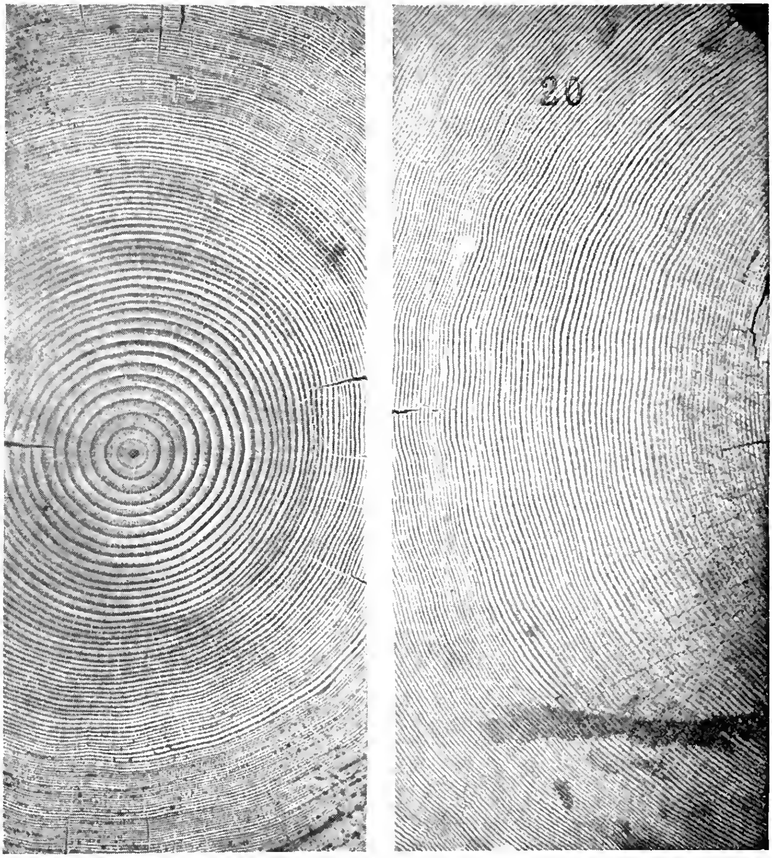


FIG. 13.

Cross-section at center of stringers 19 and 20. Stringer 19 shows box heart cut averaging 10 growth rings per inch, with a fairly small percentage of spring wood, except at pith center, which is 1¼ inches from center of specimen. Stringer 20 shows side cut averaging 11 growth rings per inch with a fairly large percentage of spring wood and pith center 7½ inches from center of specimen.

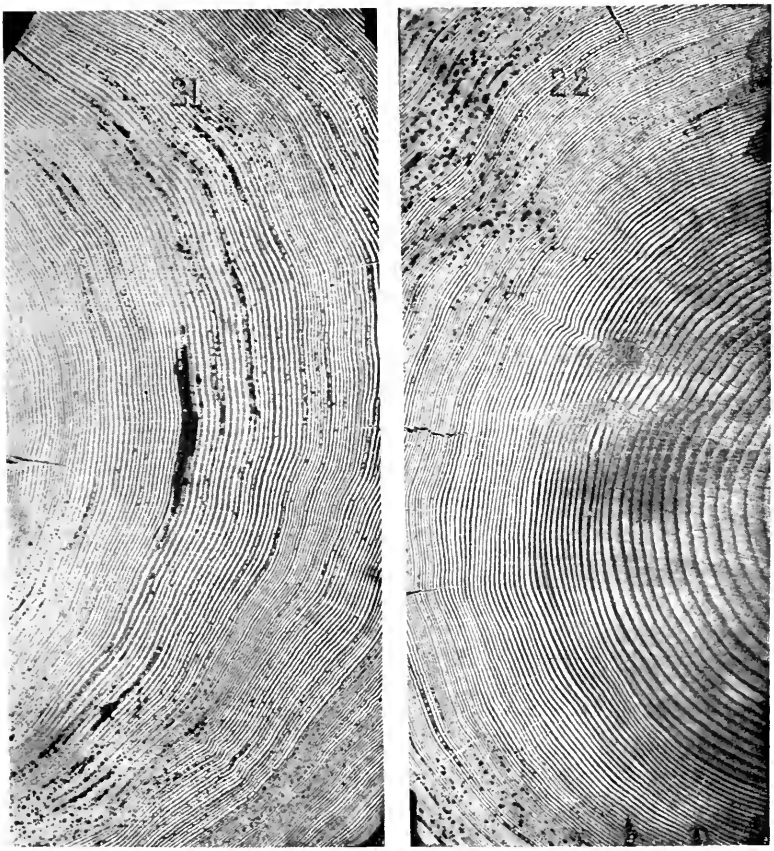


Fig. 14.

Cross-section at center of stringers 21 and 22. Stringer 21 shows side cut averaging 15 growth rings per inch with rather irregular growth and a large percentage of summer wood; pith center 8½ inches from center of specimen. Stringer 22 shows side cut averaging 13 growth rings per inch, with irregular growth and a large percentage of spring wood; pith center 8½ inches from center of stringer.

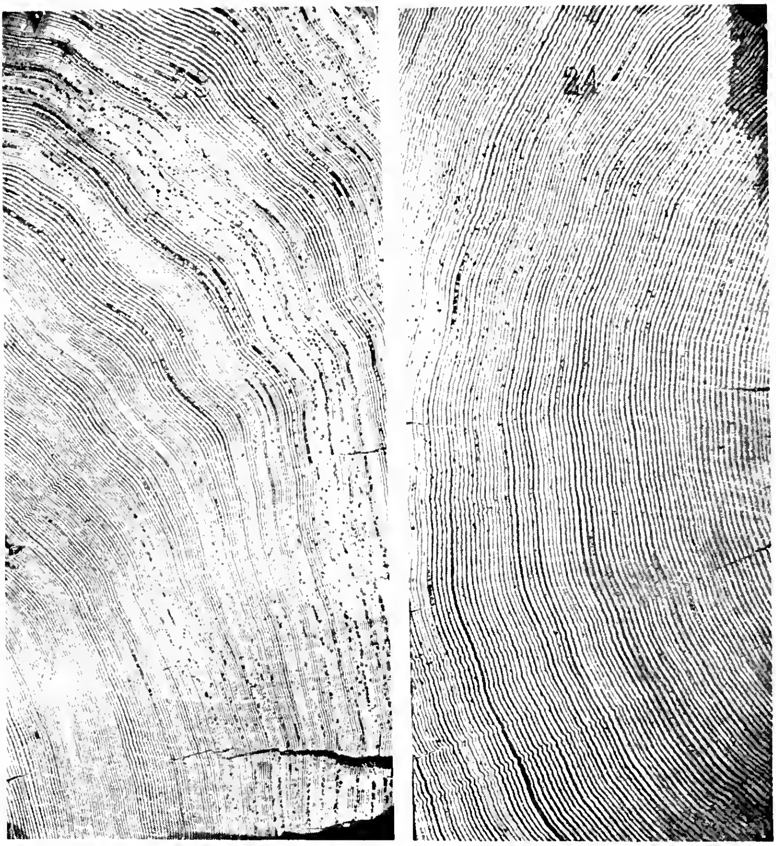


FIG. 15.

Cross-section at center of stringers 23 and 24. Stringer 23 shows side cut from quarter of log, averaging 19 growth rings per inch, irregular growth, with a small percentage of sap wood and pith center 12½ inches from center of specimen. Stringer 24 shows side cut averaging 11 growth rings per inch, with average percentage of spring and summer wood, and pith center 9½ inches from center of specimen.

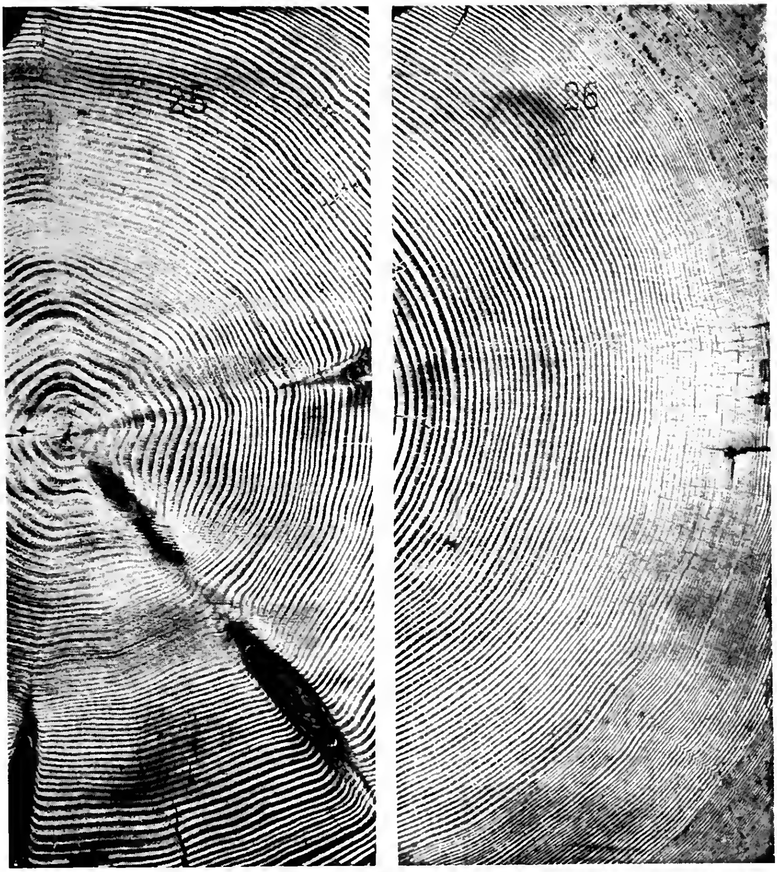


FIG. 16.

Cross-section at center of stringers 25 and 26. Stringer 25 shows box heart cut, rank growth, averaging 7 growth rings per inch, with small percentage of spring wood and pith center 2½ inches from center of specimen. Stringer 26 shows side cut varying structure, averaging 11 growth rings per inch, with heavy summer growth, and pith center 7 inches from center of specimen.

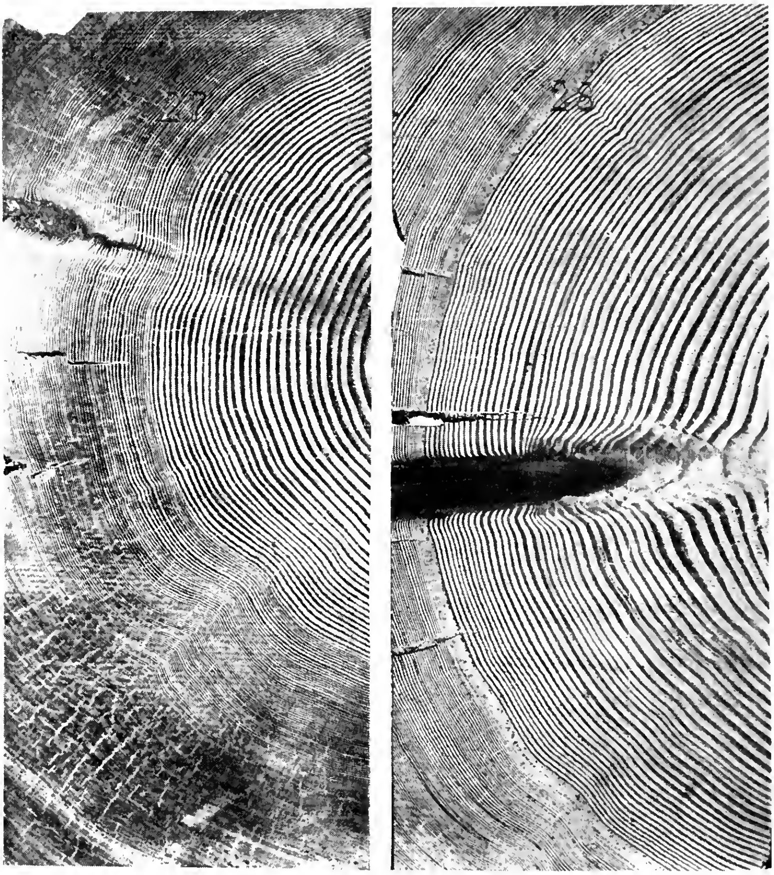


Fig. 17.

Cross-section at center of stringers 27 and 28. Stringer 27 shows side cut averaging 25 growth rings per inch, and showing irregular growth with close structure starting 5½ inches from center, small percentage of spring wood, and pith center 5 inches from center of specimen. Stringer 28 shows side cut averaging 10 growth rings per inch, and showing very irregular growth, with a large percentage of spring wood, and pith center 7½ inches from center of specimen.

Fig. 18.

Cross-section at center of stringers 29 and 30. Stringer 29 shows side cut averaging 12 growth rings per inch, with average percentage of spring and summer wood, and pith center 6 inches from center of specimen. Stringer 30 shows side cut averaging 13 growth rings per inch and showing average percentage of spring and summer wood; pith center 8 inches from center of specimen.

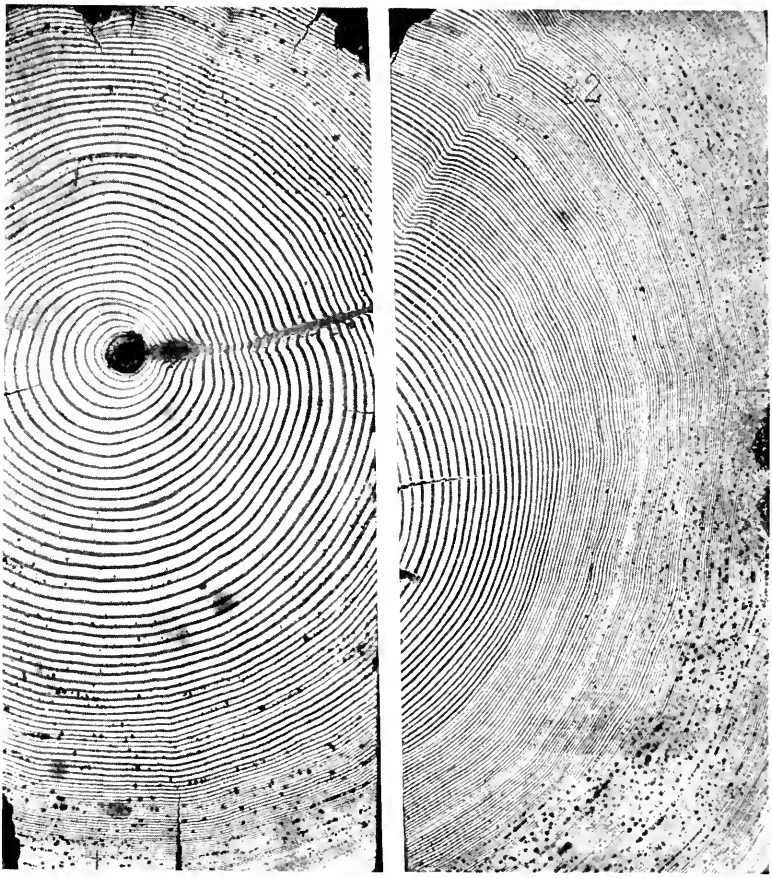


FIG. 19.

Cross-section at center of stringers 31 and 32. Stringer 31 shows box heart, cut averaging 13 growth rings per inch, with large percentage of spring wood, and pith center 2 inches from specimen. Stringer 32 shows side cut with varying growth rings, averaging 19 per inch, average percentage of spring and summer wood, and pith center 6¾ inches from center of specimen.

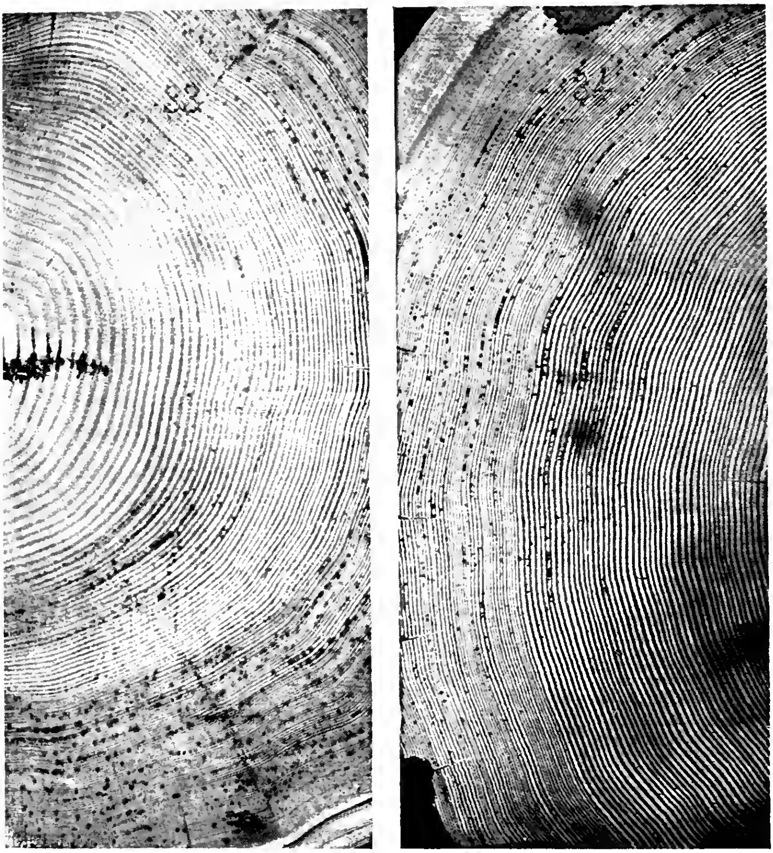


FIG. 20.

Cross-section at center of stringers 33 and 34. Stringer 33 shows side cut, irregular growth, averaging 11 growth rings per inch, with a large percentage of spring wood, and pith center 5 inches from center of specimen. Stringer 34 shows side cut averaging 14 growth rings per inch, showing change in growth conditions along line of demarcation, through center of section, small percentage of spring wood and pith center 8¾ inches from center of specimen.

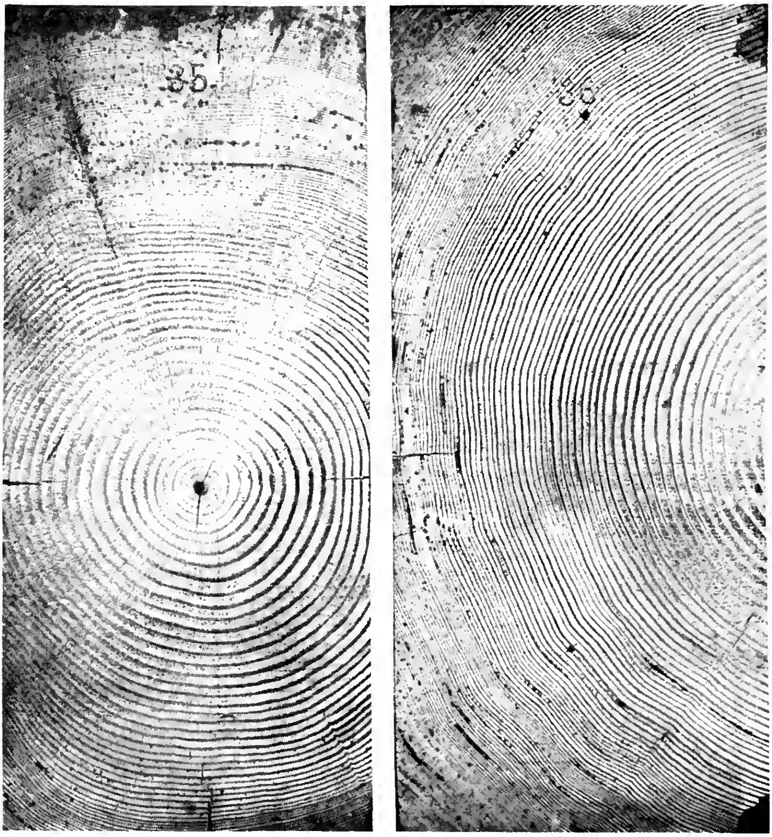


FIG. 21.

Cross-section at center of stringers 35 and 36. Stringer 35 shows box heart cut, averaging 12 growth rings per inch, with a large percentage of spring wood, and pith center 1½ inches from center of specimen. Stringer 36 shows side cut, averaging 10 growth rings per inch, with large percentage of spring wood and pith center 6 inches from center of specimen.

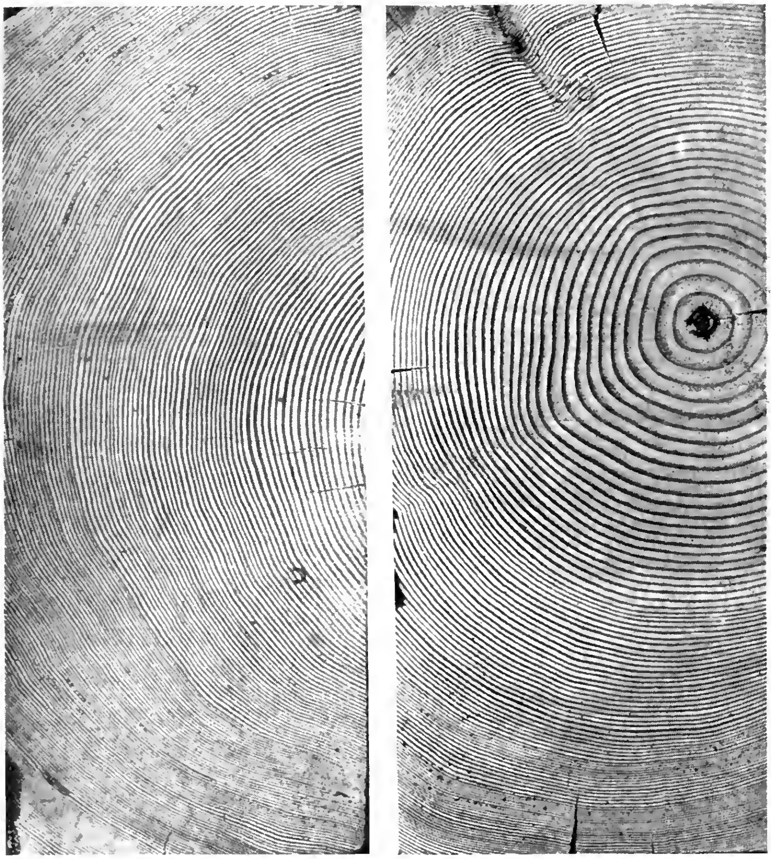


FIG. 22.

Cross-section at center of stringers 37 and 38. Stringer 37 shows side cut averaging 15 growth rings per inch, with a small percentage of spring wood, and pith center 5¼ inches from center of specimen. Stringer 38 shows box heart cut, rank growth at pith center, averaging 7 growth rings per inch, with a large percentage of spring wood, and pith center 3¼ inches from center of specimen.

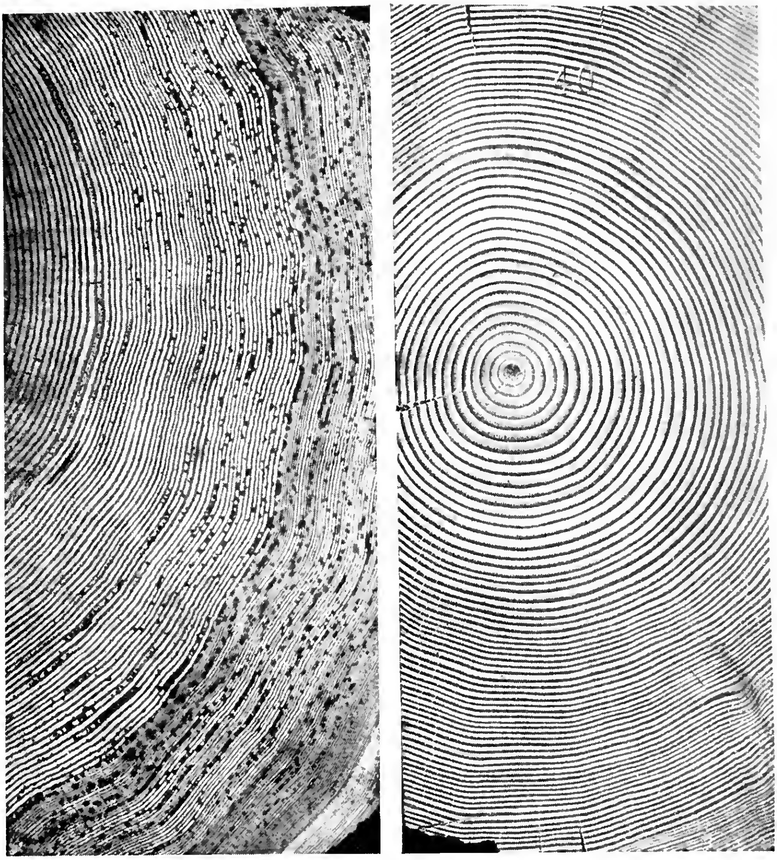


FIG. 23.

Cross-section at center of stringers 39 and 40. Stringer 39 shows side cut averaging 13 growth rings per inch, showing clearly defined irregular growth, and pith center 9½ inches from center of specimen. Stringer 40 shows box heart cut, averaging 8 growth rings per inch, showing a rank growth and large percentage of spring wood, and pith center 1½ inches from center of specimen.

FIG. 24.

Cross-section at center of stringers 41 and 42. Stringer 41 shows side cut averaging 14 growth rings per inch, showing irregular growth with large percentage of summer wood, and pith center 3½ inches from center of specimen. Stringer 42 shows box heart cut, rank growth averaging 8 growth rings per inch, showing a large percentage of spring wood, and pith center 1 inch from center of specimen.

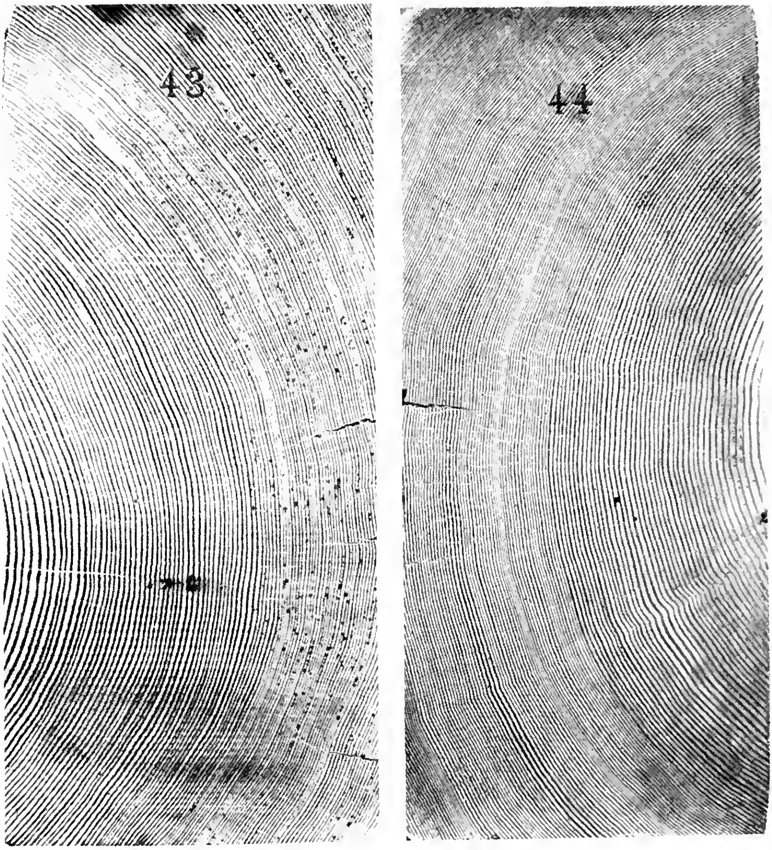


Fig. 25.

Cross-section at center of stringers 43 and 44. Stringer 43 shows side cut averaging 13 growth rings per inch, showing a fairly large percentage of spring wood, and with pith center 7½ inches from center of specimen. Stringer 44 shows side cut, averaging 17 growth rings per inch, showing an everage structure, and pith center 8¼ inches from center of specimen.

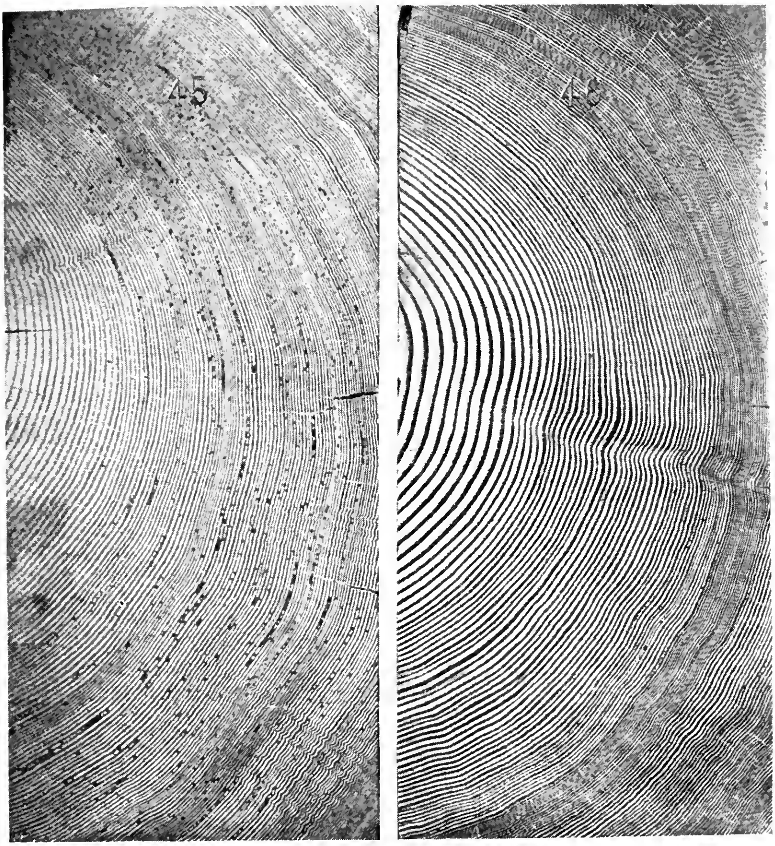


FIG. 26.

Cross-section at center of stringers 45 and 46. Stringer 45 shows side cut averaging 12 growth rings per inch, showing a small percentage of spring wood, and pith center 7¼ inches from center of specimen. Stringer 46 shows side cut averaging 11 growth rings per inch, showing large percentage of summer wood, irregular growth, and pith center 5¾ inches from center of specimen.

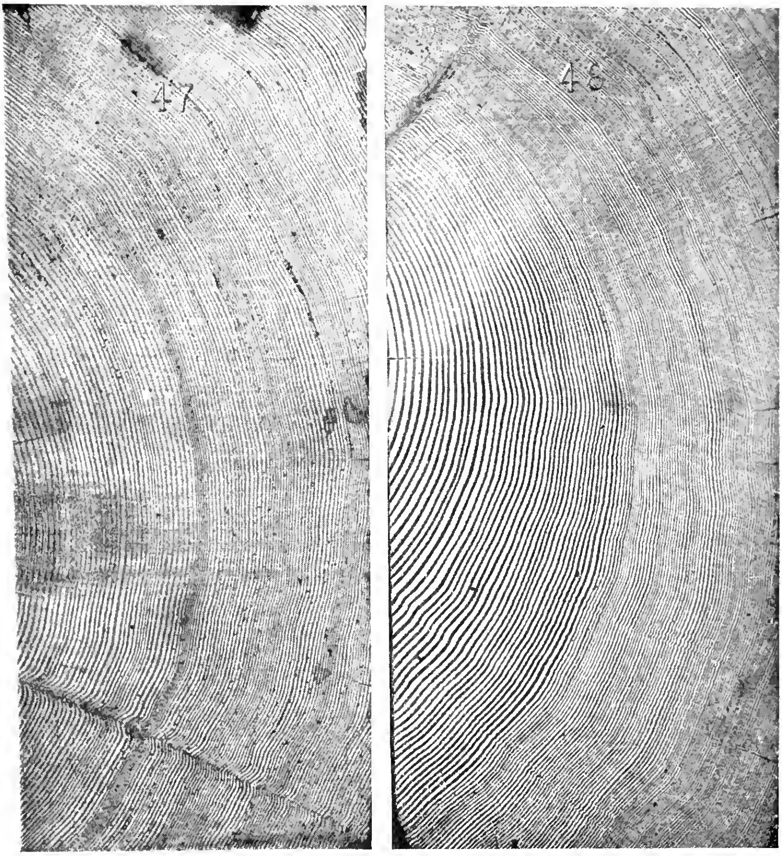


FIG. 27.

Cross-section at center of stringers 47 and 48. Stringer 47 shows side cut averaging 13 growth rings per inch, showing uniform structure, and large percentage of spring wood; pith center 10 inches from center of specimen. Stringer 48 shows side cut, averaging 12 growth rings per inch, irregular growth, an average percentage of spring wood, and pith center 8½ inches from center of specimen.

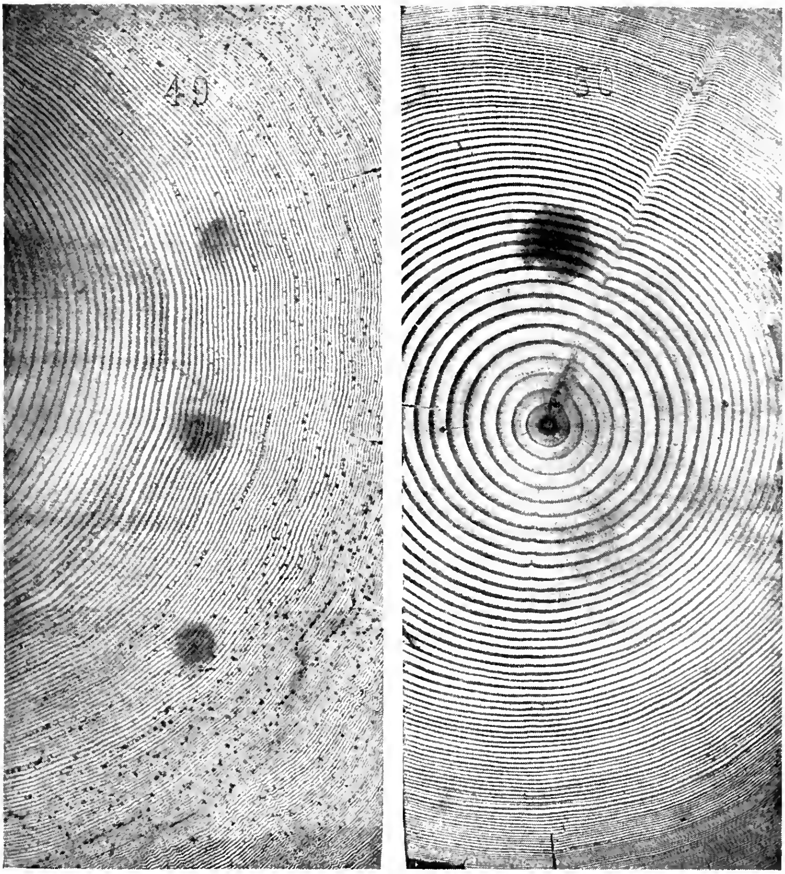


Fig. 28.

Cross-section at center of stringers 49 and 50. Stringer 49 shows side cut averaging 12 growth rings per inch, showing a large percentage of spring wood and pith center 6¼ inches from center of specimen. Stringer 50 shows box heart cut averaging 10 growth rings per inch with large percentage of spring wood, and pith center 1 inch from center of specimen.

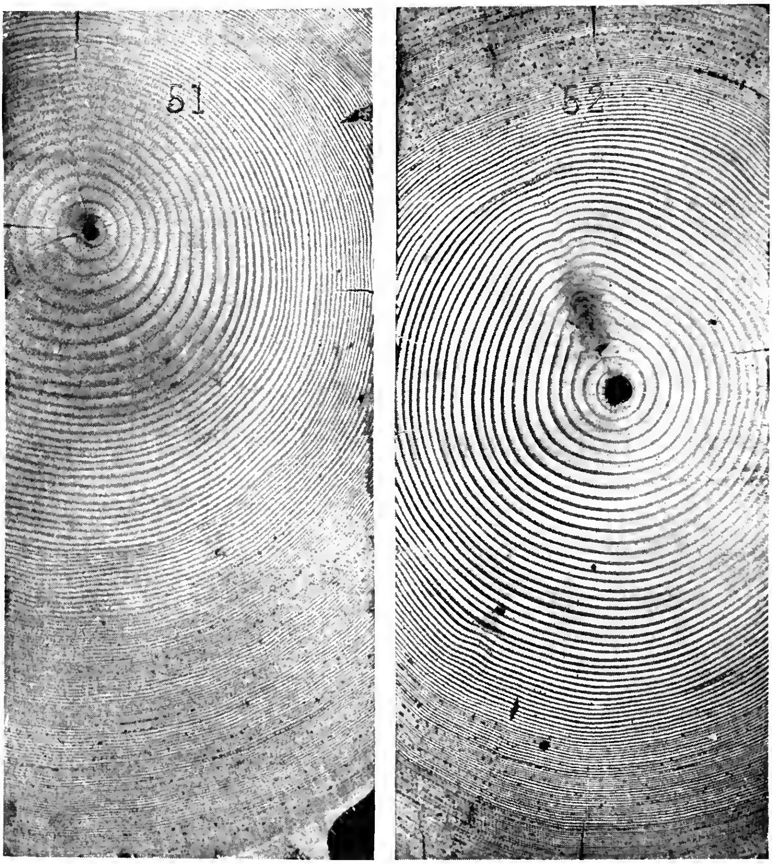


FIG. 29.

Cross-section at center of stringers 51 and 52. Stringer 51 shows box heart cut, abnormal growth averaging 11 growth rings per inch, showing a large percentage of spring wood and pith center 3½ inches above center of specimen. Stringer 52 shows box heart cut, averaging 13 growth rings per inch, a large percentage of spring wood, and pith center 1¼ inches from center of specimen.

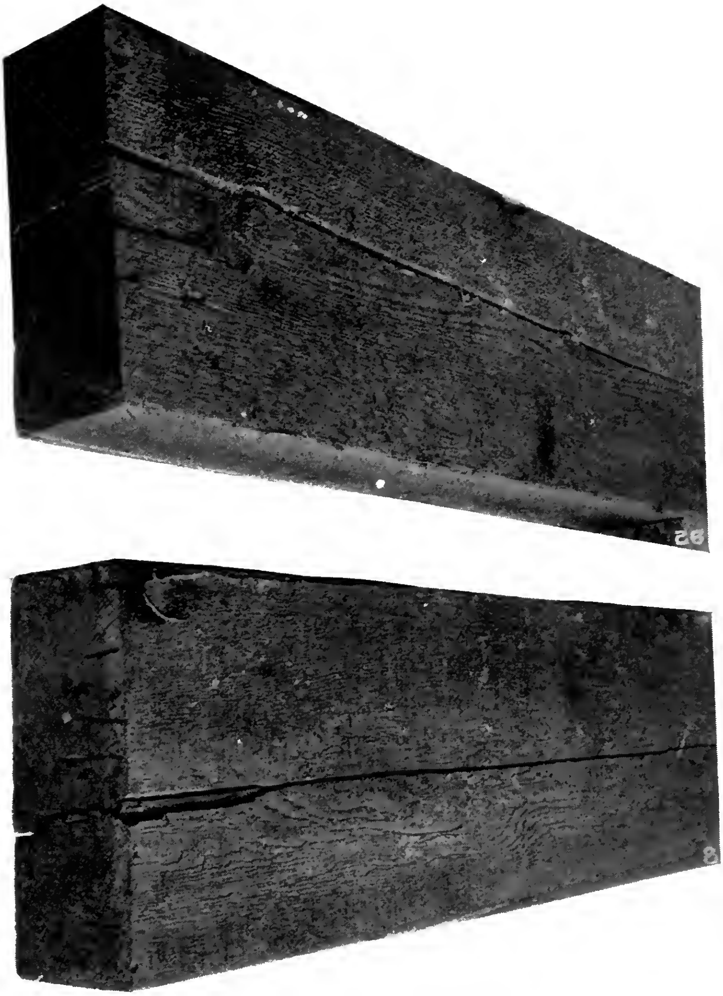


FIG. 30.

Typical longitudinal shear failures after transverse test, treated stringers 26 and 8.

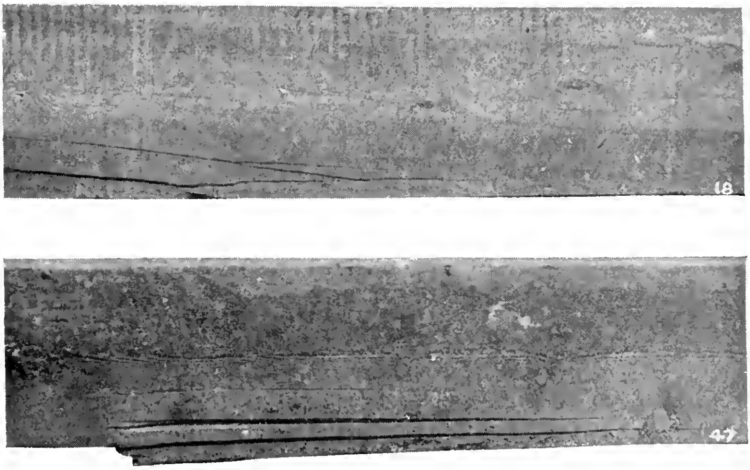


Fig. 31.

Typical slivering tension failures after transverse test, treated stringers 18 and 47.

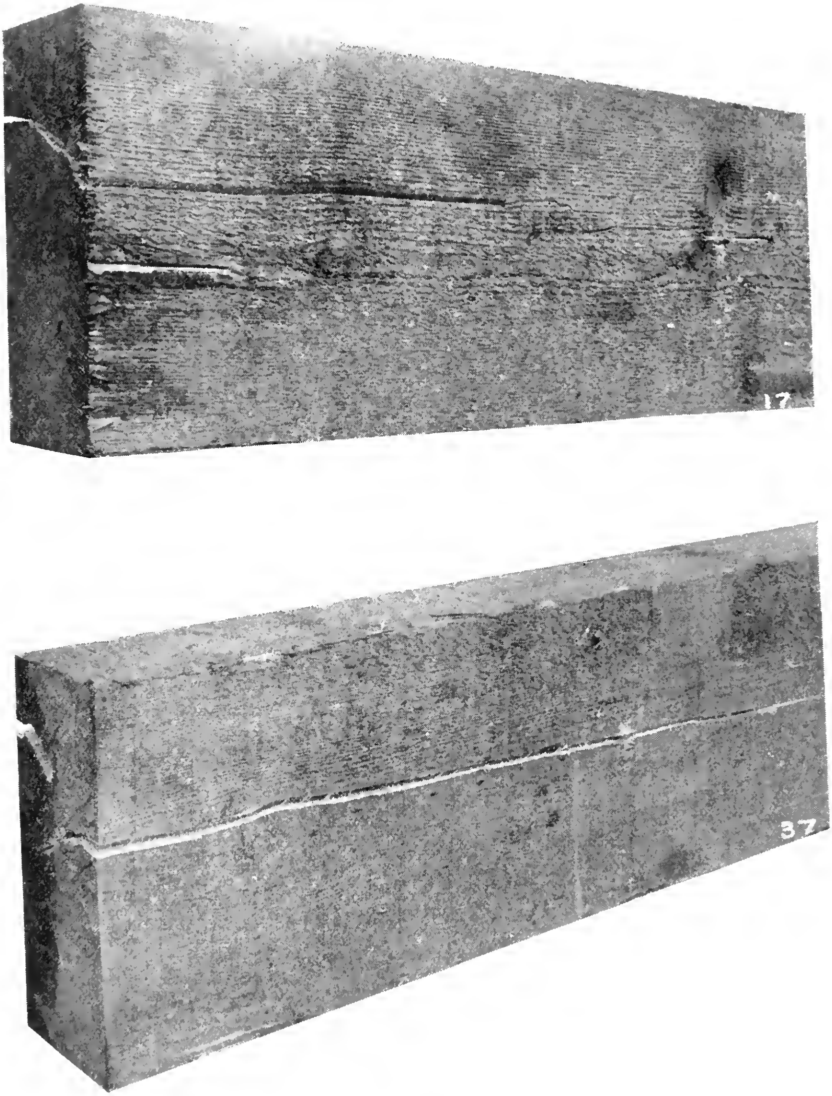


FIG. 32.

Typical longitudinal shear failures after transverse test, untreated stringers 17 and 37.

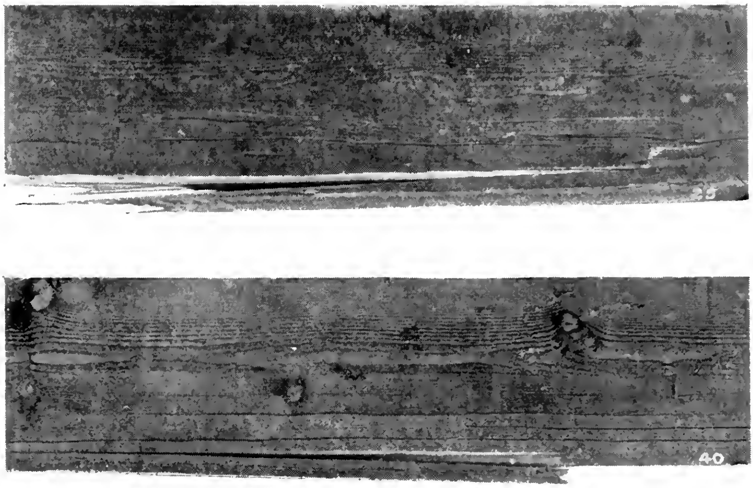


FIG. 33.

Typical slivering tension failures after transverse test, untreated stringers 25 and 40.

FIG. 34.

Typical cross grain tension failures after transverse test, untreated stringers 45 and 7.

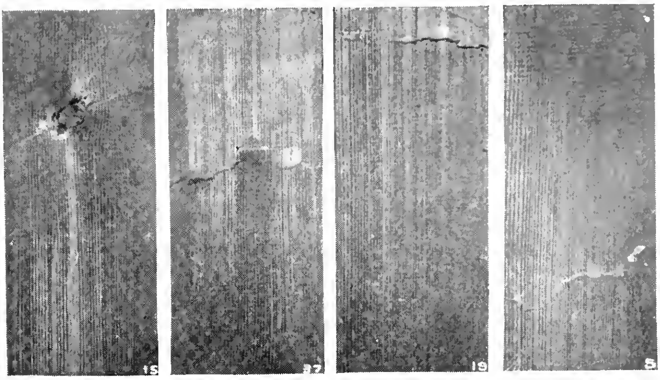


FIG. 35.

Specimens from treated stringers after compression test parallel to grain. Typical failures shown.

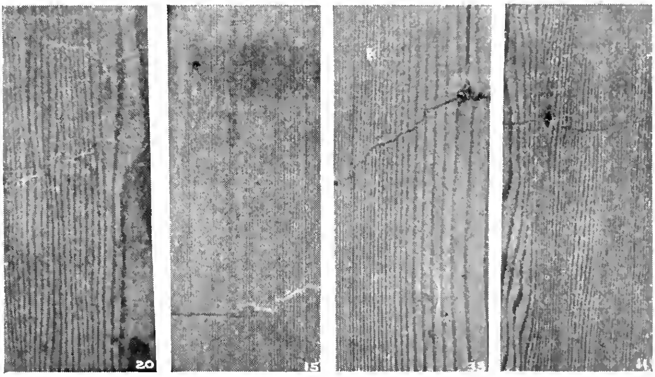


FIG. 36.

Specimens from untreated stringers after compression test parallel to grain. Typical failures shown.

FIG. 37.

Specimens from treated stringers after compression test perpendicular to grain. Typical failures shown.

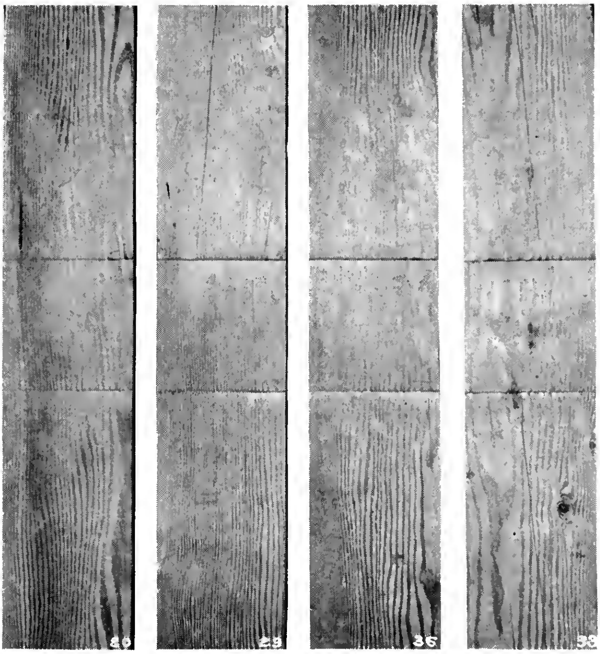


FIG. 38.

Specimens from untreated stringers after compression test perpendicular to grain. Typical failures shown.

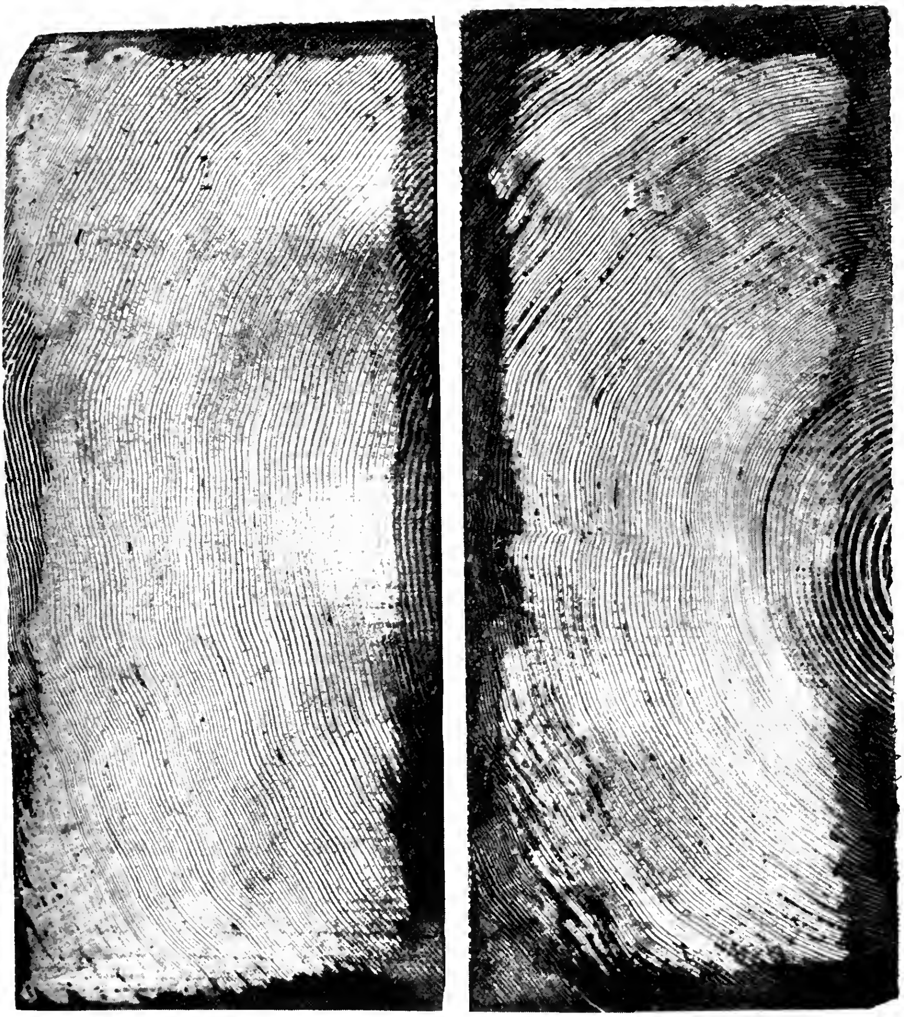


FIG. 39.

Cross-sections of treated stringers after transverse test, showing penetration of creosote in a close growth structure. Section 48 inches from end of specimen taken.

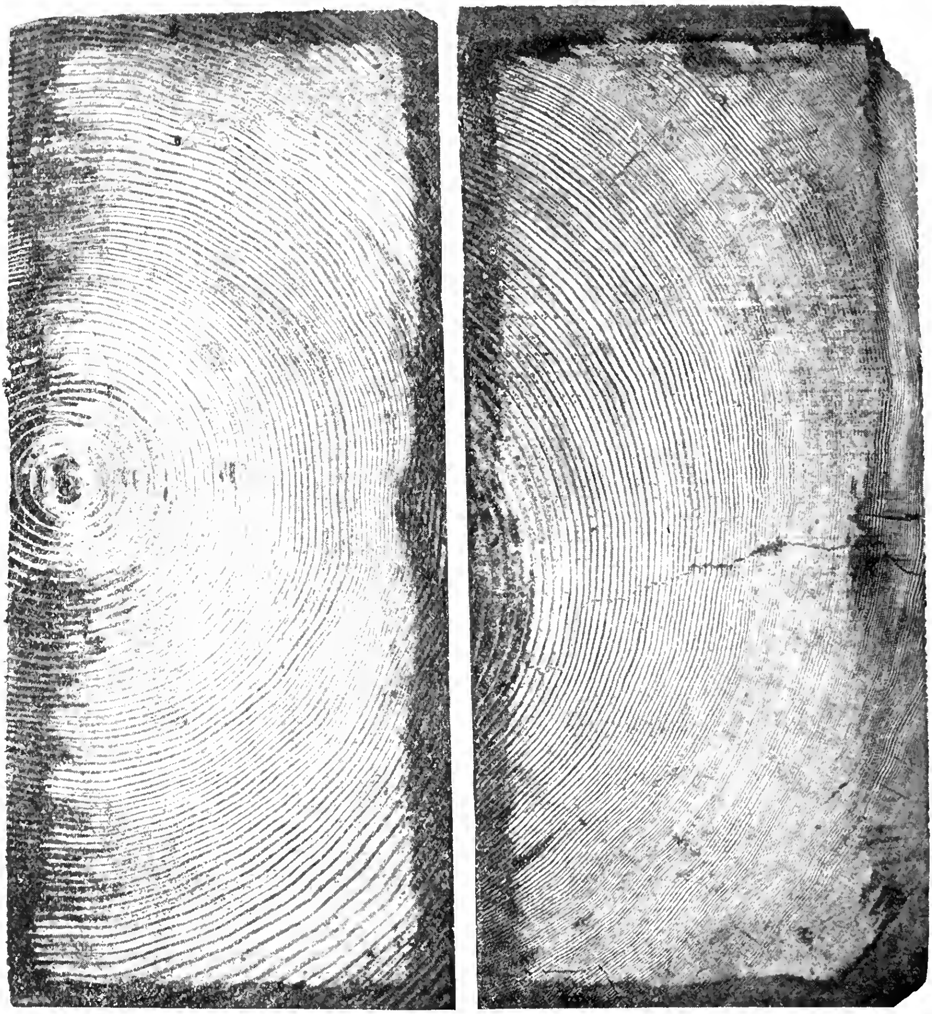


FIG. 40.

Cross-section of treated stringers after transverse test, showing penetration of creosote in an average growth structure. Section taken 48 inches from end of specimen.

FIG. 41.

Cross-section of treated stringers after transverse test, showing penetration of creosote in rank growth structure. Section taken 48 inches from end of specimen.

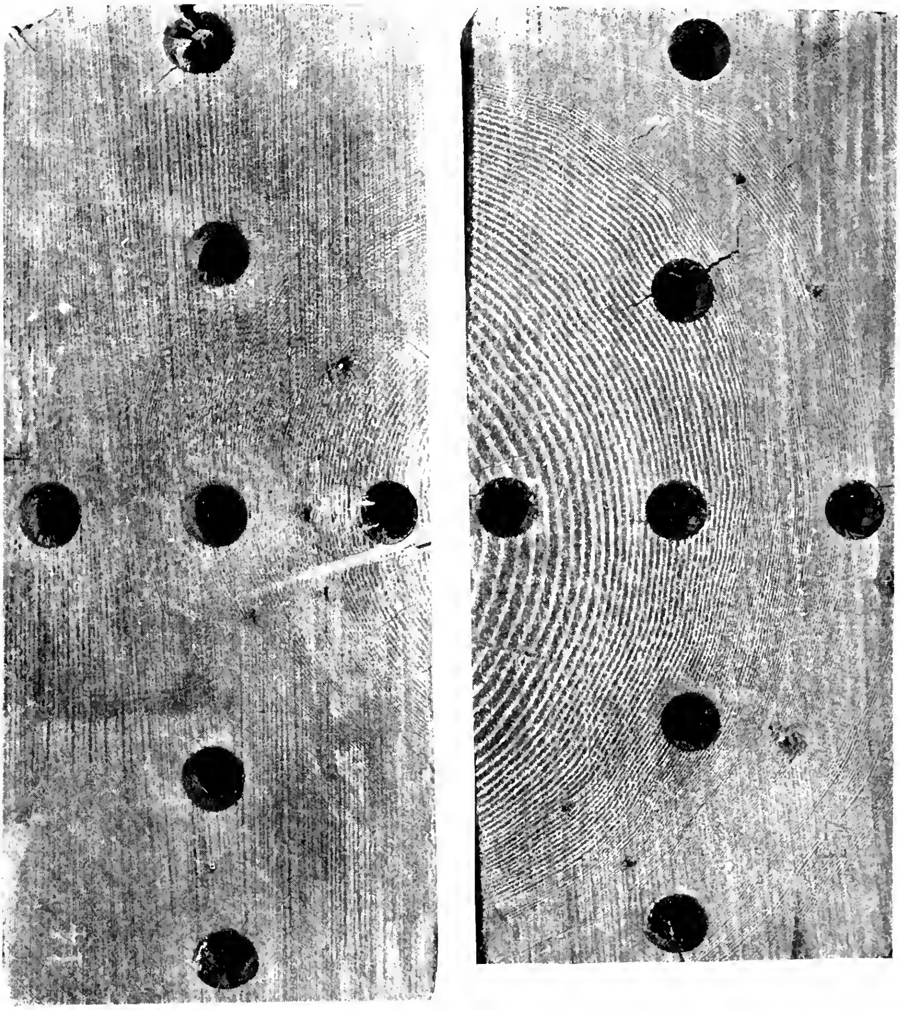


FIG. 42.

Cross-sections of stringers showing standard location of holes from which borings for moisture determinations were taken. Seven 1-inch holes, two inches deep, located as shown in each stringer. Borings from untreated stringers taken from cross-section at center and from untreated stringers at cross-sections 48 inches from center. Borings from three interior holes used for moisture determination of center region, and four holes around edges used for moisture determination at outside edge. Average of these values taken as moisture content of stringer.

FIG. 43.

Cross-sections of stringers 53 and 55 given special test to determine effect of treatment on strength of wood fiber. Treated outer surface planed off prior to test and specimen reduced from 6x16 inches to 5½x12¾ inches.

Stringer 53 shows side cut averaging 12 growth rings per inch, with a large percentage of spring wood, and pith center 8¾ inches from center of specimen. Stringer 55 shows box heart cut, averaging 6 growth rings per inch with rank growth, large percentage of spring wood and pith center 1½ inches from center of specimen.

Depth of penetration shown by photograph is not representative of the original cut, due to flow after surfacing. The original depth can be traced (by careful examination) as about one-third of that shown.

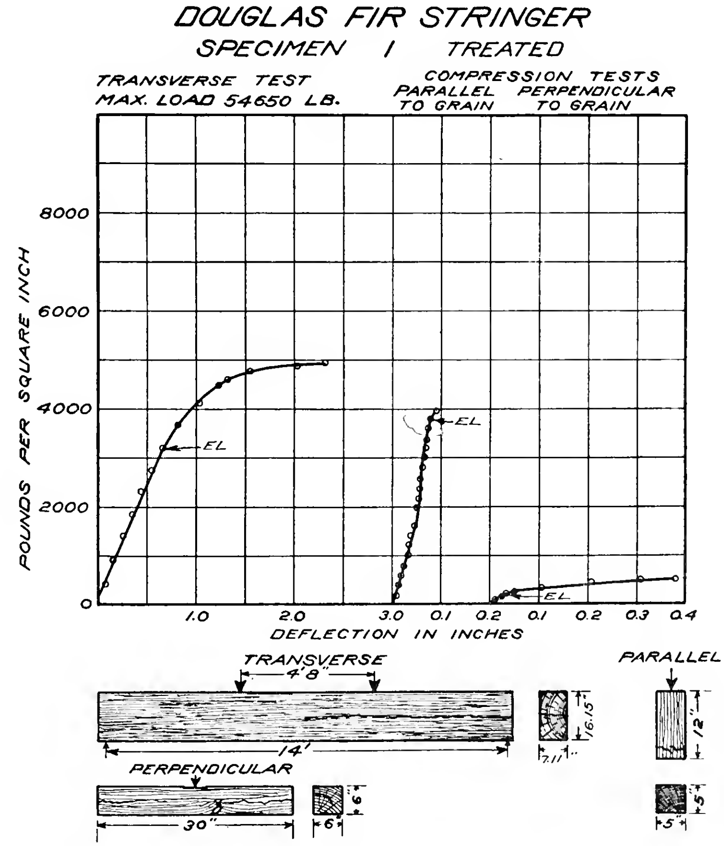

DOUGLAS FIR STRINGER
SPECIMEN 1 TREATED
TRANSVERSE TEST
MAX. LOAD 54650 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.15"
7.11"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 44

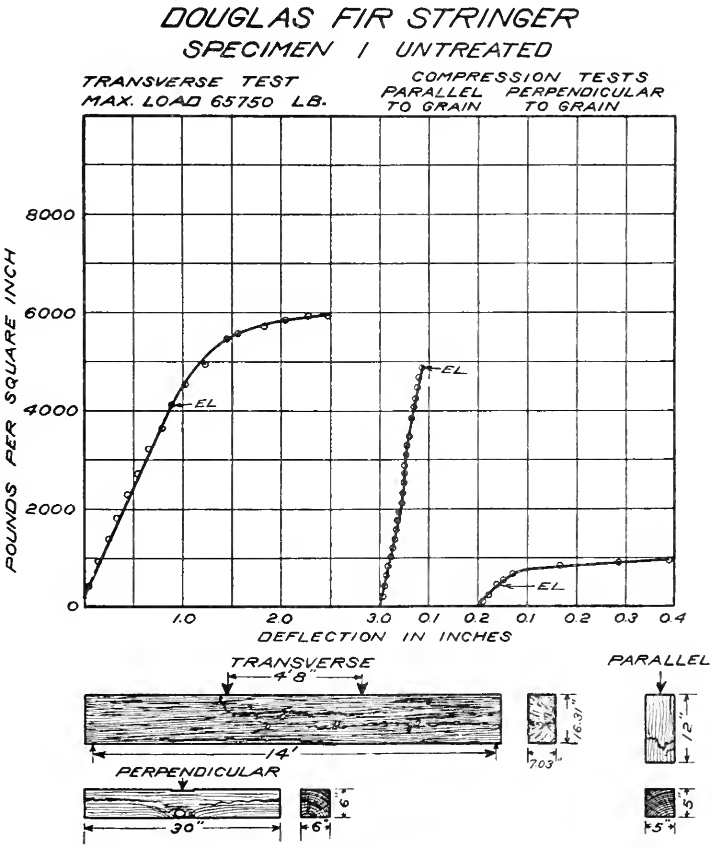

DOUGLAS FIR STRINGER
SPECIMEN 1 UNTREATED
TRANSVERSE TEST
MAX. LOAD 65750 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.31"
7.03"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 45

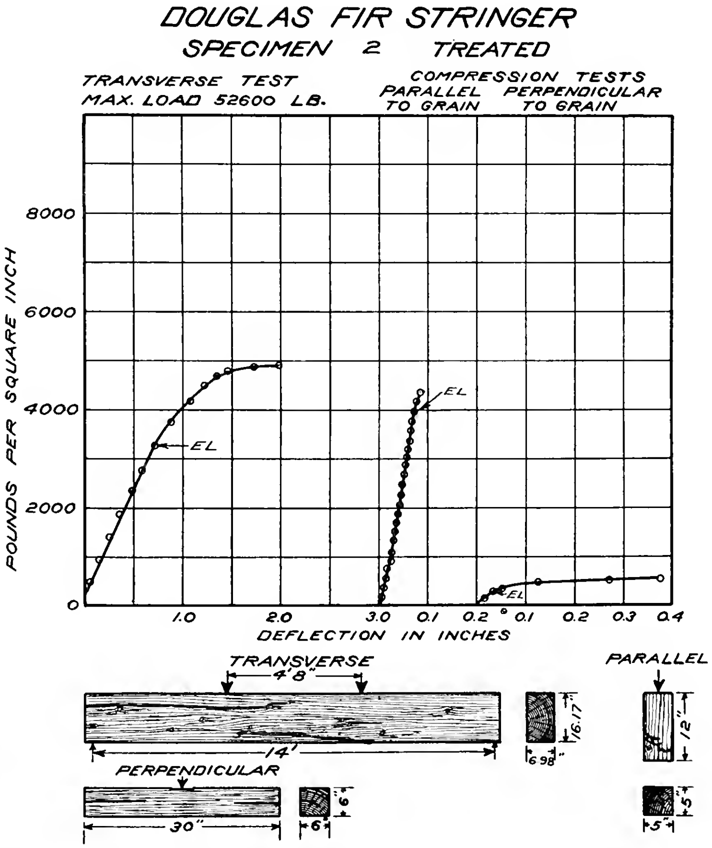

DOUGLAS FIR STRINGER
SPECIMEN 2 TREATED
TRANSVERSE TEST
MAX. LOAD 52600 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.17"
6.98"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 46

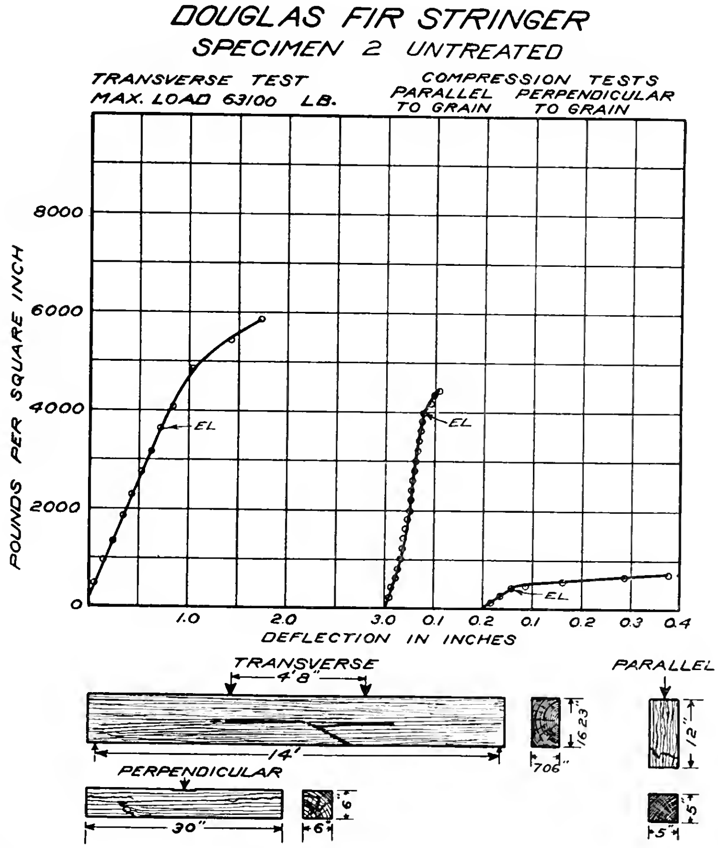

DOUGLAS FIR STRINGER
SPECIMEN 2 UNTREATED
TRANSVERSE TEST
MAX. LOAD 63100 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.23"
7.06"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 47

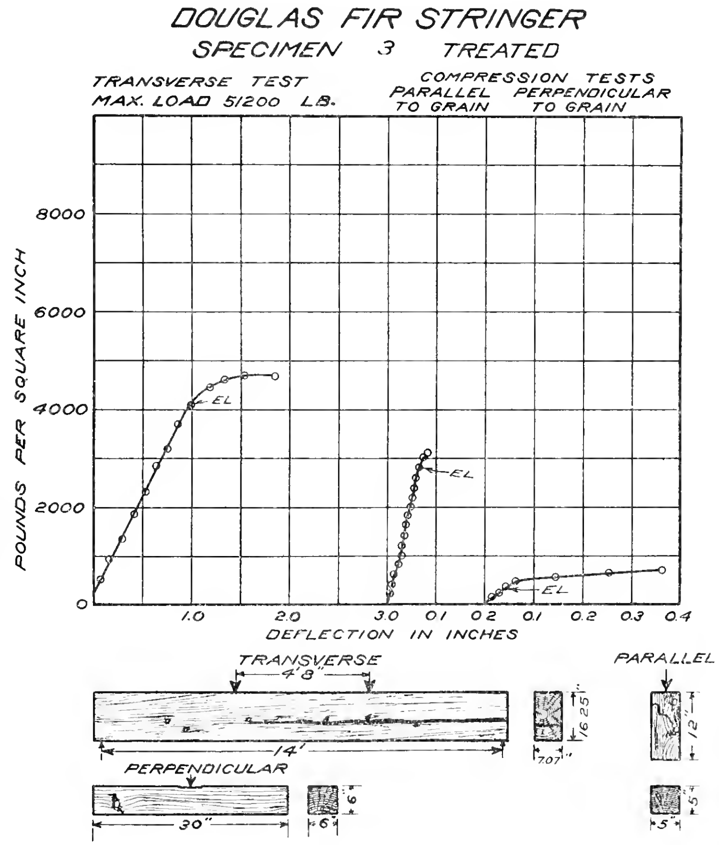

DOUGLAS FIR STRINGER
SPECIMEN 3 TREATED
TRANSVERSE TEST
MAX. LOAD 51200 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
7.07"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 48

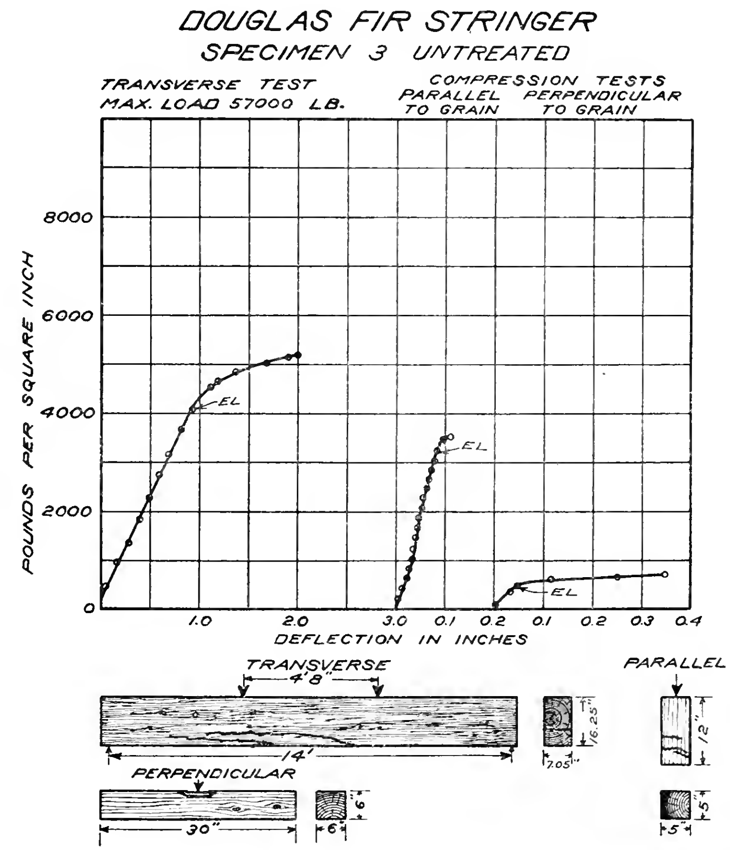

DOUGLAS FIR STRINGER
SPECIMEN 3 UNTREATED
TRANSVERSE TEST
MAX. LOAD 57000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
7.05"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 49

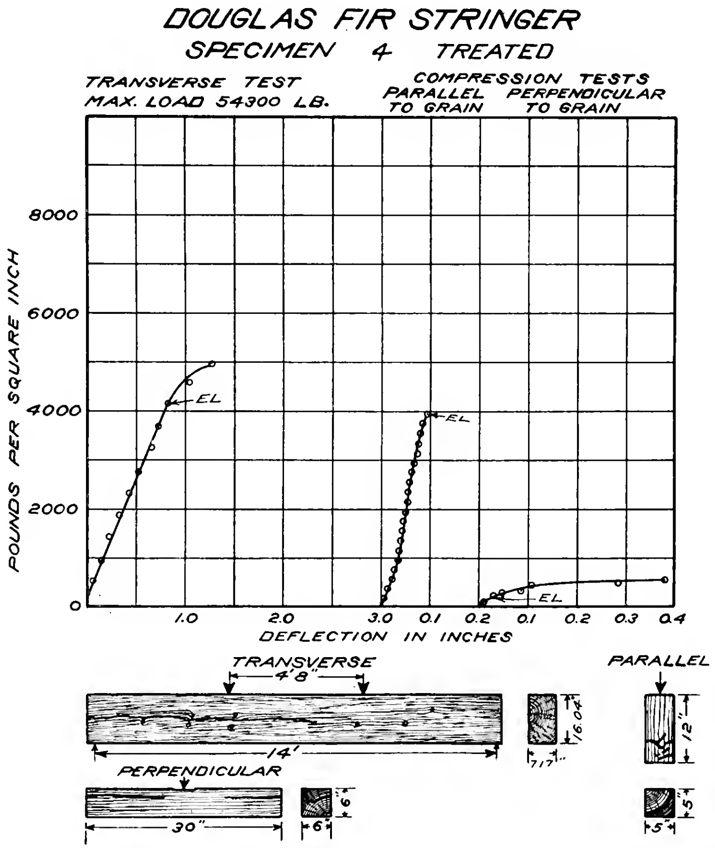

DOUGLAS FIR STRINGER
SPECIMEN 4 TREATED
TRANSVERSE TEST
MAX. LOAD 54300 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.04"
7.17"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 50

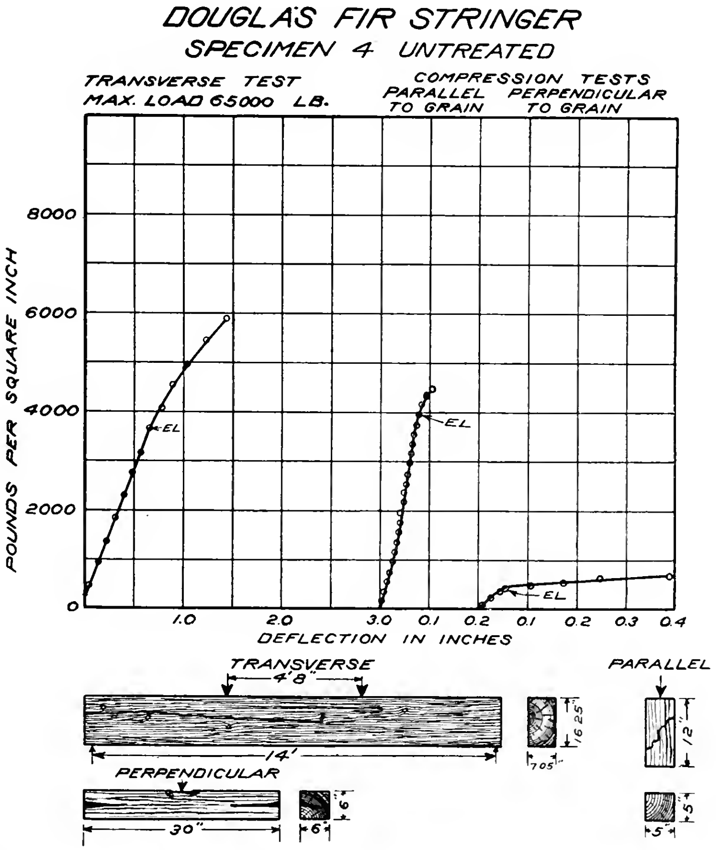

DOUGLAS FIR STRINGER
SPECIMEN 4 UNTREATED
TRANSVERSE TEST
MAX. LOAD 65000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
7.05"
16.25"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 51

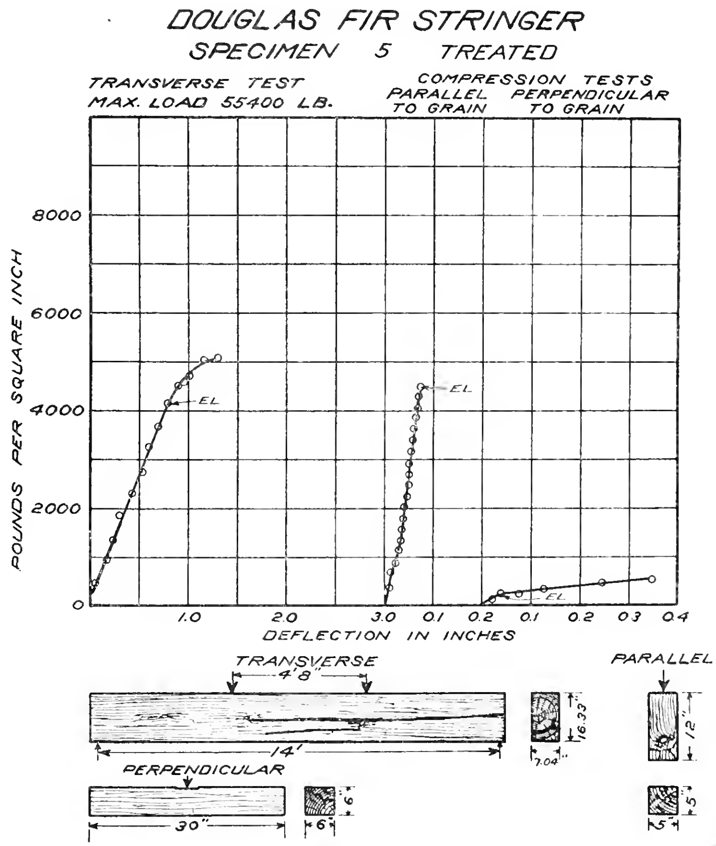

DOUGLAS FIR STRINGER
SPECIMEN 5 TREATED
TRANSVERSE TEST
MAX. LOAD 55400 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.33"
7.04"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 52

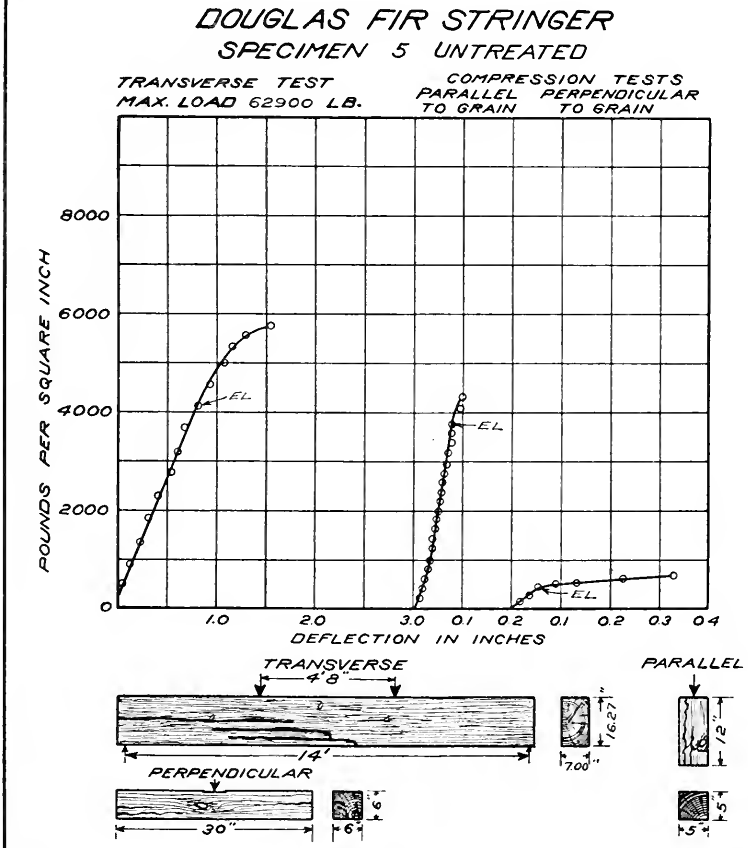

DOUGLAS FIR STRINGER
SPECIMEN 5 UNTREATED
TRANSVERSE TEST
MAX. LOAD 62900 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.27"
7.00"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 53

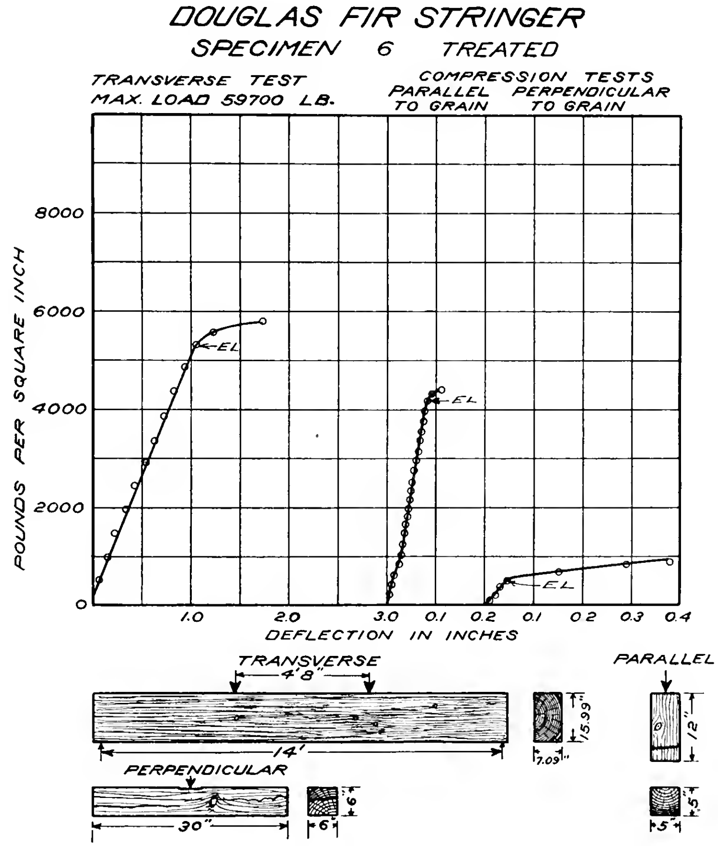

DOUGLAS FIR STRINGER
SPECIMEN 6 TREATED
TRANSVERSE TEST
MAX. LOAD 59700 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
15.99"
7.09"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 54

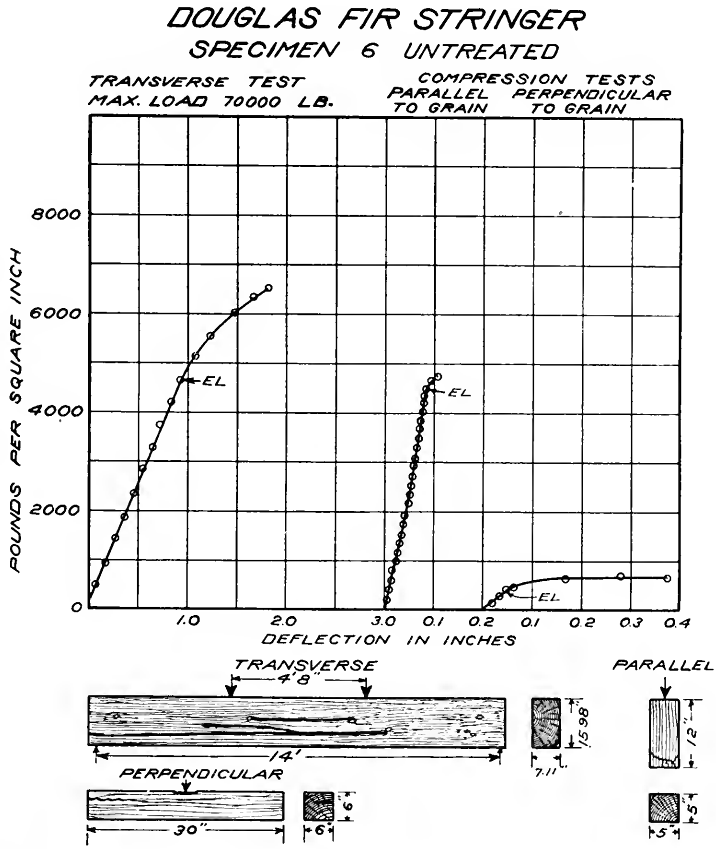

DOUGLAS FIR STRINGER
SPECIMEN 6 UNTREATED
TRANSVERSE TEST
MAX. LOAD 70000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
15.98"
7.11"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 55

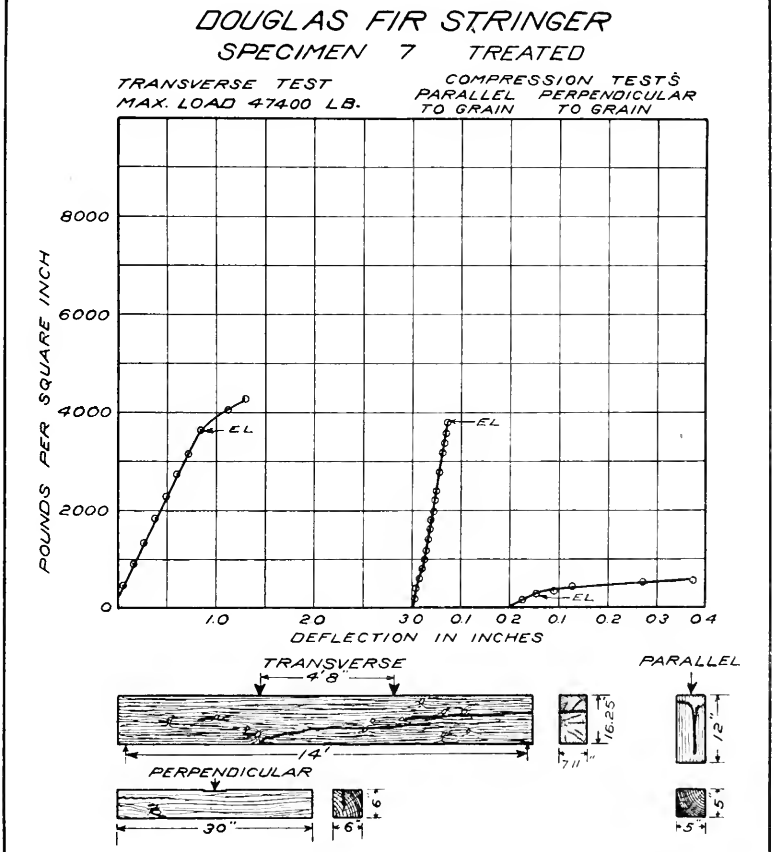

DOUGLAS FIR STRINGER
SPECIMEN 7 TREATED
TRANSVERSE TEST
MAX. LOAD 47400 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
7 11"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 56

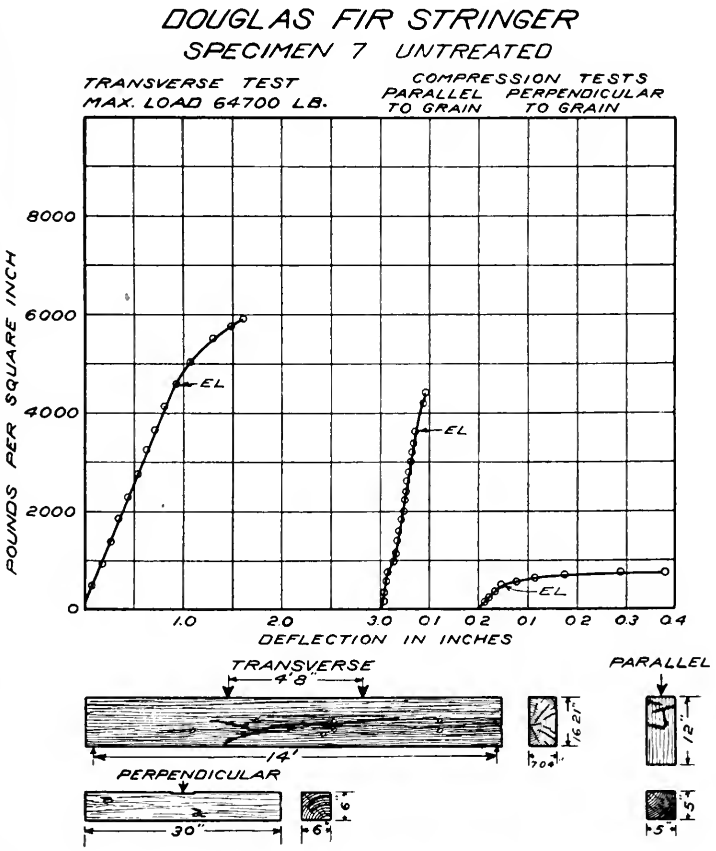

DOUGLAS FIR STRINGER
SPECIMEN 7 UNTREATED
TRANSVERSE TEST
MAX. LOAD 64700 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
01
02
01
02
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16 2/1"
7 04"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 57

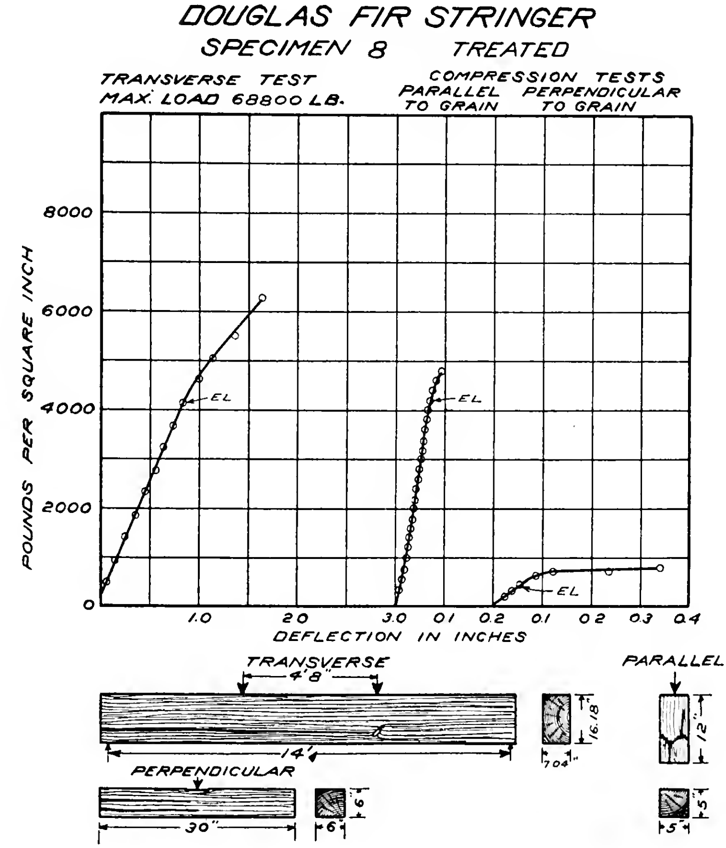

DOUGLAS FIR STRINGER
SPECIMEN 8 TREATED
TRANSVERSE TEST
MAX. LOAD 68800 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.18"
7.04"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 58

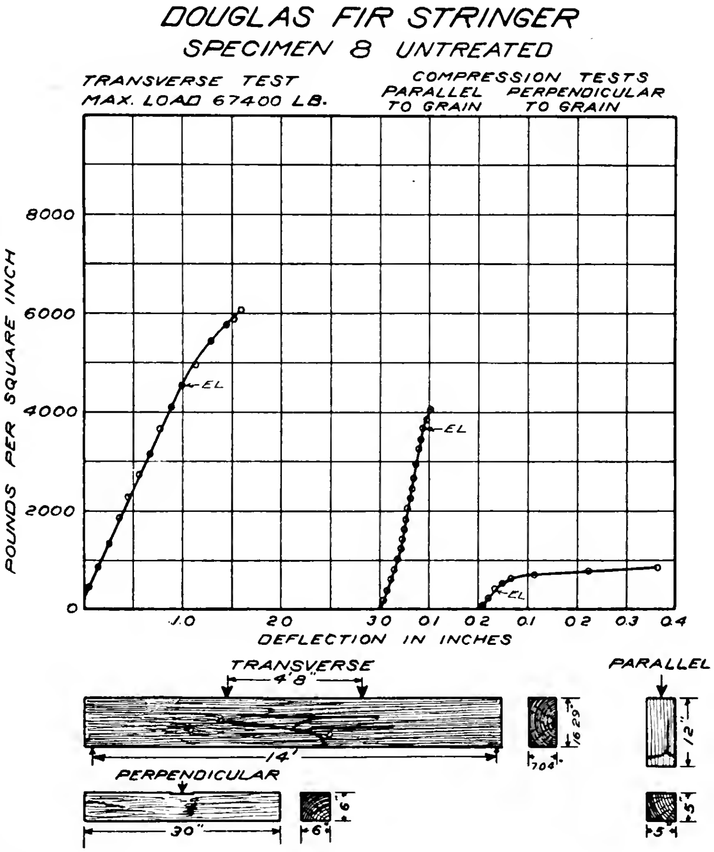

DOUGLAS FIR STRINGER
SPECIMEN 8 UNTREATED
TRANSVERSE TEST
MAX. LOAD 67400 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
7.04"
16.29"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 59

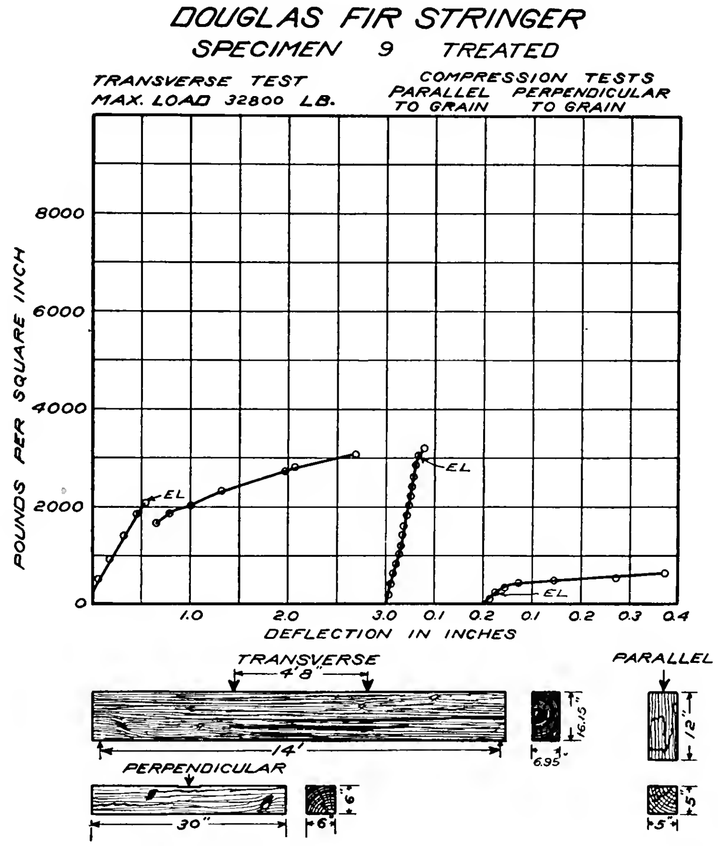

DOUGLAS FIR STRINGER
SPECIMEN 9 TREATED
TRANSVERSE TEST
MAX. LOAD 32800 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.15"
6.95"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 60

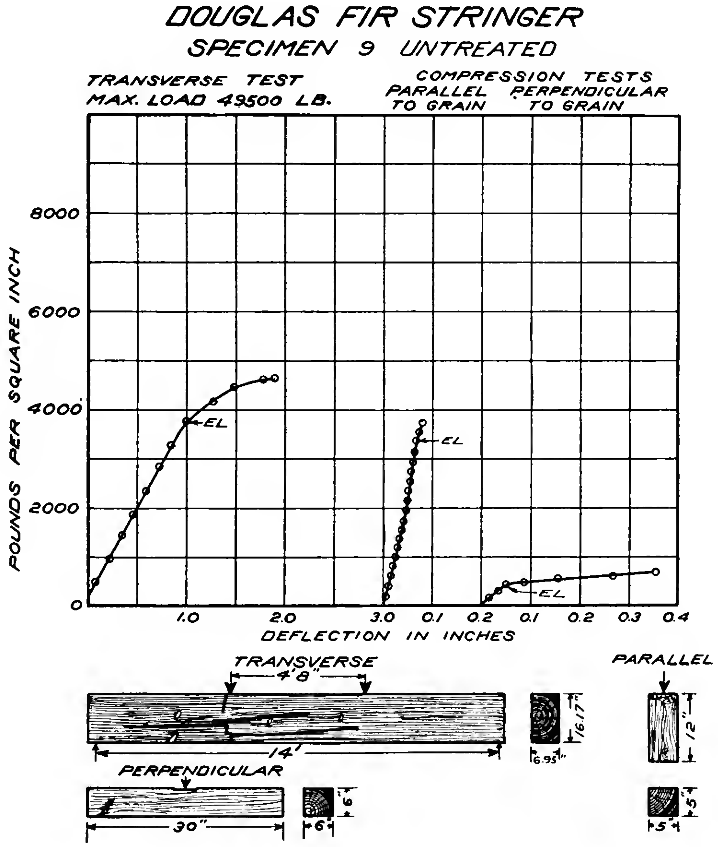

DOUGLAS FIR STRINGER
SPECIMEN 9 UNTREATED
TRANSVERSE TEST
MAX. LOAD 49500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.17"
6.95"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 61

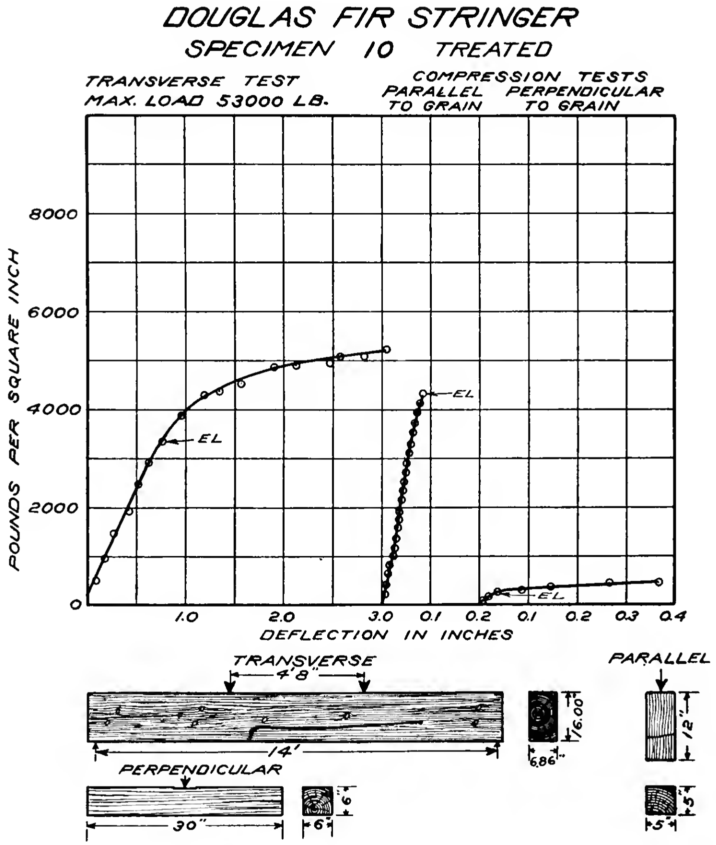

DOUGLAS FIR STRINGER
SPECIMEN 10 TREATED
TRANSVERSE TEST
MAX. LOAD 53000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.00"
6.86"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 62

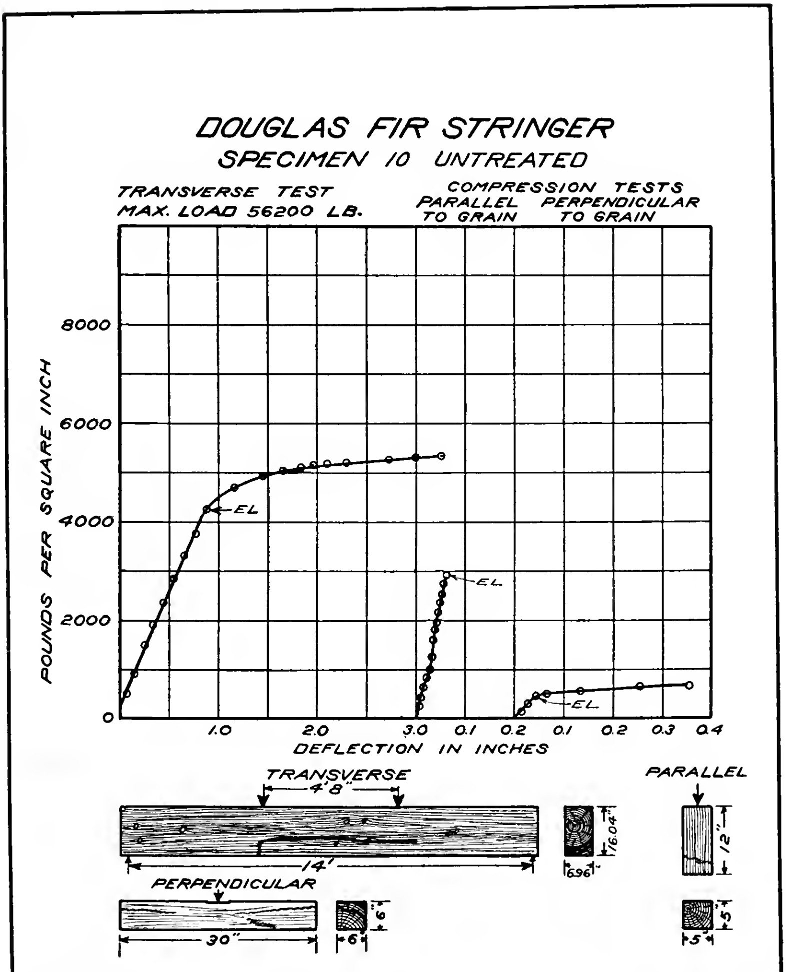

DOUGLAS FIR STRINGER
SPECIMEN 10 UNTREATED
TRANSVERSE TEST
MAX. LOAD 56200 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.04"
6.96"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 63

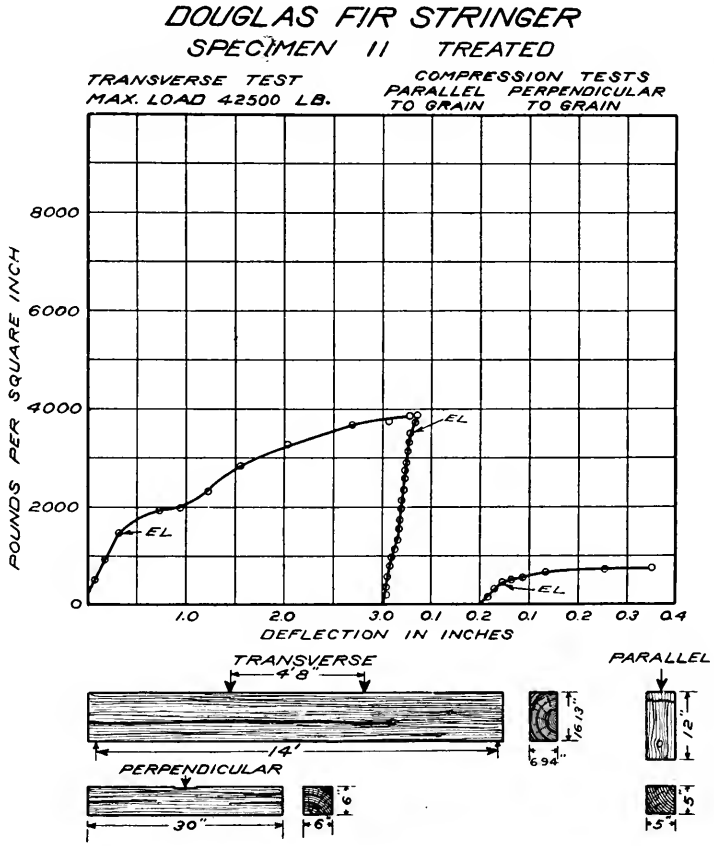

DOUGLAS FIR STRINGER
SPECIMEN 11 TREATED
TRANSVERSE TEST
MAX. LOAD 42500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.13"
6.94"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 64

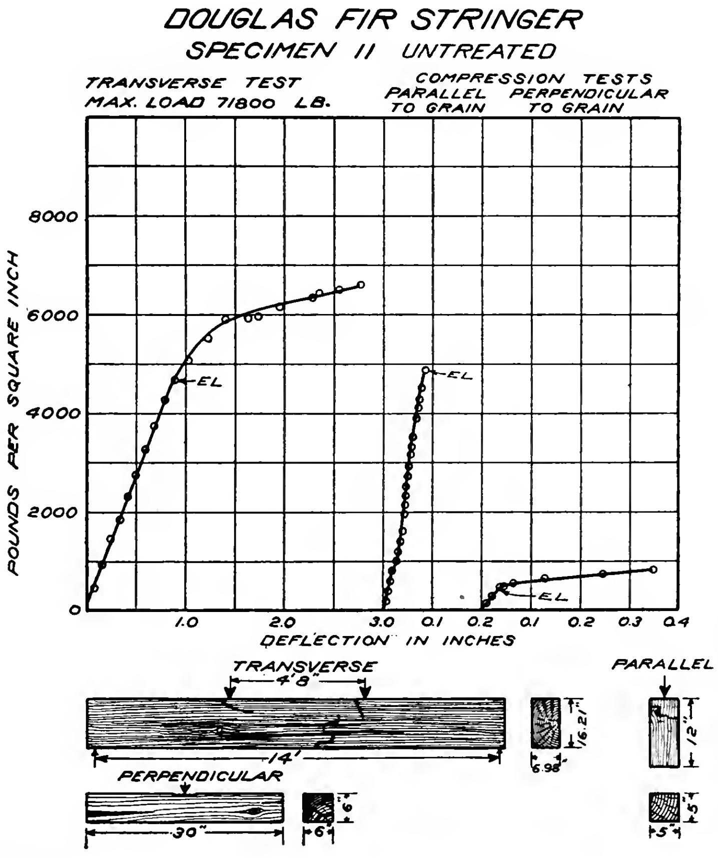

DOUGLAS FIR STRINGER
SPECIMEN 11 UNTREATED
TRANSVERSE TEST
MAX. LOAD 71800 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.21"
6.98"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 65

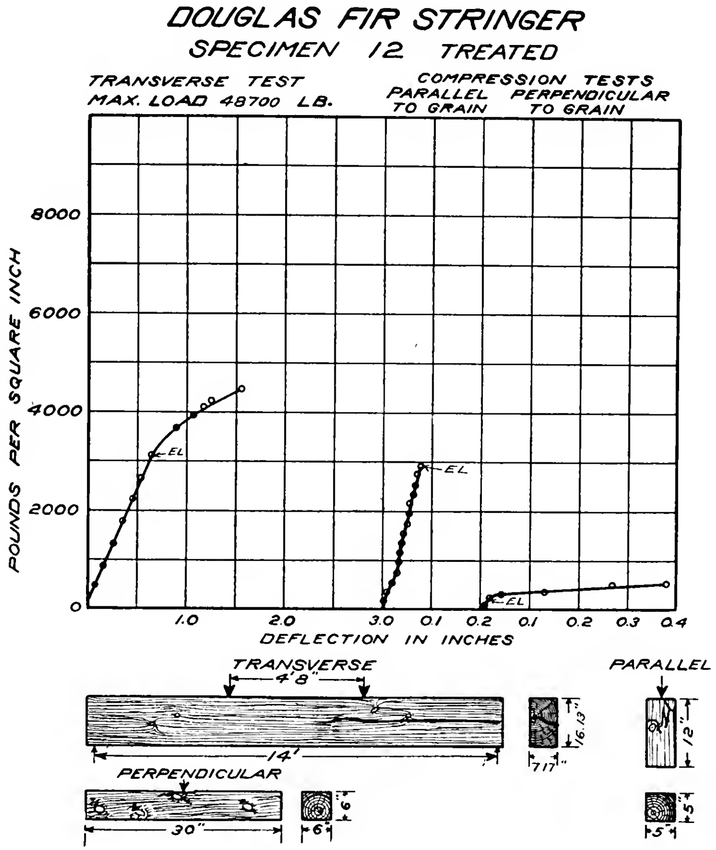

DOUGLAS FIR STRINGER
SPECIMEN 12 TREATED
TRANSVERSE TEST
MAX. LOAD 48700 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.13"
7.17"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 66

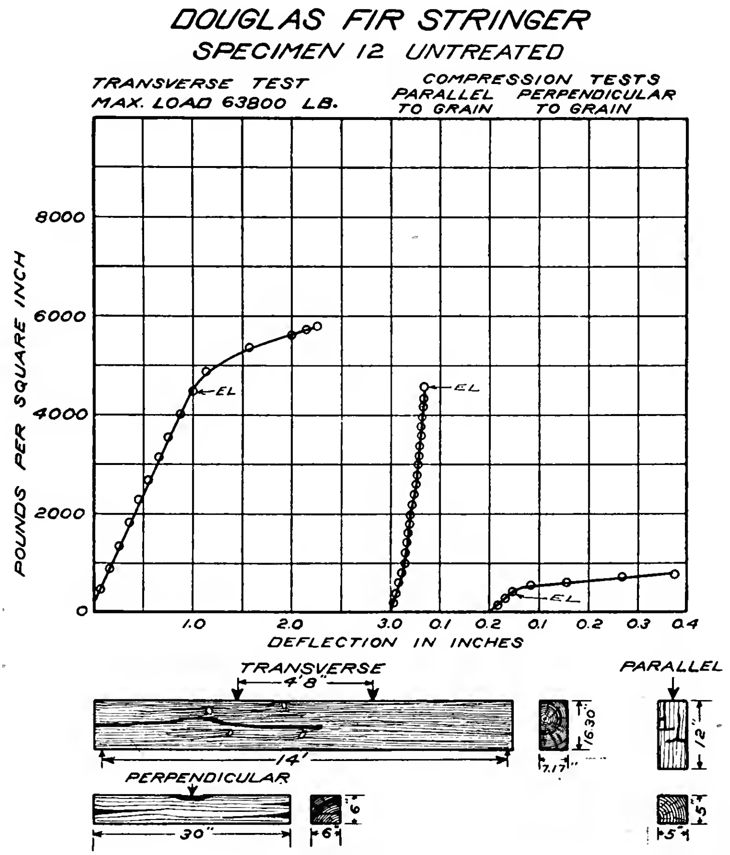

DOUGLAS FIR STRINGER
SPECIMEN 12 UNTREATED
TRANSVERSE TEST
MAX. LOAD 63800 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
EL
EL
EL
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.30"
7.17"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 67

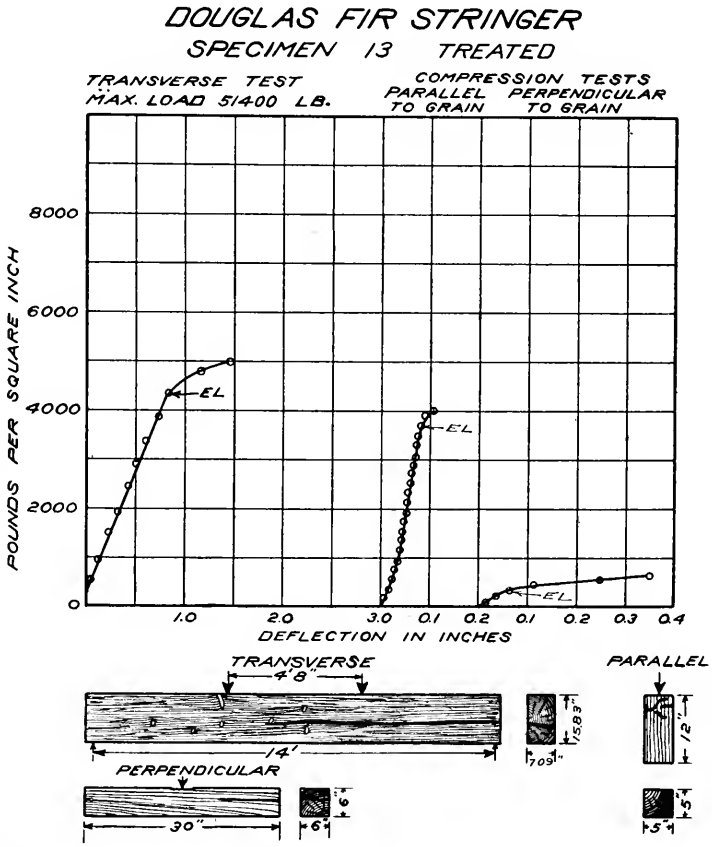

DOUGLAS FIR STRINGER
SPECIMEN 13 TREATED
TRANSVERSE TEST
MAX. LOAD 51400 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
15.83"
7.09"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 68

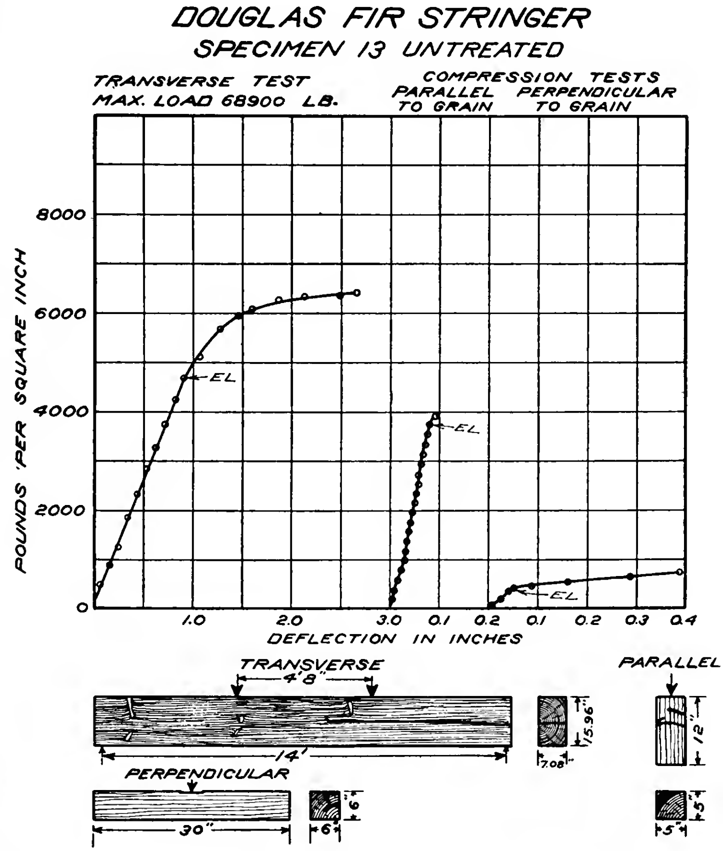

DOUGLAS FIR STRINGER
SPECIMEN 13 UNTREATED
TRANSVERSE TEST
MAX. LOAD 68900 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
15.96"
7.08"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 69

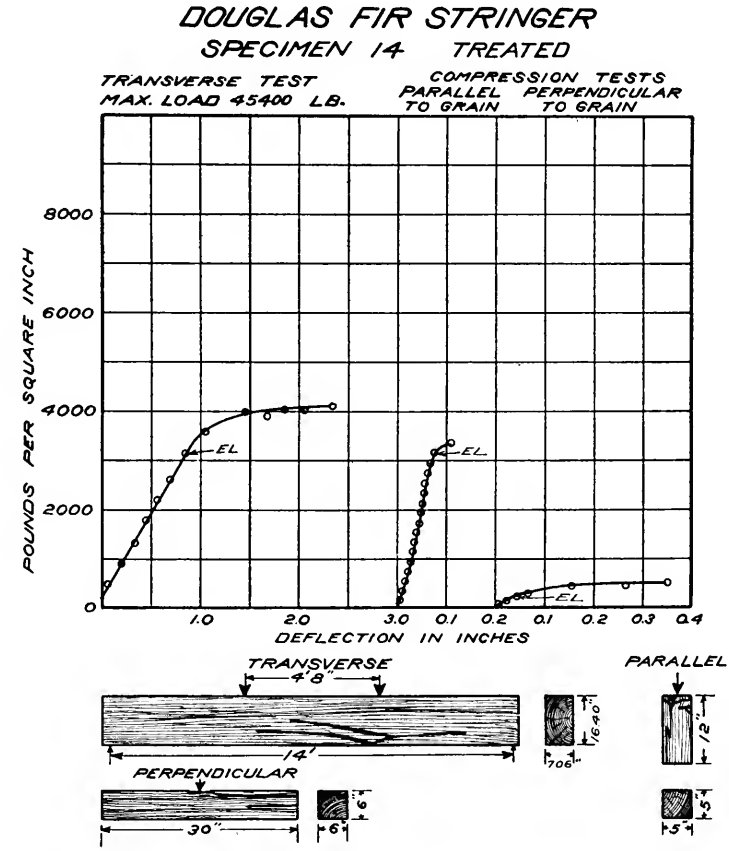

DOUGLAS FIR STRINGER
SPECIMEN 14 TREATED
TRANSVERSE TEST
MAX. LOAD 45400 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.40"
7.06"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 70

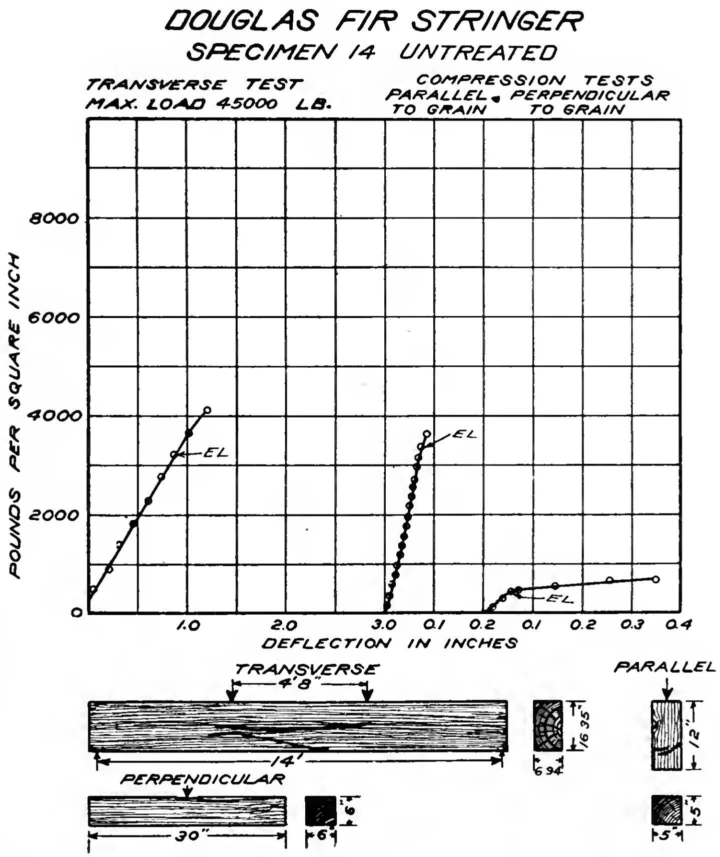

DOUGLAS FIR STRINGER
SPECIMEN 14 UNTREATED
TRANSVERSE TEST
MAX. LOAD 45000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.35"
6.94
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 71

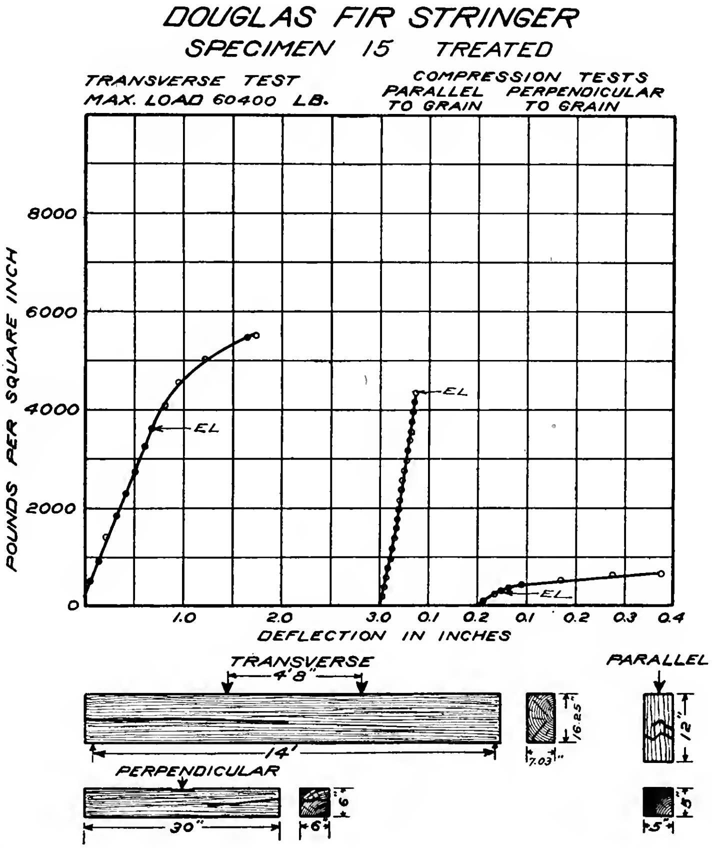

DOUGLAS FIR STRINGER
SPECIMEN 15 TREATED
TRANSVERSE TEST
MAX. LOAD 60400 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
7.03"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 72

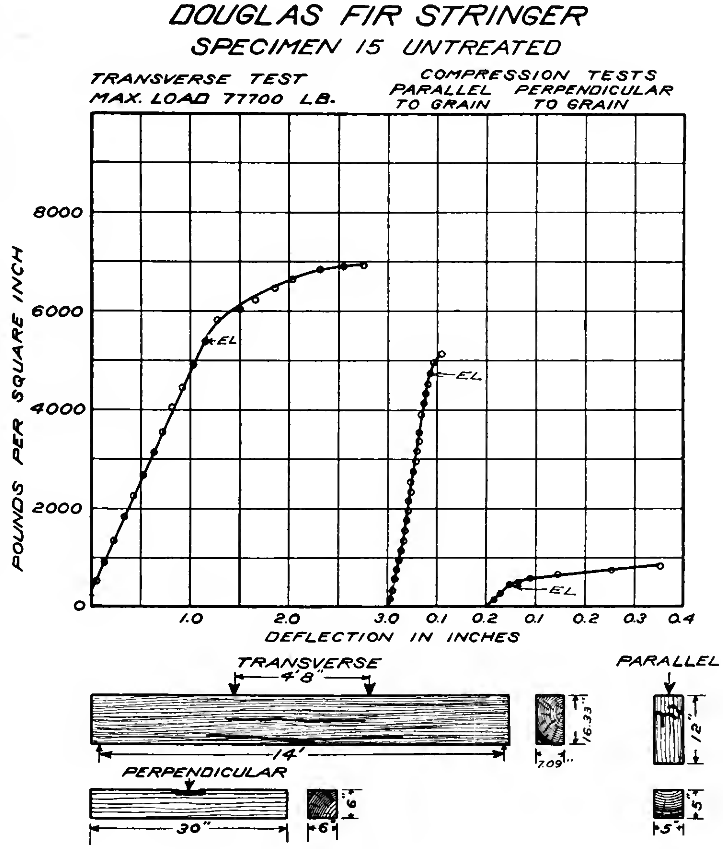

DOUGLAS FIR STRINGER
SPECIMEN 15 UNTREATED
TRANSVERSE TEST
MAX. LOAD 77700 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.33"
7.09"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 73

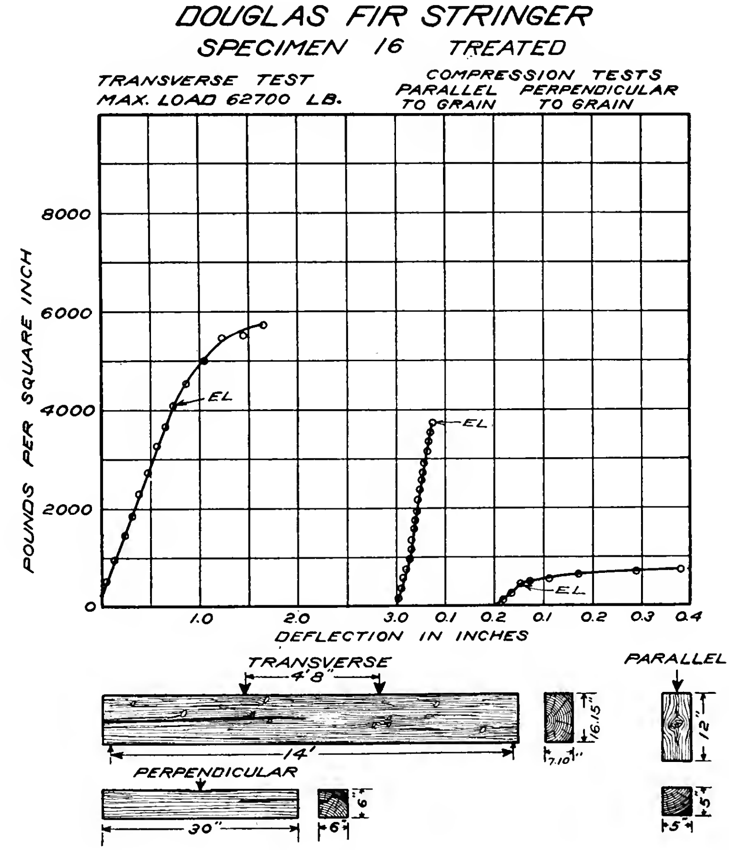

DOUGLAS FIR STRINGER
SPECIMEN 16 TREATED
TRANSVERSE TEST
MAX. LOAD 62700 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
8000
6000
4000
2000
0
POUNDS PER SQUARE INCH
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.5"
7.10"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 74

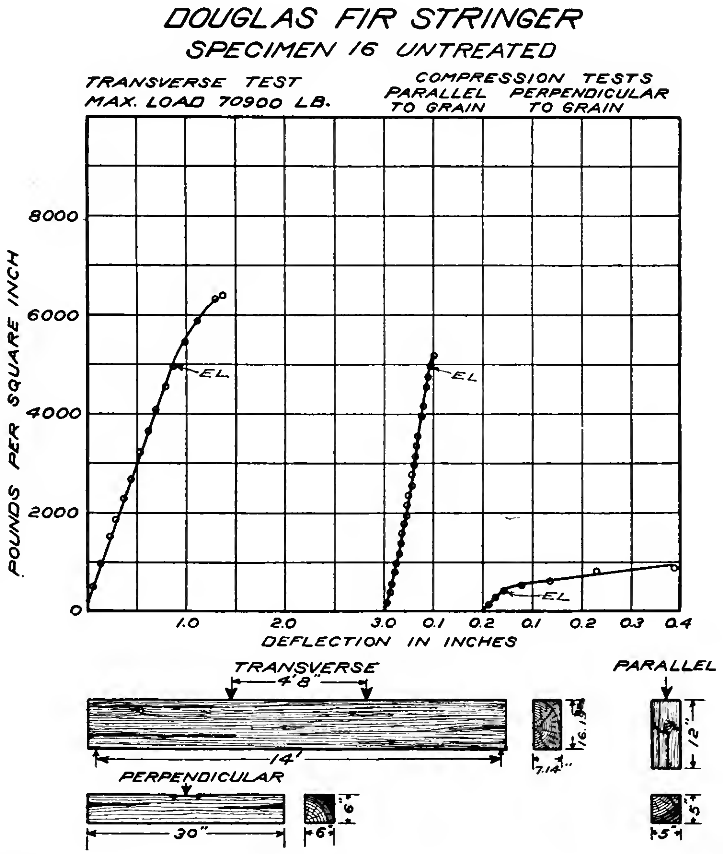

DOUGLAS FIR STRINGER
SPECIMEN 16 UNTREATED
TRANSVERSE TEST
MAX. LOAD 70900 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.13"
7.14"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 75

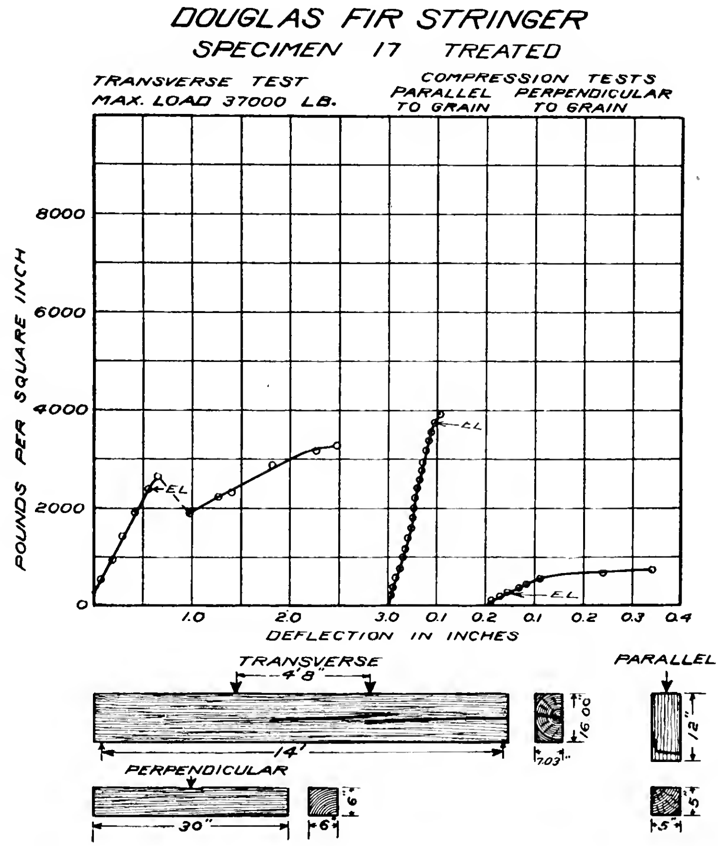

DOUGLAS FIR STRINGER
SPECIMEN 17 TREATED
TRANSVERSE TEST
MAX. LOAD 37000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
E.L.
E.L.
E.L.
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.00"
7.03"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 76

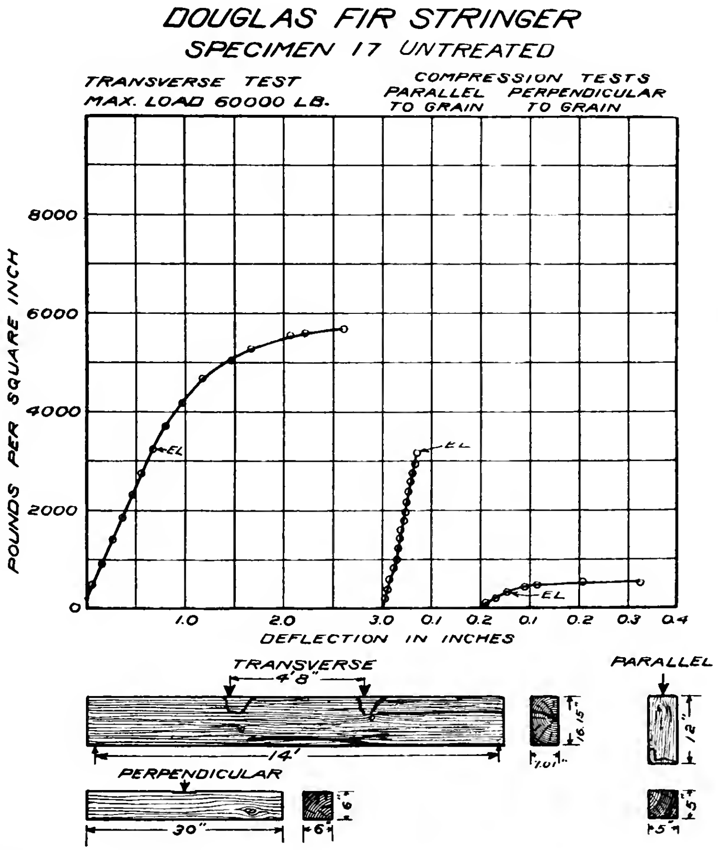

DOUGLAS FIR STRINGER
SPECIMEN 17 UNTREATED
TRANSVERSE TEST
MAX. LOAD 60000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.15"
7.01"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 77

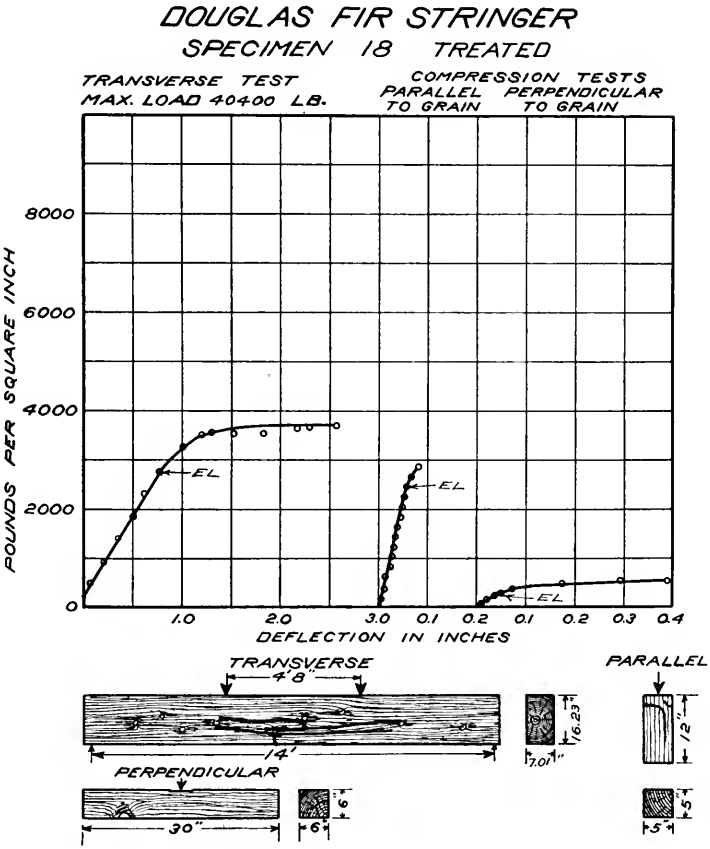

DOUGLAS FIR STRINGER
SPECIMEN 18 TREATED
TRANSVERSE TEST
MAX. LOAD 40400 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.23"
7.01"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 78

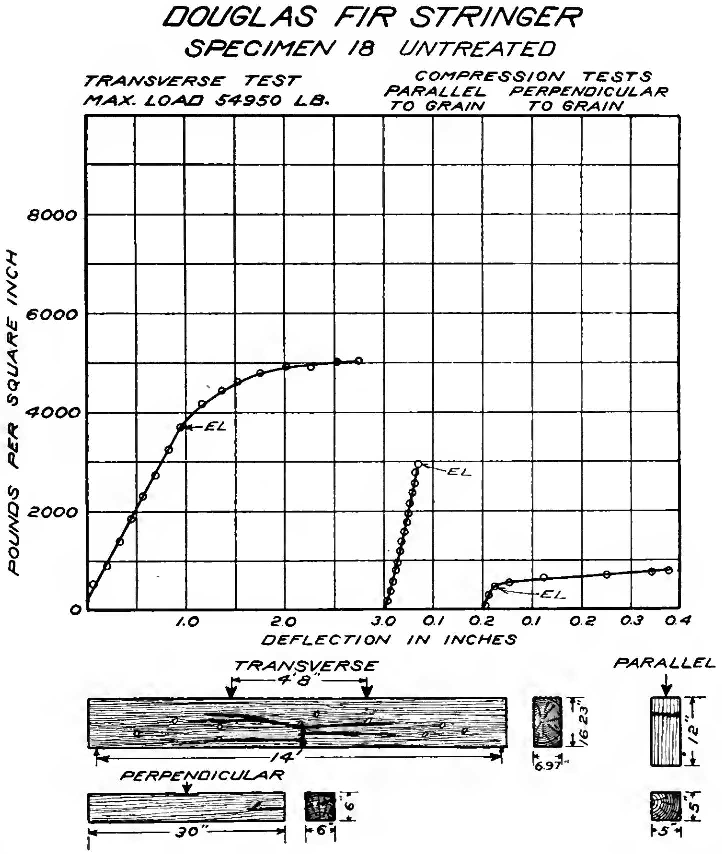

DOUGLAS FIR STRINGER
SPECIMEN 18 UNTREATED
TRANSVERSE TEST
MAX. LOAD 54950 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.23"
6.97"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 79

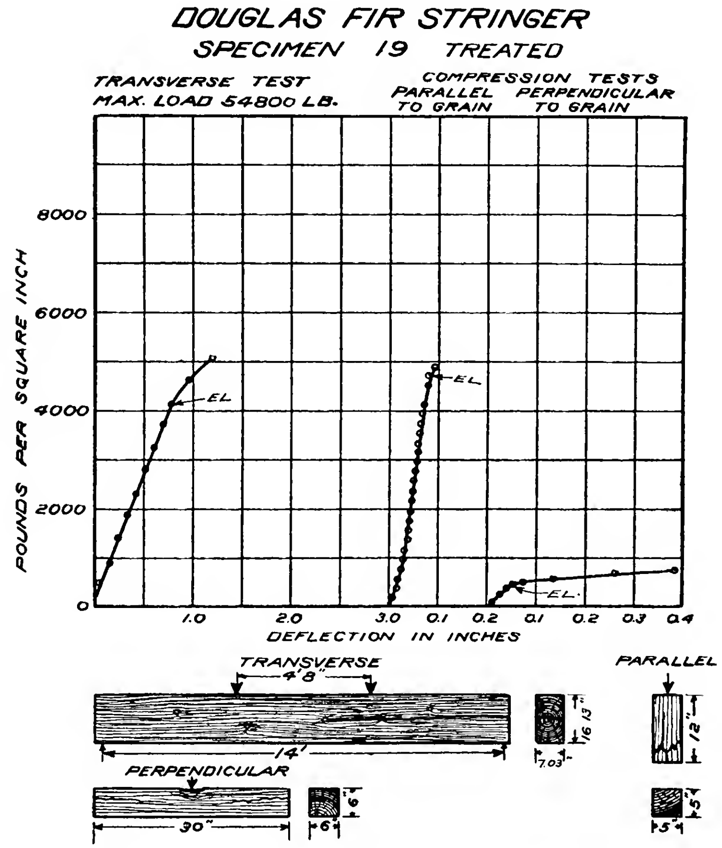

DOUGLAS FIR STRINGER
SPECIMEN 19 TREATED
TRANSVERSE TEST
MAX. LOAD 54800 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL.
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16 13"
7.03"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 80

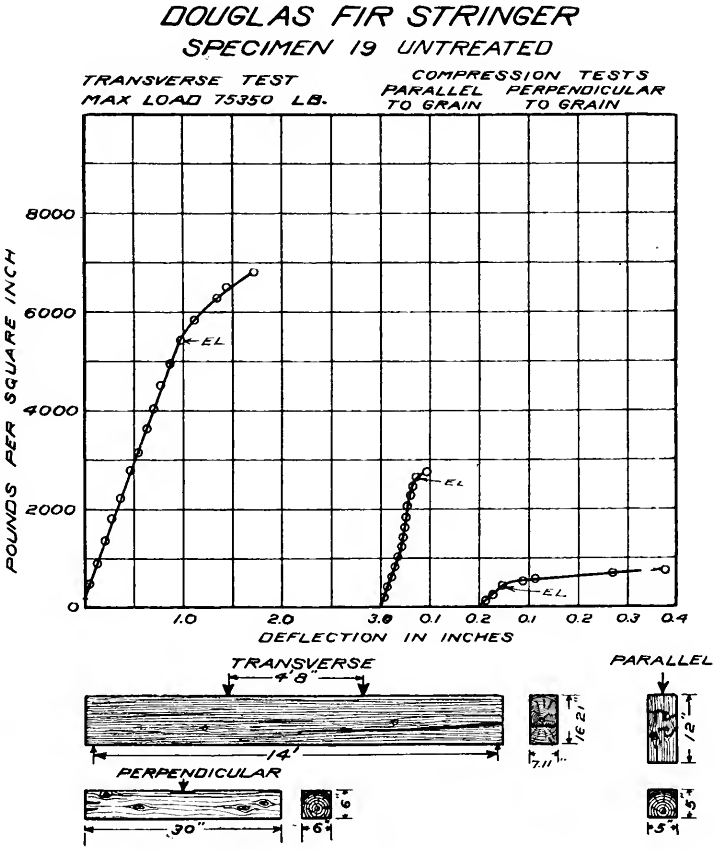

DOUGLAS FIR STRINGER
SPECIMEN 19 UNTREATED
TRANSVERSE TEST
MAX LOAD 75350 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
12"
7.1"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 81

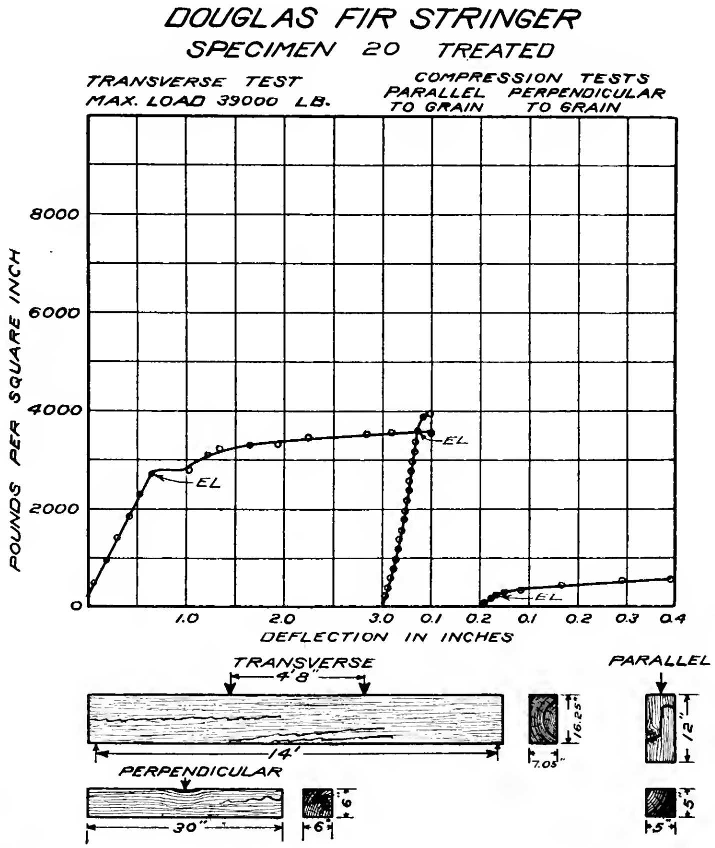

DOUGLAS FIR STRINGER
SPECIMEN 20 TREATED
TRANSVERSE TEST
MAX. LOAD 39000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
7.05"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 82

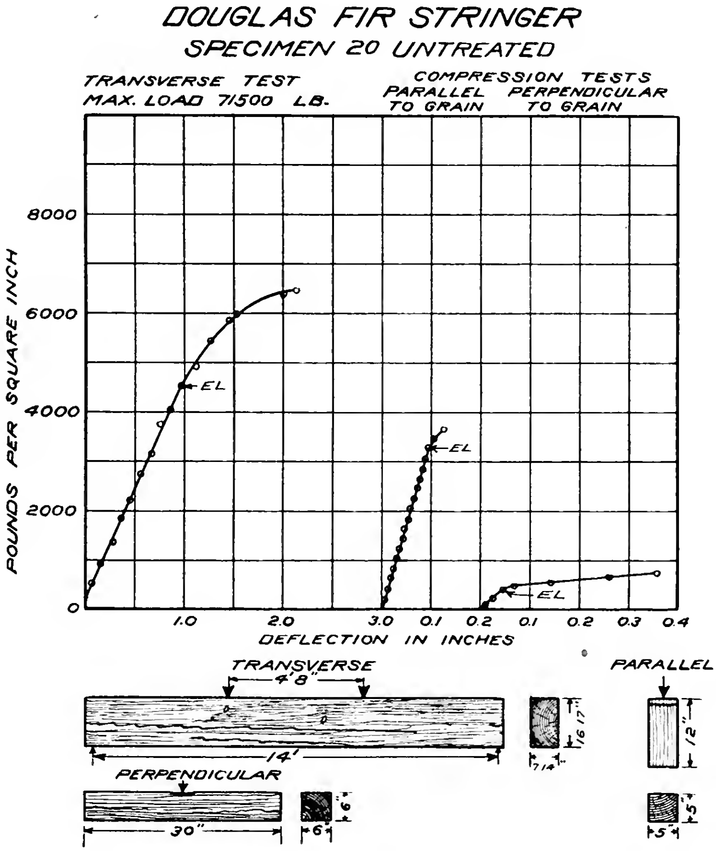

DOUGLAS FIR STRINGER
SPECIMEN 20 UNTREATED
TRANSVERSE TEST
MAX. LOAD 71500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16 1/7"
7 1/4"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 83

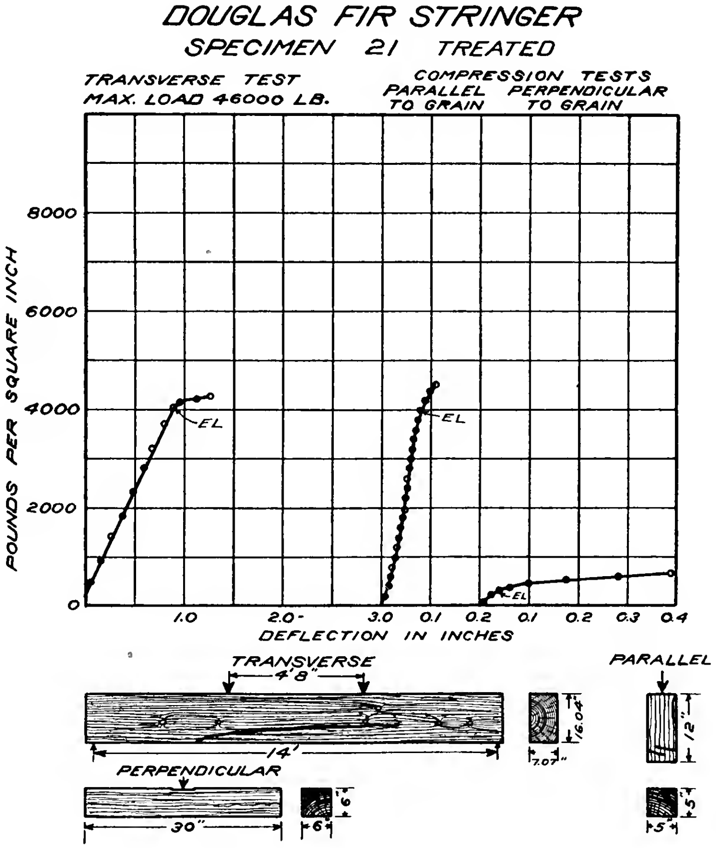

DOUGLAS FIR STRINGER
SPECIMEN 21 TREATED
TRANSVERSE TEST
MAX. LOAD 46000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.04"
7.07"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 84

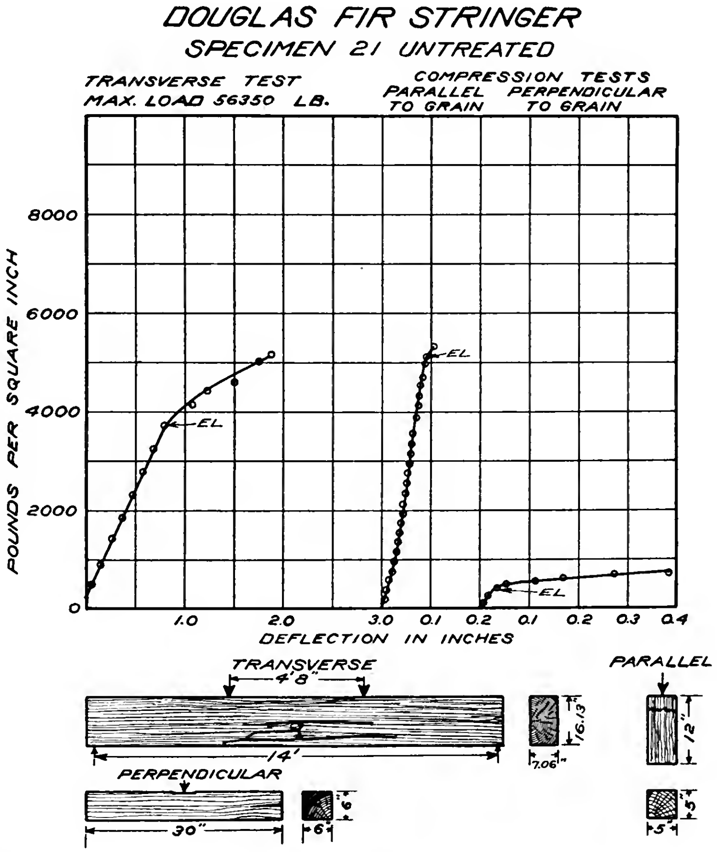

DOUGLAS FIR STRINGER
SPECIMEN 21 UNTREATED
TRANSVERSE TEST
MAX. LOAD 56350 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.13"
7.06"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 85

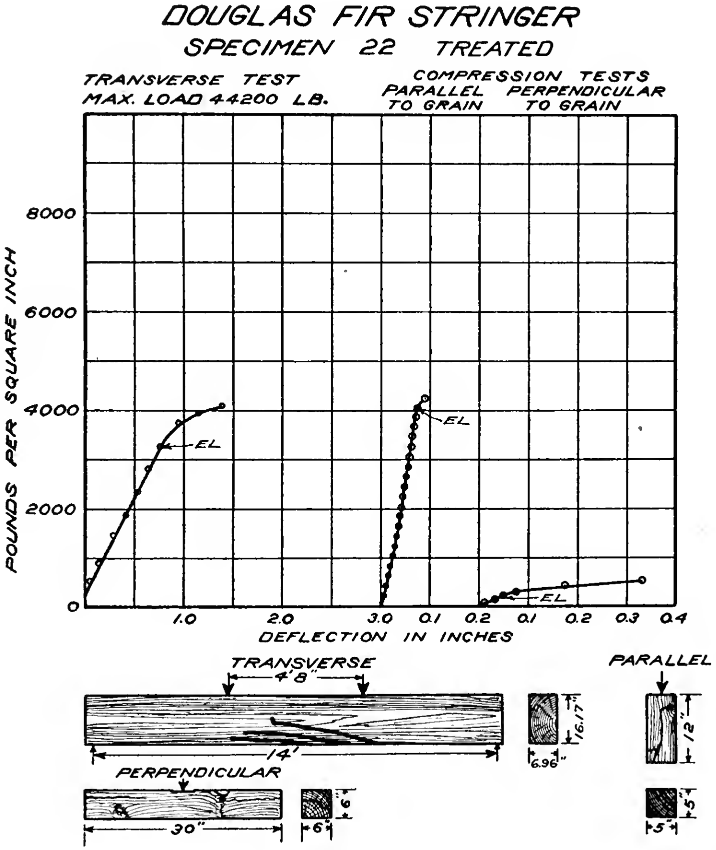

DOUGLAS FIR STRINGER
SPECIMEN 22 TREATED
TRANSVERSE TEST
MAX. LOAD 44200 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.17"
6.96"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG 86

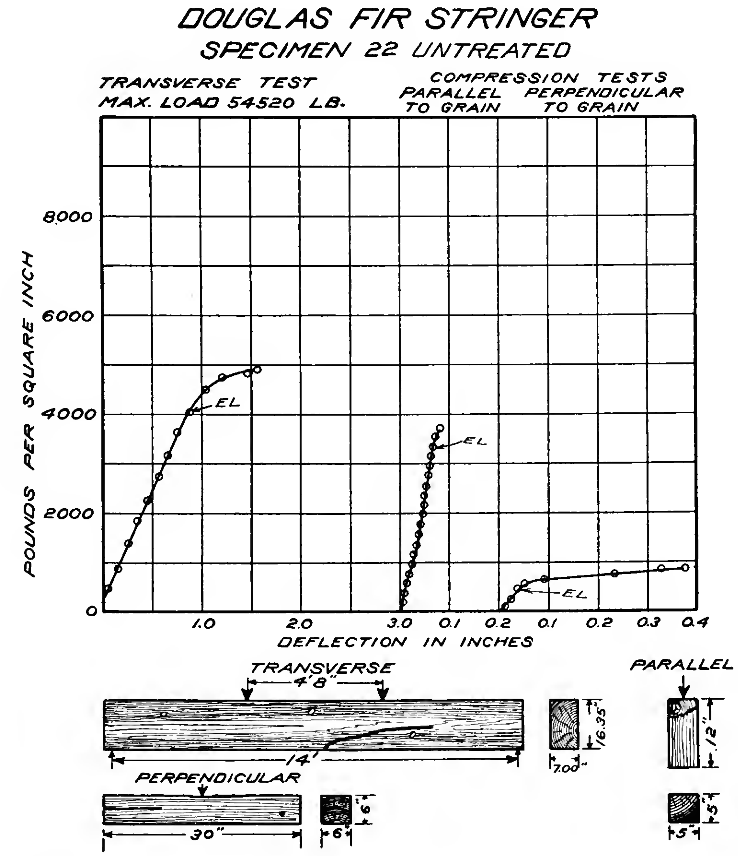

DOUGLAS FIR STRINGER
SPECIMEN 22 UNTREATED
TRANSVERSE TEST
MAX. LOAD 54520 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.35"
7.00"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 87

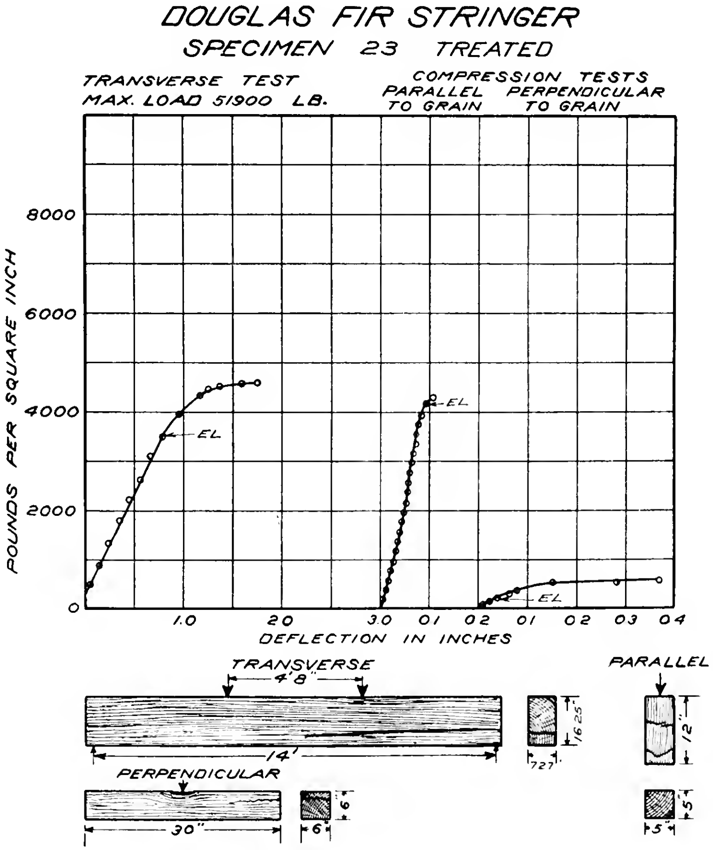

DOUGLAS FIR STRINGER
SPECIMEN 23 TREATED
TRANSVERSE TEST
MAX. LOAD 51900 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
01
02
01
02
03
04
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
7.27"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 88

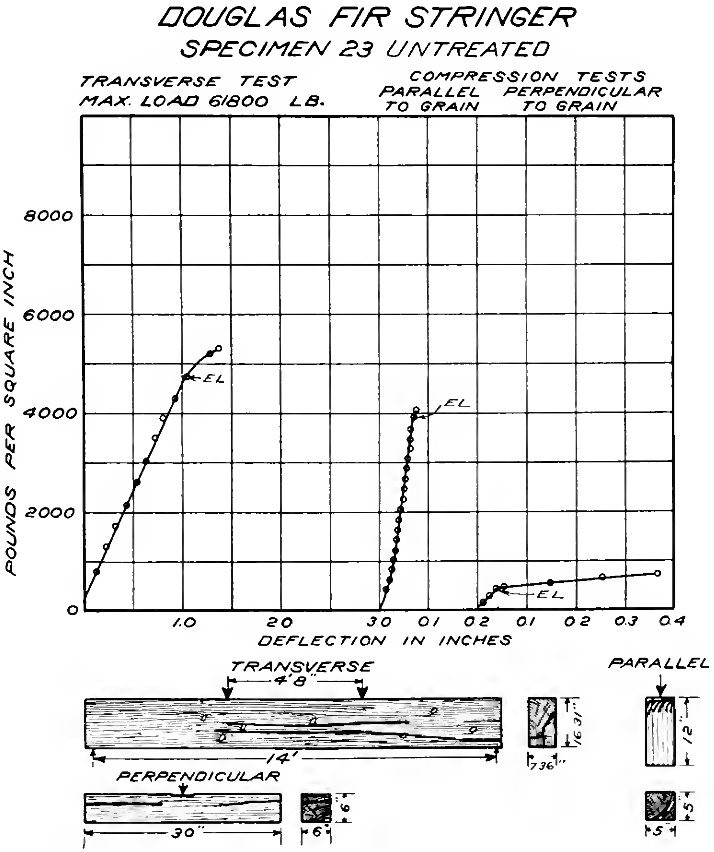

DOUGLAS FIR STRINGER
SPECIMEN 23 UNTREATED
TRANSVERSE TEST
MAX. LOAD 61800 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.31"
7.36"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG 89

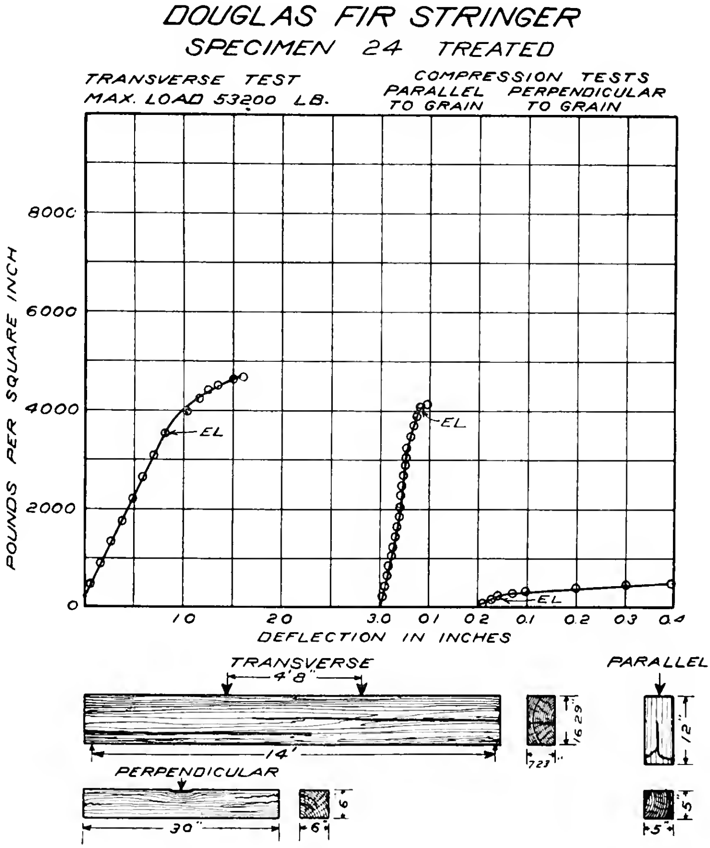

DOUGLAS FIR STRINGER
SPECIMEN 24 TREATED
TRANSVERSE TEST
MAX. LOAD 53200 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.29"
7.23"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 90

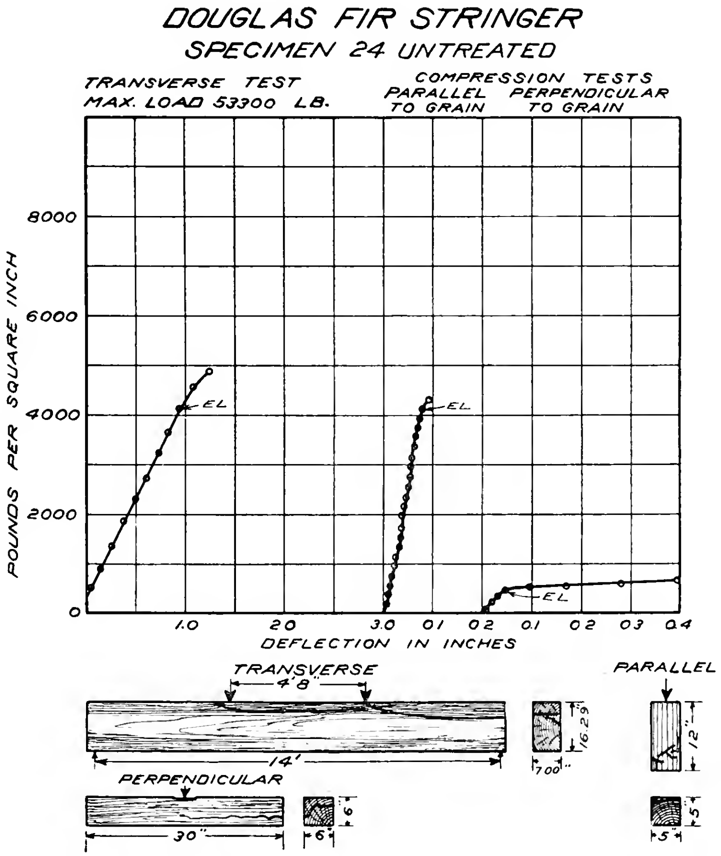

DOUGLAS FIR STRINGER
SPECIMEN 24 UNTREATED
TRANSVERSE TEST
MAX. LOAD 53300 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.29"
7.00"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 91

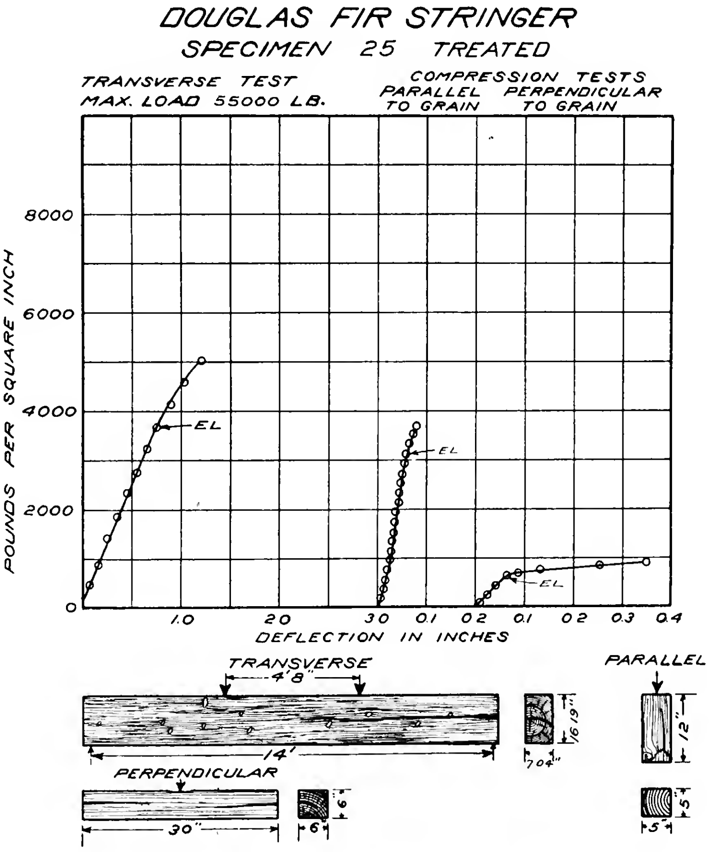

DOUGLAS FIR STRINGER
SPECIMEN 25 TREATED
TRANSVERSE TEST
MAX. LOAD 55000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.9"
7.04"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 92

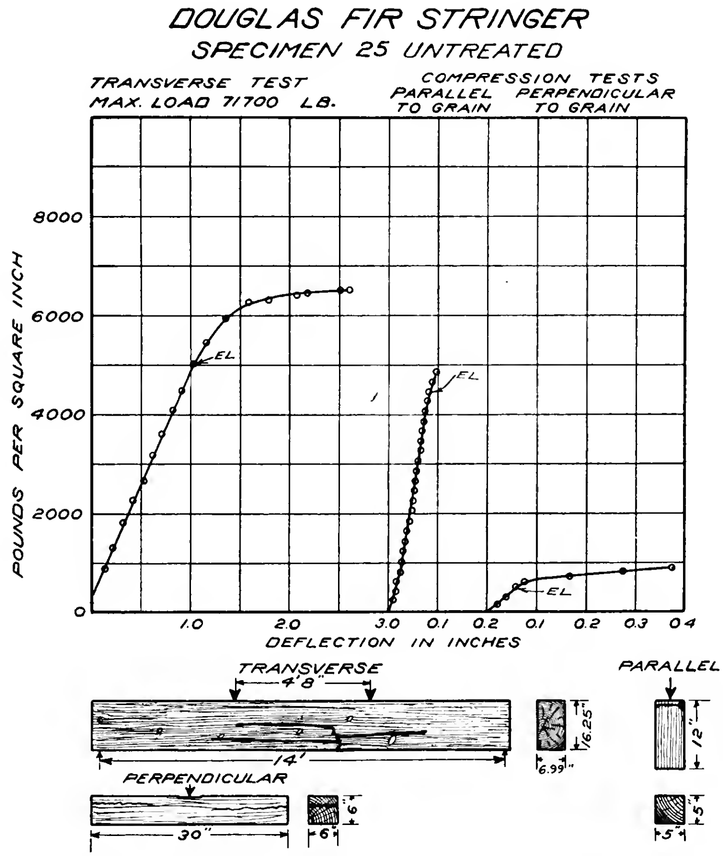

DOUGLAS FIR STRINGER
SPECIMEN 25 UNTREATED
TRANSVERSE TEST
MAX. LOAD 71700 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
6.99"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 93

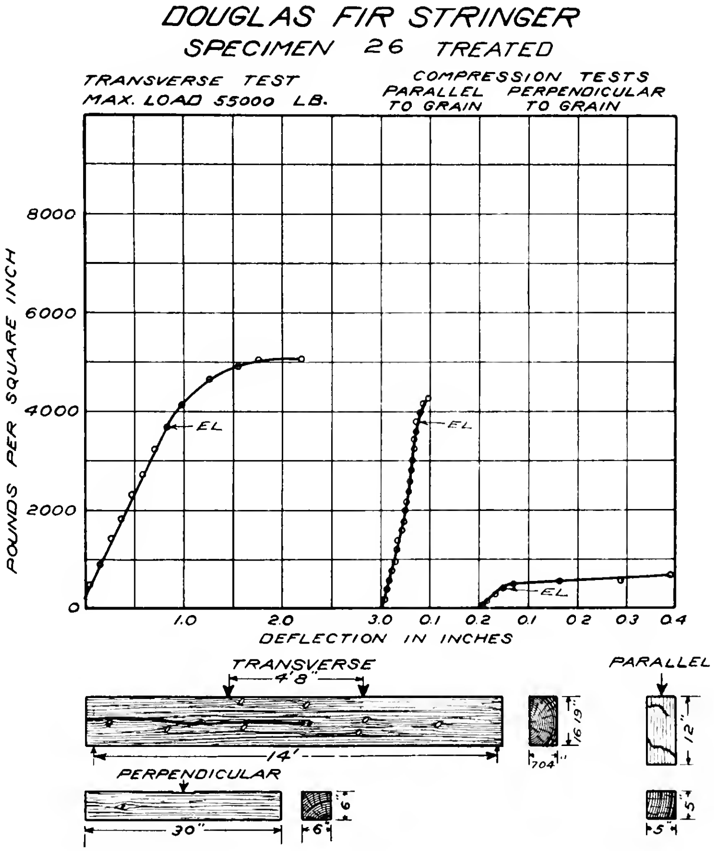

DOUGLAS FIR STRINGER
SPECIMEN 26 TREATED
TRANSVERSE TEST
MAX. LOAD 55000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16 19"
7 04"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 94

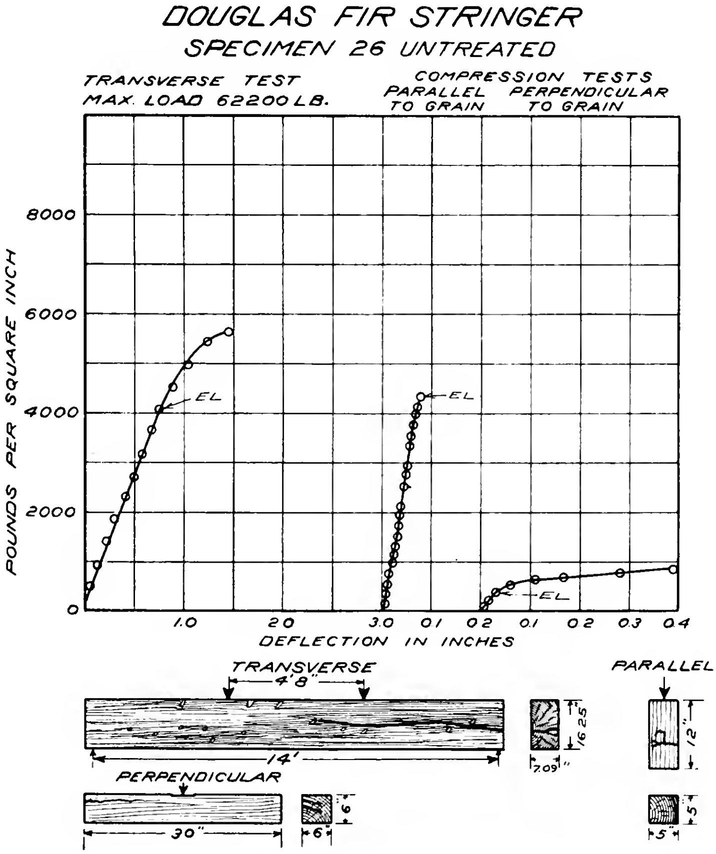

DOUGLAS FIR STRINGER
SPECIMEN 26 UNTREATED
TRANSVERSE TEST
MAX. LOAD 62200 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
7.09"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 95

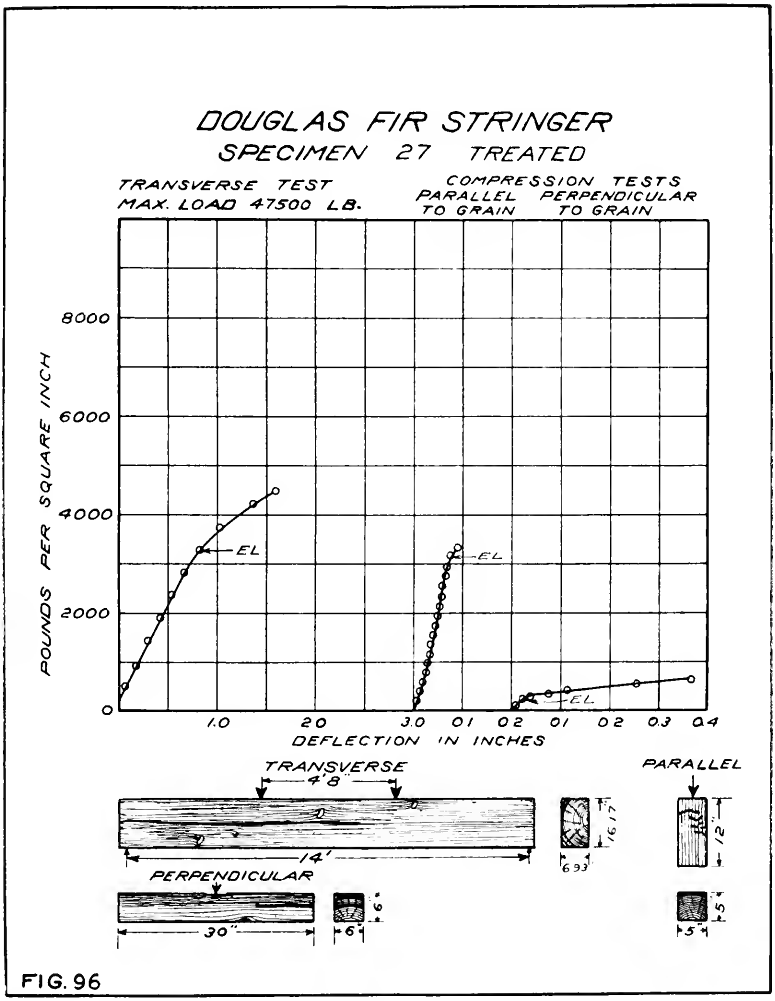

DOUGLAS FIR STRINGER
SPECIMEN 27 TREATED
TRANSVERSE TEST
MAX. LOAD 47500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.17
6.93
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 96

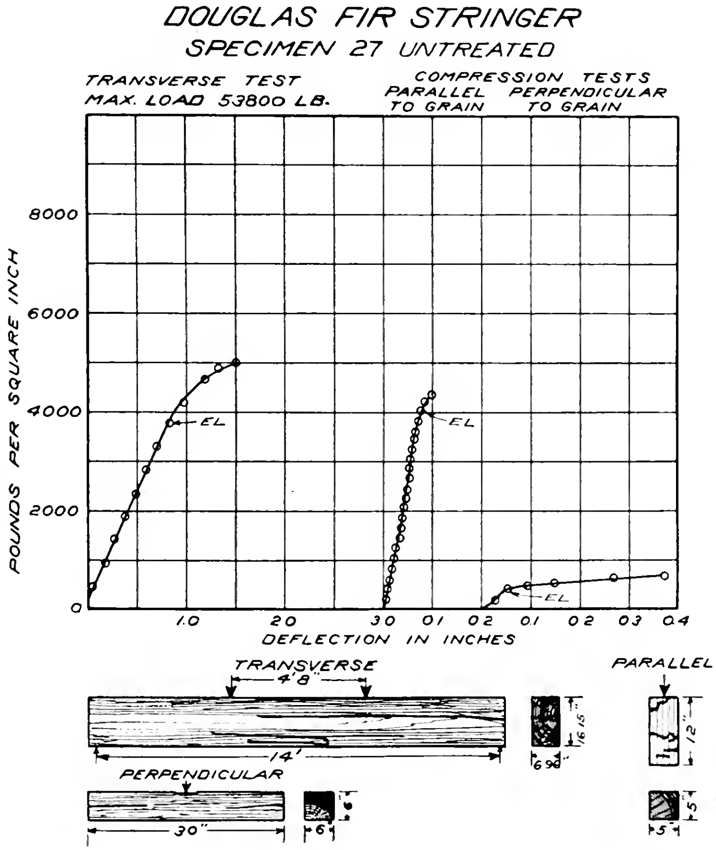

DOUGLAS FIR STRINGER
SPECIMEN 27 UNTREATED
TRANSVERSE TEST
MAX. LOAD 53800 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.5"
6.5"
PARALLEL
12"
PERPENDICULAR
30"
6
6
5"
5"

FIG. 97

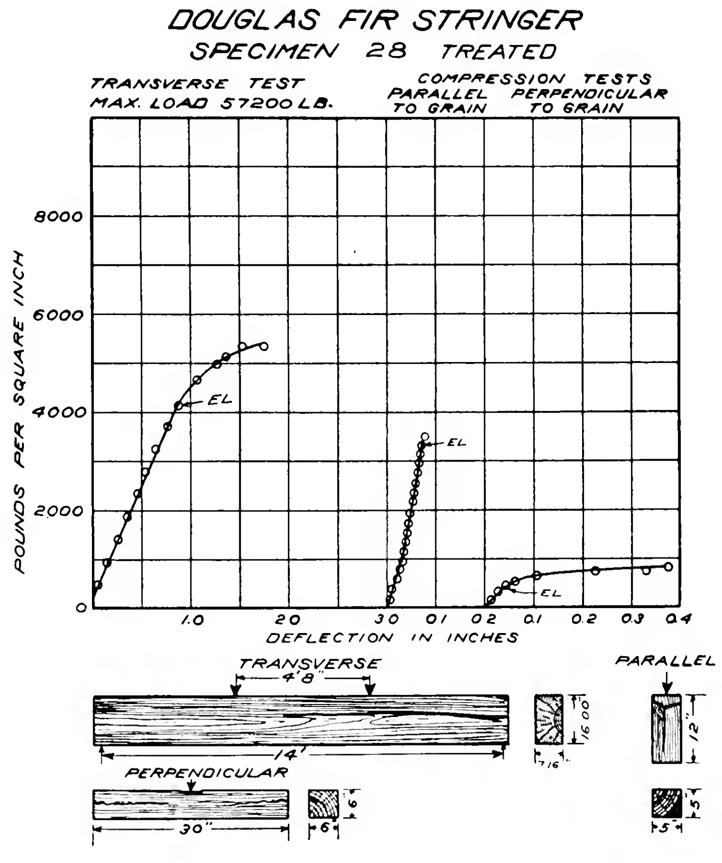

DOUGLAS FIR STRINGER
SPECIMEN 28 TREATED
TRANSVERSE TEST
MAX. LOAD 57200 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.00"
7.16"
PARALLEL
12"
PERPENDICULAR
30"
6
6
5
5

FIG. 98

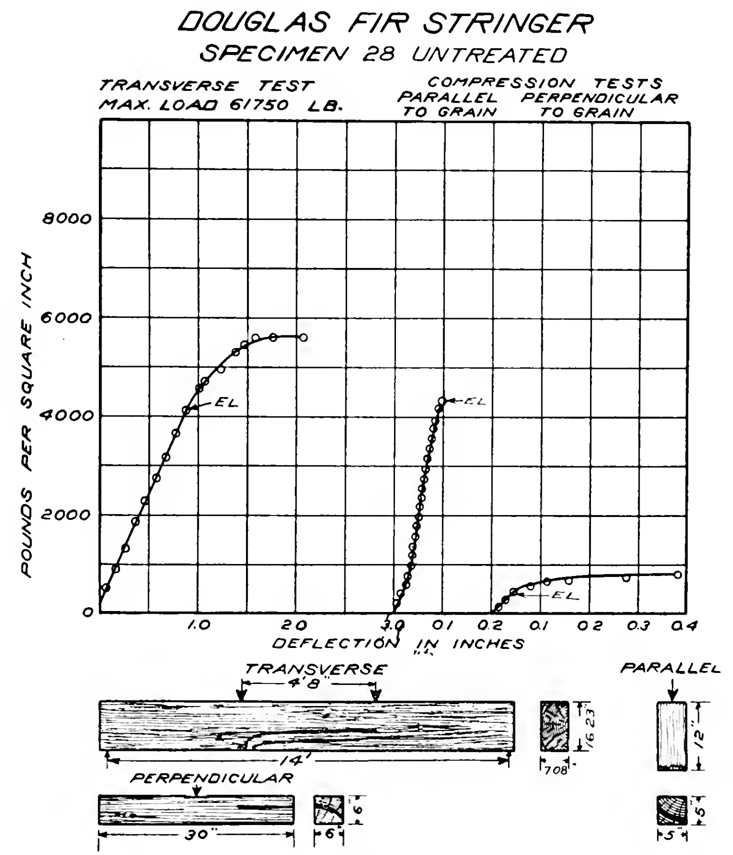

DOUGLAS FIR STRINGER
SPECIMEN 28 UNTREATED
TRANSVERSE TEST
MAX. LOAD 61750 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.23
7.08
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 99

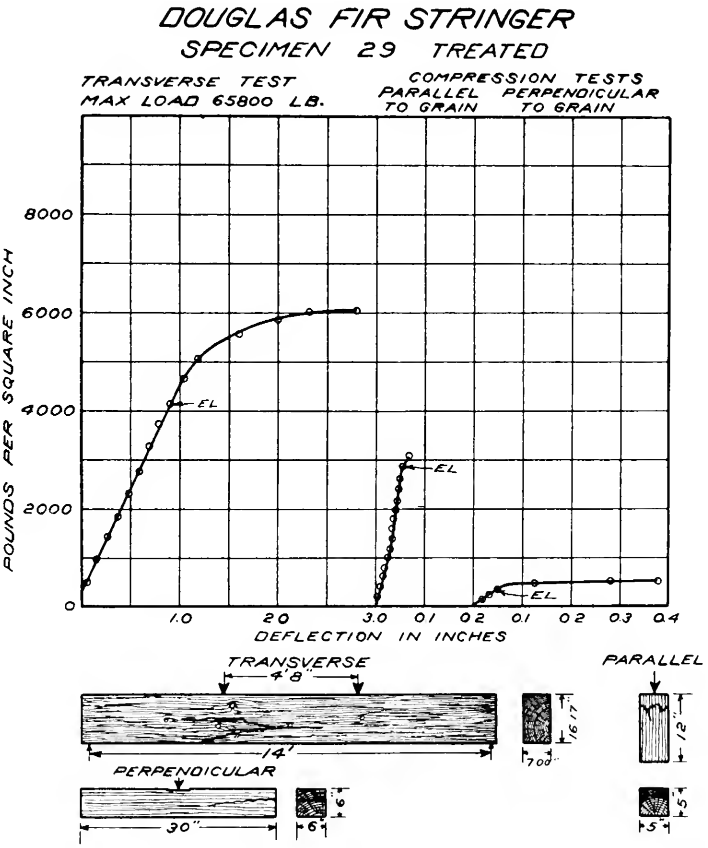

DOUGLAS FIR STRINGER
SPECIMEN 29 TREATED
TRANSVERSE TEST
MAX LOAD 65800 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
EL
EL
EL
TRANSVERSE
4'8"
14'
16.7"
7.0"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 100

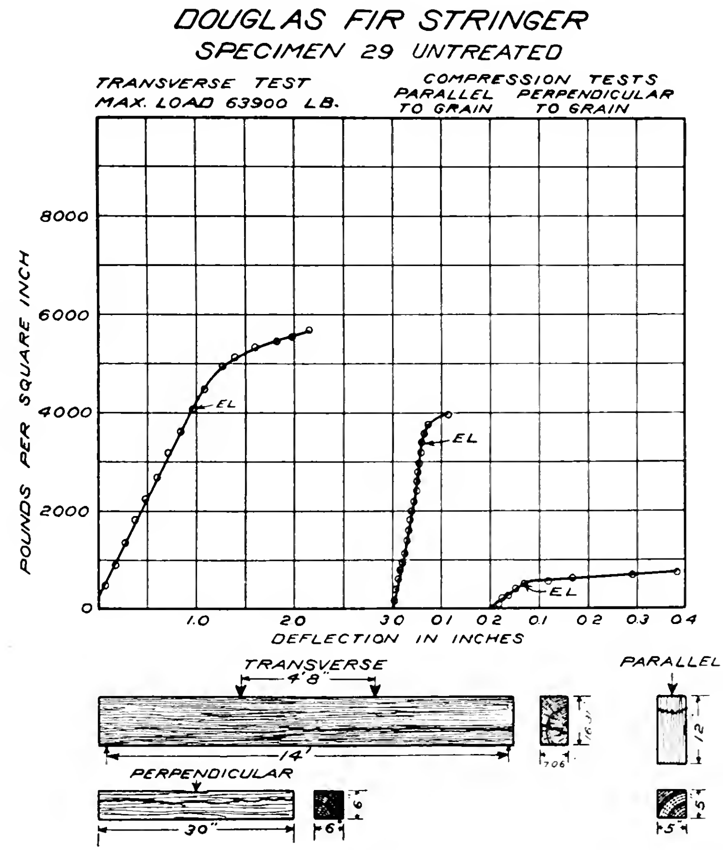

DOUGLAS FIR STRINGER
SPECIMEN 29 UNTREATED
TRANSVERSE TEST
MAX. LOAD 63900 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.3"
7.06"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 101

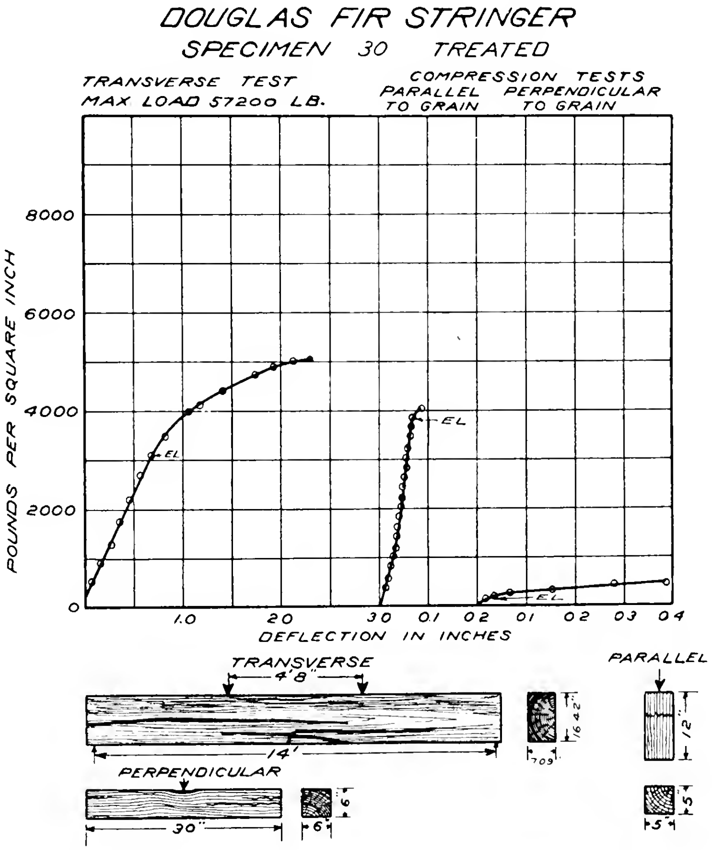

DOUGLAS FIR STRINGER
SPECIMEN 30 TREATED
TRANSVERSE TEST
MAX. LOAD 57200 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.42"
7.09"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 102

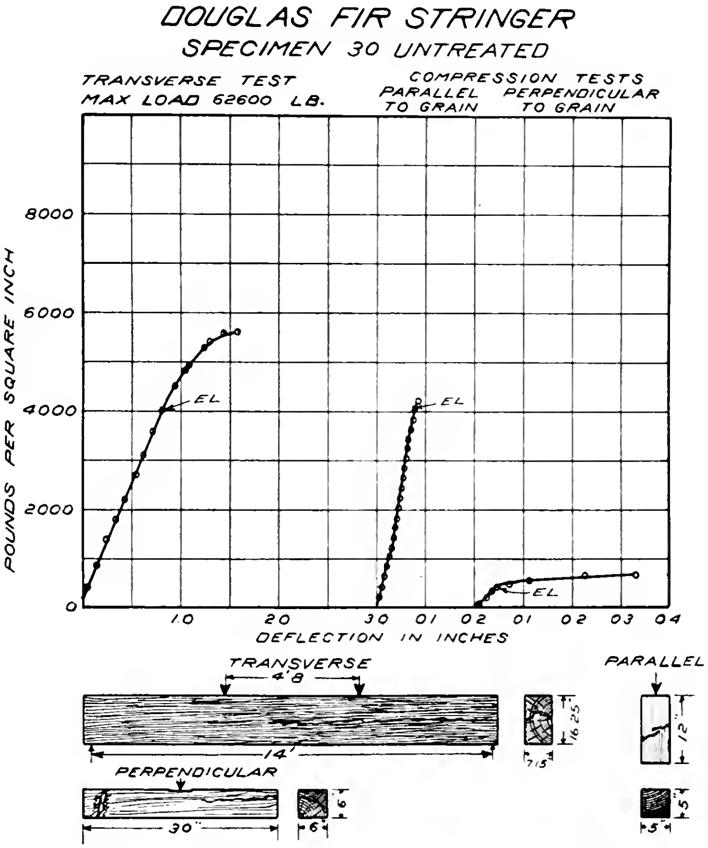

DOUGLAS FIR STRINGER
SPECIMEN 30 UNTREATED
TRANSVERSE TEST
MAX LOAD 62600 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
20
30
01
02
01
02
03
04
DEFLECTION IN INCHES
TRANSVERSE
4'8
14'
16.25"
7.5"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 103

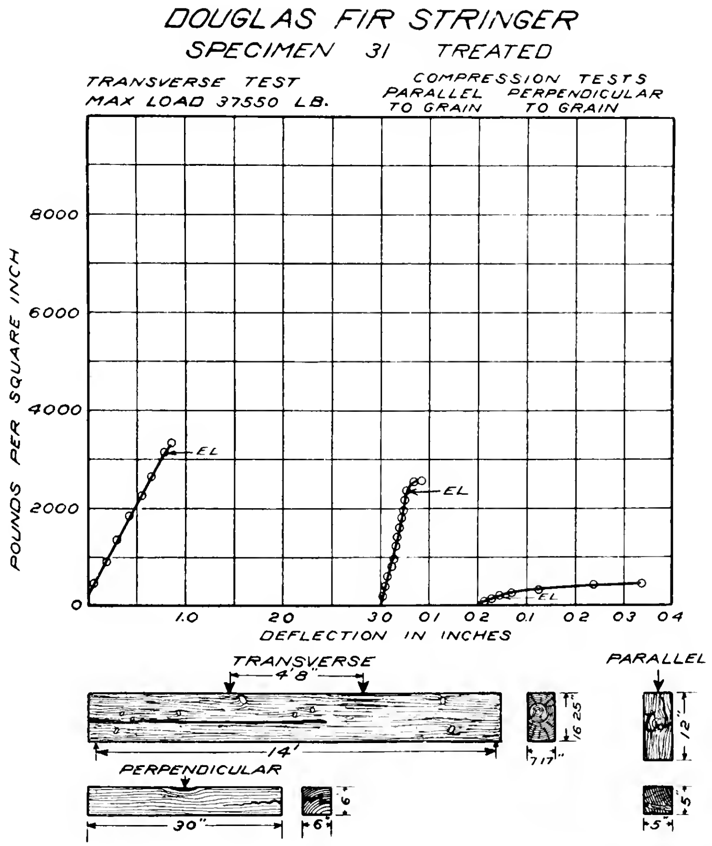

DOUGLAS FIR STRINGER
SPECIMEN 31 TREATED
TRANSVERSE TEST
MAX LOAD 37550 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
7.17"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 104

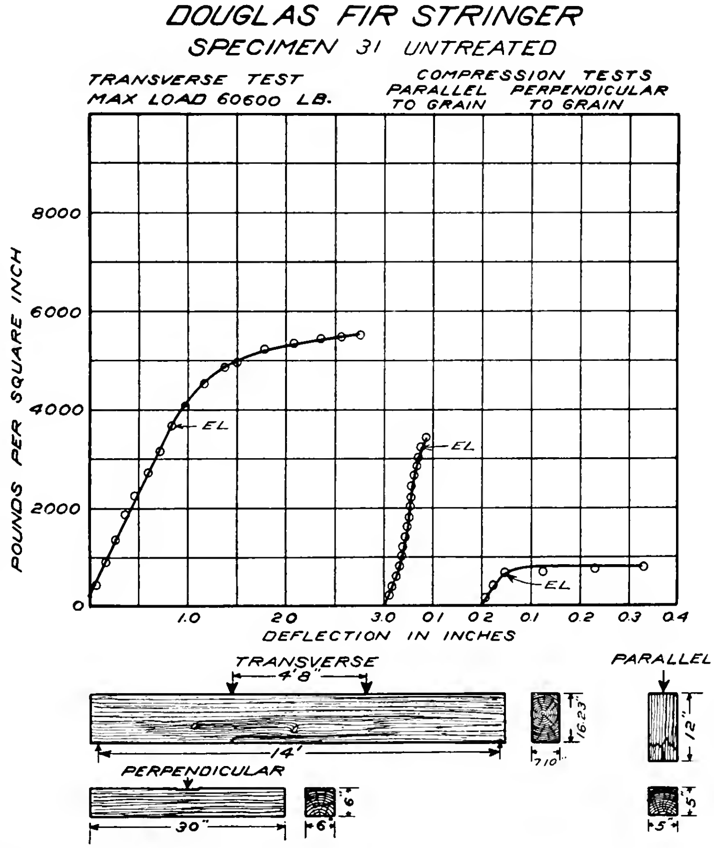

DOUGLAS FIR STRINGER
SPECIMEN 31 UNTREATED
TRANSVERSE TEST
MAX LOAD 60600 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.23"
7.10"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG.105

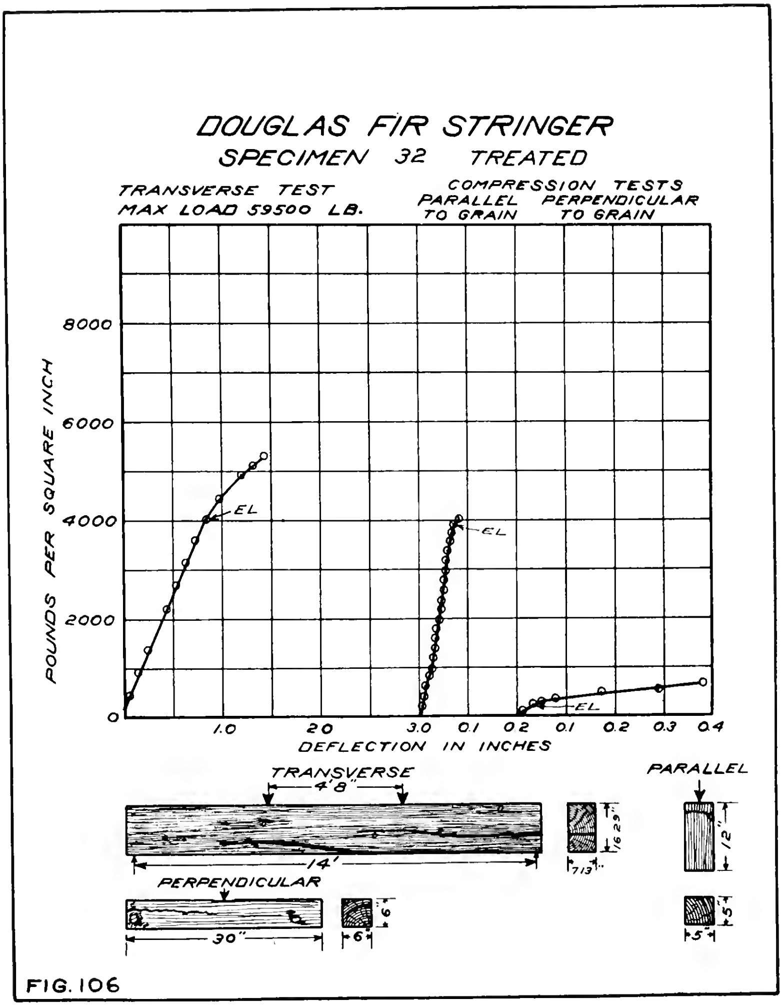

DOUGLAS FIR STRINGER
SPECIMEN 32 TREATED
TRANSVERSE TEST
MAX LOAD 59500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
8000
6000
4000
2000
0
POUNDS PER SQUARE INCH
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.29"
7.13"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 106

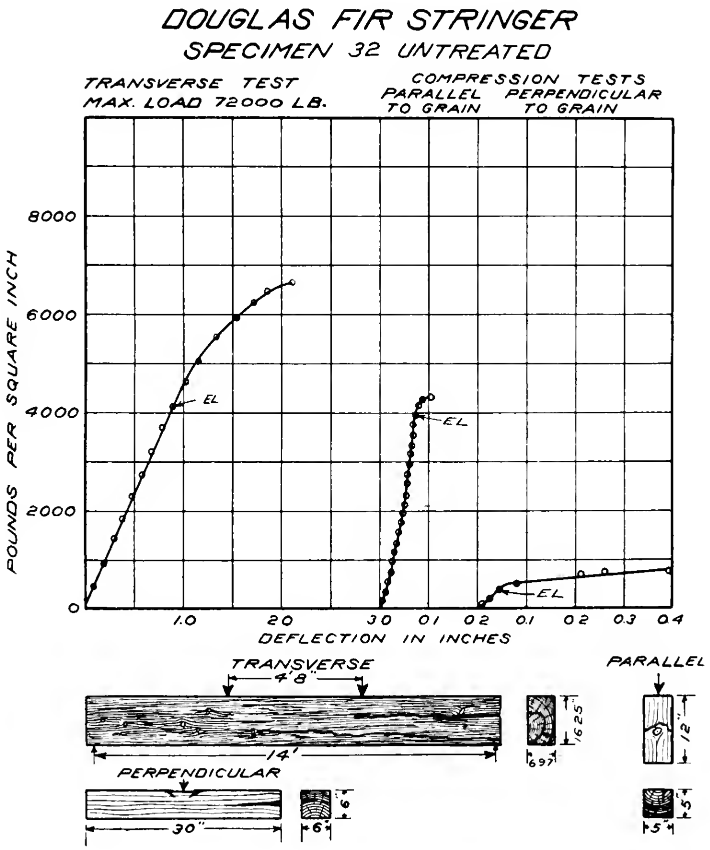

DOUGLAS FIR STRINGER
SPECIMEN 32 UNTREATED
TRANSVERSE TEST
MAX. LOAD 72000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2 0
3 0
0 1
0 2
0.1
0 2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4' 8"
14'
16.25"
6.97"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 107.

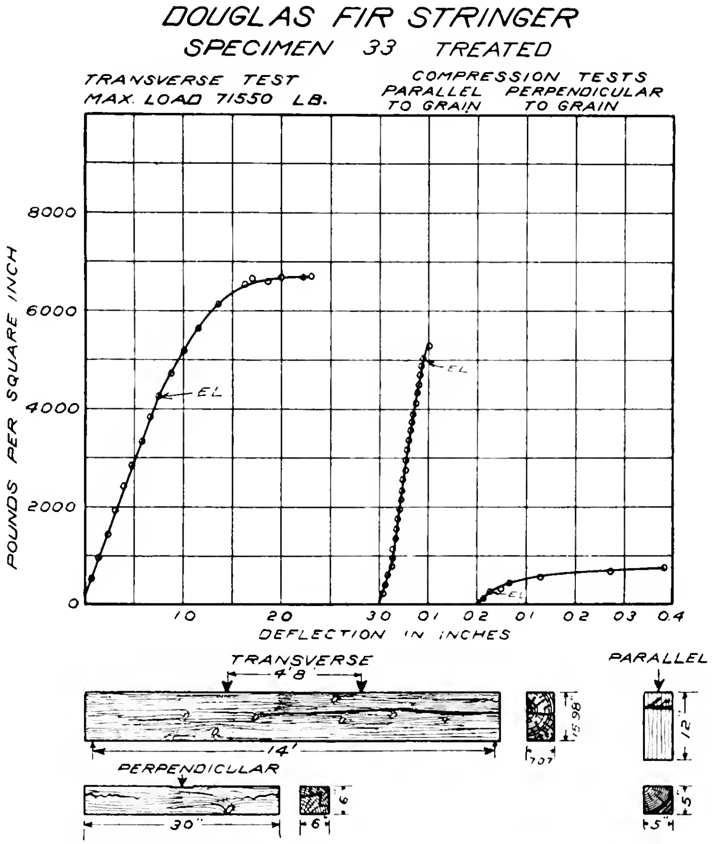

DOUGLAS FIR STRINGER
SPECIMEN 33 TREATED
TRANSVERSE TEST
MAX. LOAD 71550 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
10
20
30
01
02
01
02
03
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
15.98"
7.07"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG 108

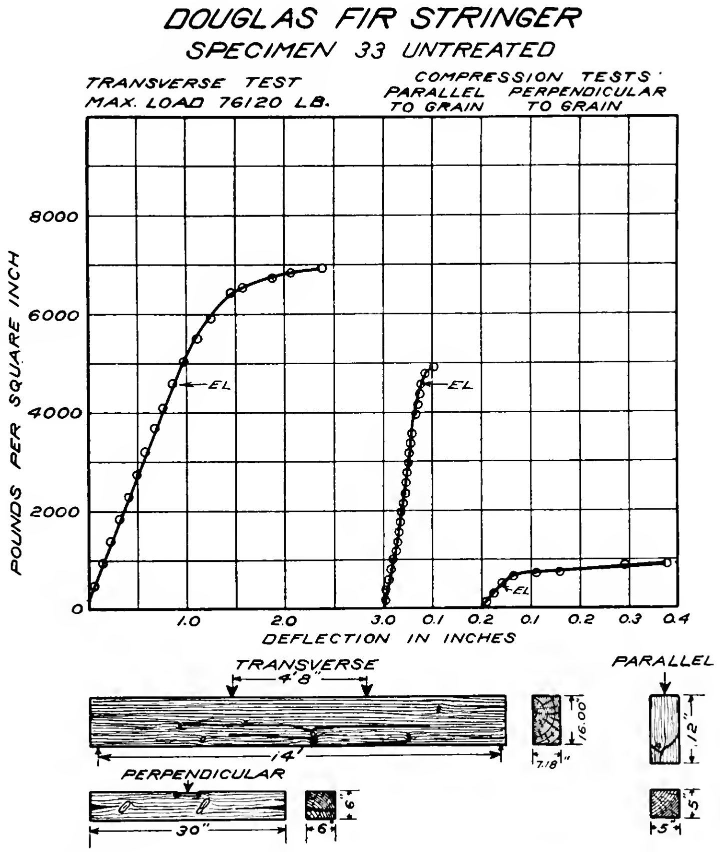

DOUGLAS FIR STRINGER
SPECIMEN 33 UNTREATED
TRANSVERSE TEST
MAX. LOAD 76120 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.00"
7.18"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 109

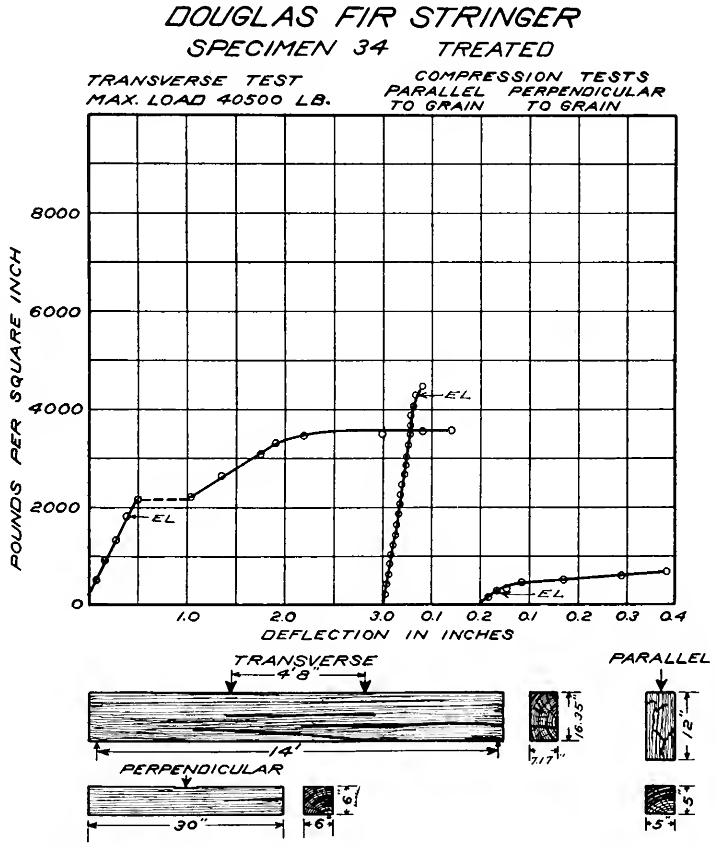

DOUGLAS FIR STRINGER
SPECIMEN 34 TREATED
TRANSVERSE TEST
MAX. LOAD 40500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.35"
7.17"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 110

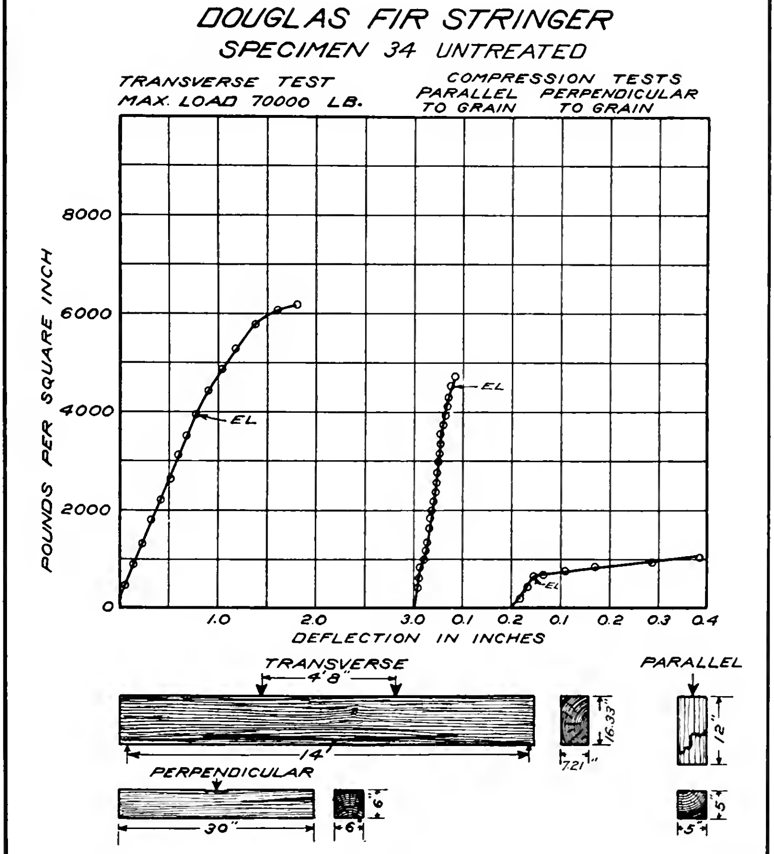

DOUGLAS FIR STRINGER
SPECIMEN 34 UNTREATED
TRANSVERSE TEST
MAX. LOAD 70000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.33"
7.21"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 111.

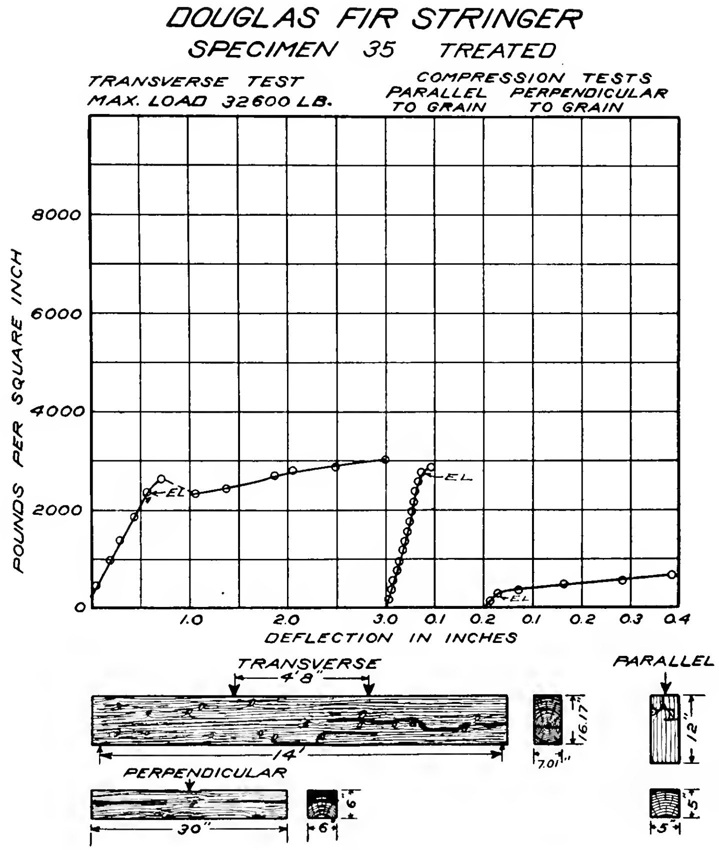

DOUGLAS FIR STRINGER
SPECIMEN 35 TREATED
TRANSVERSE TEST
MAX. LOAD 32600 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.17"
7.01"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 112

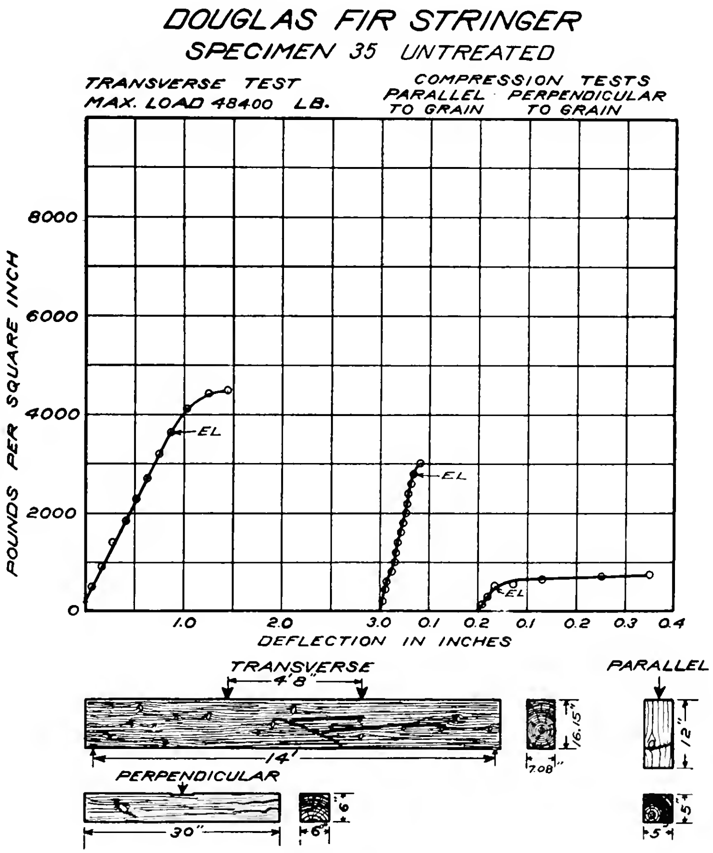

DOUGLAS FIR STRINGER
SPECIMEN 35 UNTREATED
TRANSVERSE TEST
MAX. LOAD 48400 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.15"
7.08"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 113

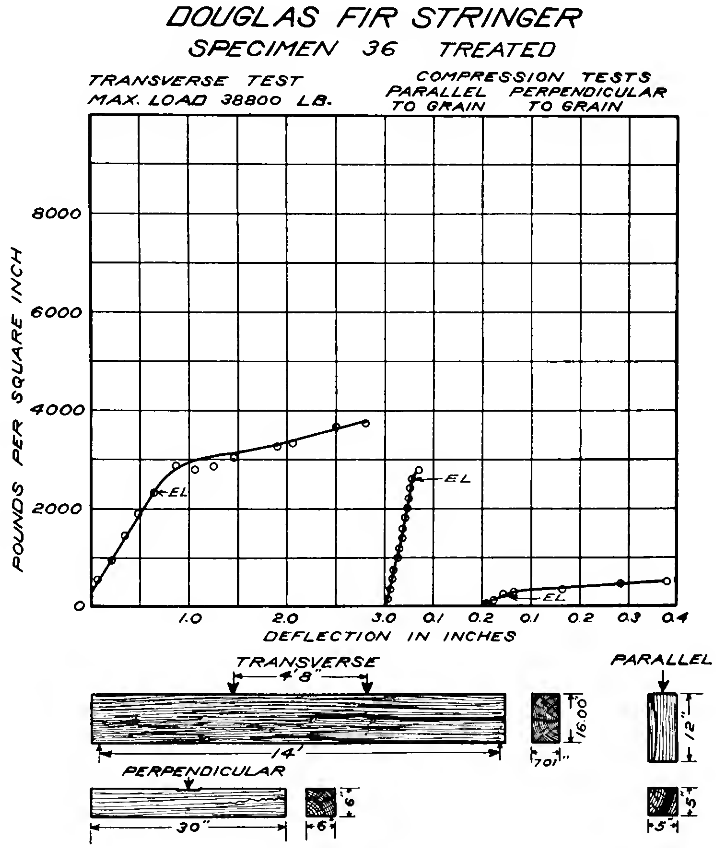

DOUGLAS FIR STRINGER
SPECIMEN 36 TREATED
TRANSVERSE TEST
MAX. LOAD 38800 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.00"
7.01"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 114

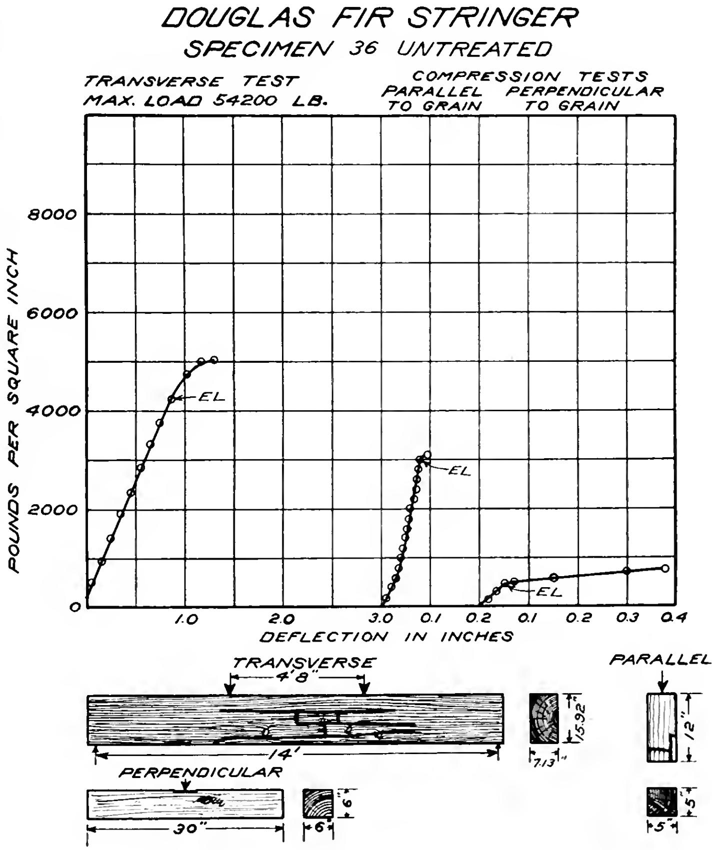

DOUGLAS FIR STRINGER
SPECIMEN 36 UNTREATED
TRANSVERSE TEST
MAX. LOAD 54200 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
15.92"
7.13"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 115

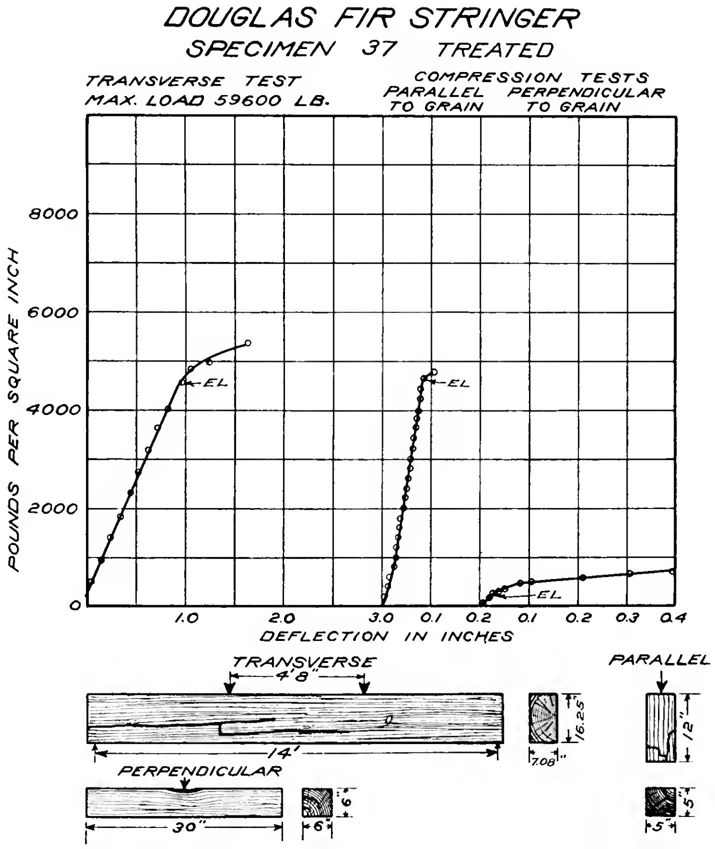

DOUGLAS FIR STRINGER
SPECIMEN 37 TREATED
TRANSVERSE TEST
MAX. LOAD 59600 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
7.08"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 116

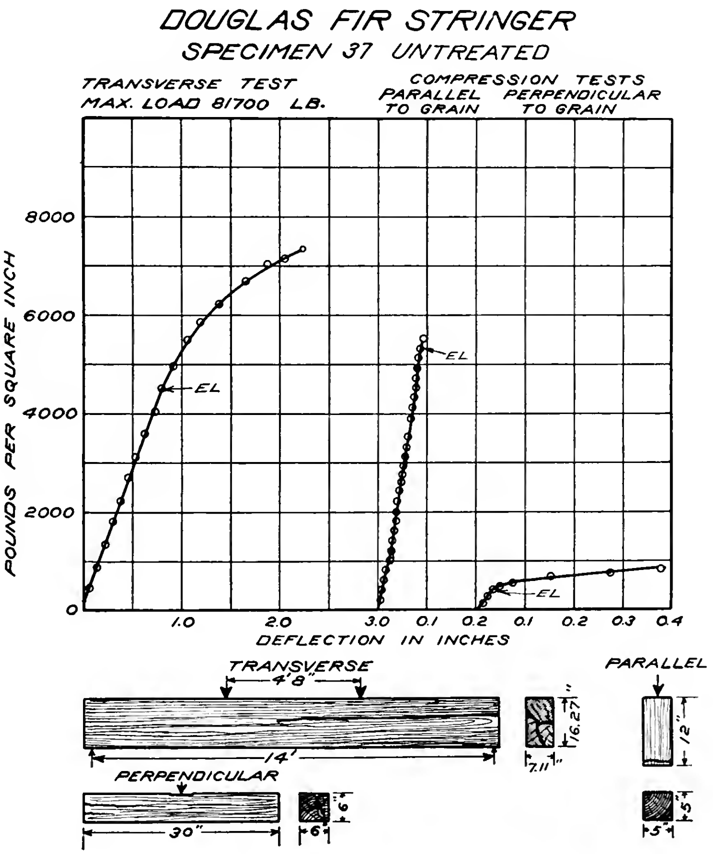

DOUGLAS FIR STRINGER
SPECIMEN 37 UNTREATED
TRANSVERSE TEST
MAX. LOAD 81700 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.27"
7.11"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 117

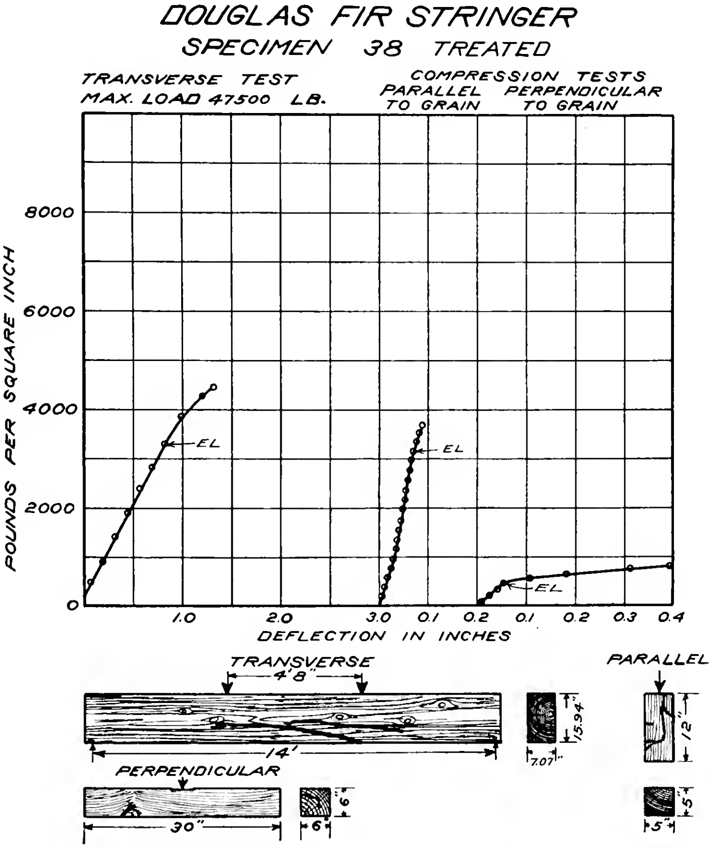

DOUGLAS FIR STRINGER
SPECIMEN 38 TREATED
TRANSVERSE TEST
MAX. LOAD 47500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
15.94"
7.07"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 118

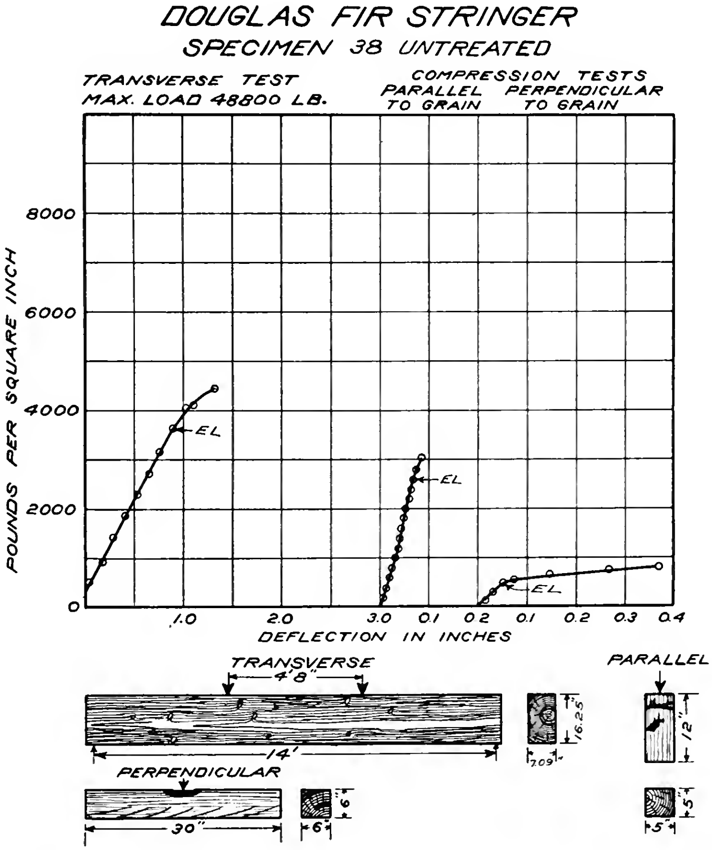

DOUGLAS FIR STRINGER
SPECIMEN 38 UNTREATED
TRANSVERSE TEST
MAX. LOAD 48800 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
7.09"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 119

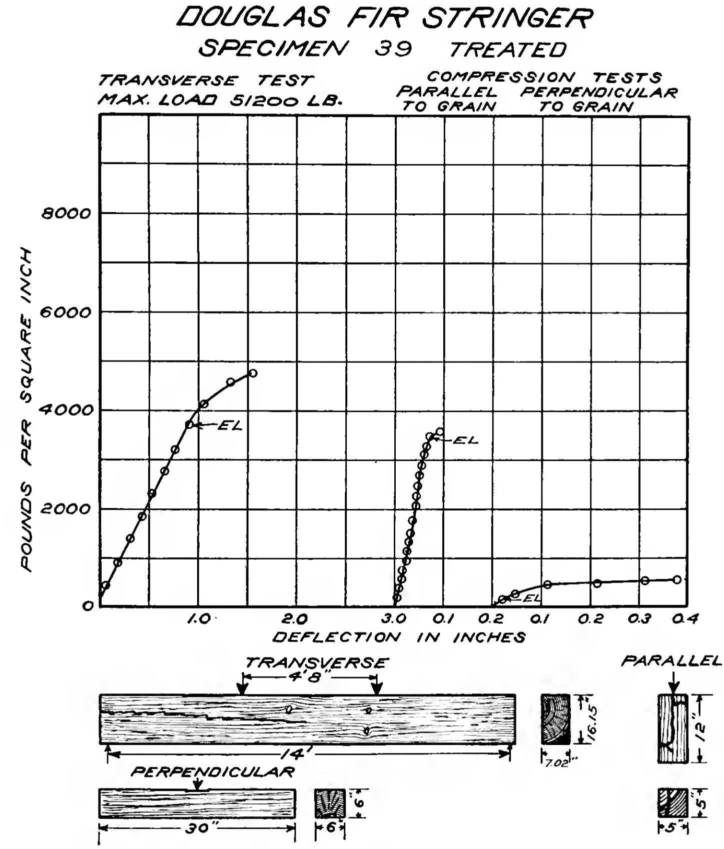

DOUGLAS FIR STRINGER
SPECIMEN 39 TREATED
TRANSVERSE TEST
MAX. LOAD 51200 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.15"
7.02"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 120

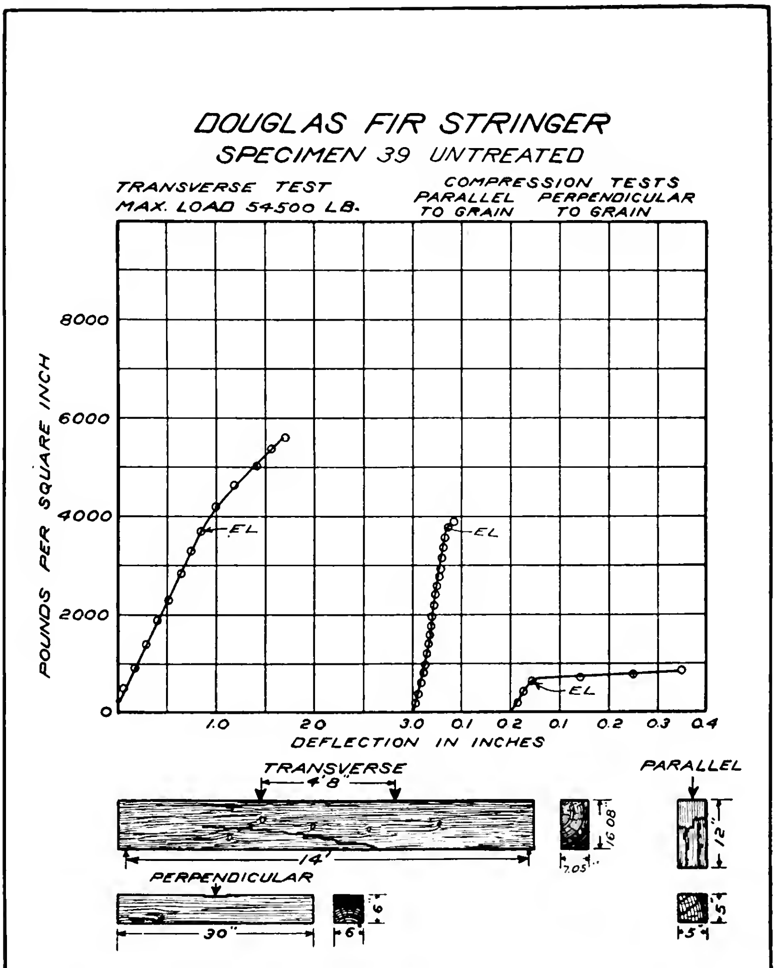

DOUGLAS FIR STRINGER
SPECIMEN 39 UNTREATED
TRANSVERSE TEST
MAX. LOAD 54500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.08"
7.05"
PARALLEL
12"
PERPENDICULAR
30"
6"
6
5"
5

FIG. 121

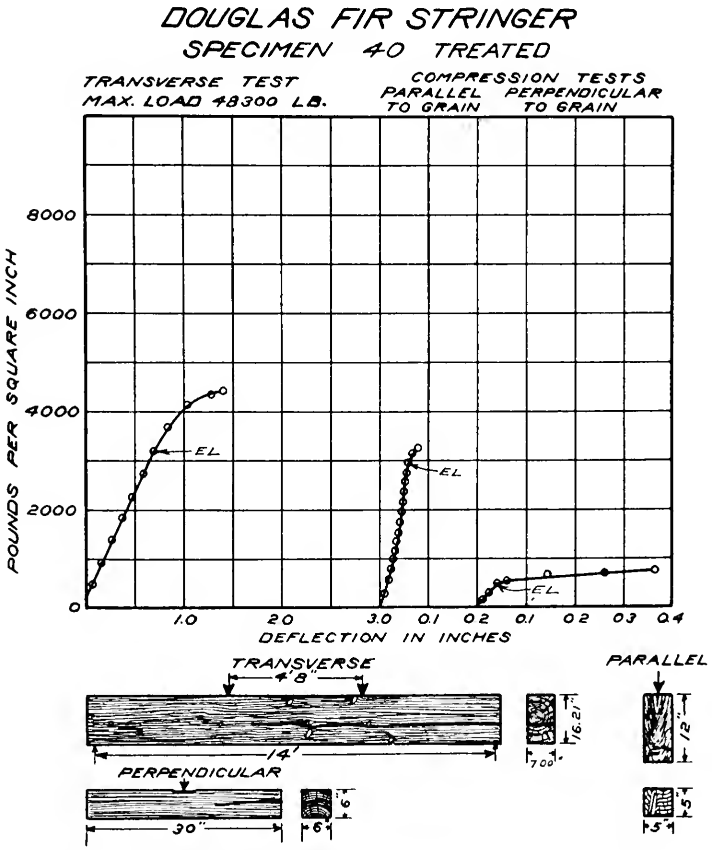

DOUGLAS FIR STRINGER
SPECIMEN 40 TREATED
TRANSVERSE TEST
MAX. LOAD 48300 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.21"
7.00"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 122

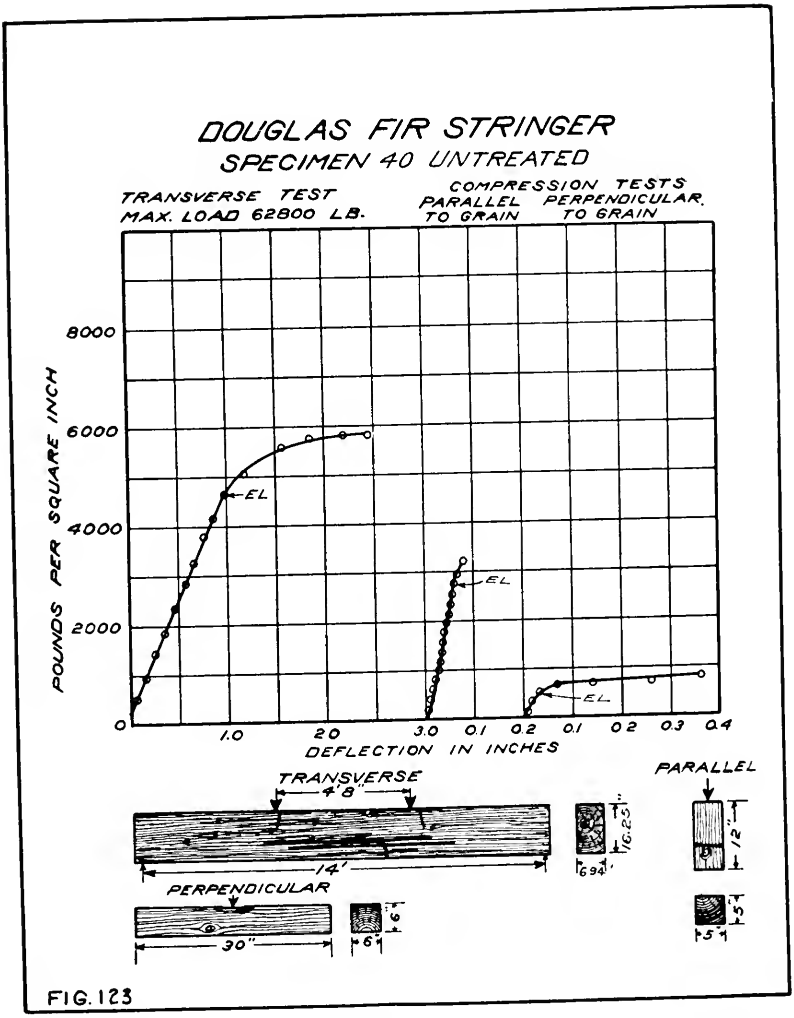

DOUGLAS FIR STRINGER
SPECIMEN 40 UNTREATED
TRANSVERSE TEST
MAX. LOAD 62800 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2 0
3.0
0.1
0.2
0.1
0 2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
6 9/4"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 123

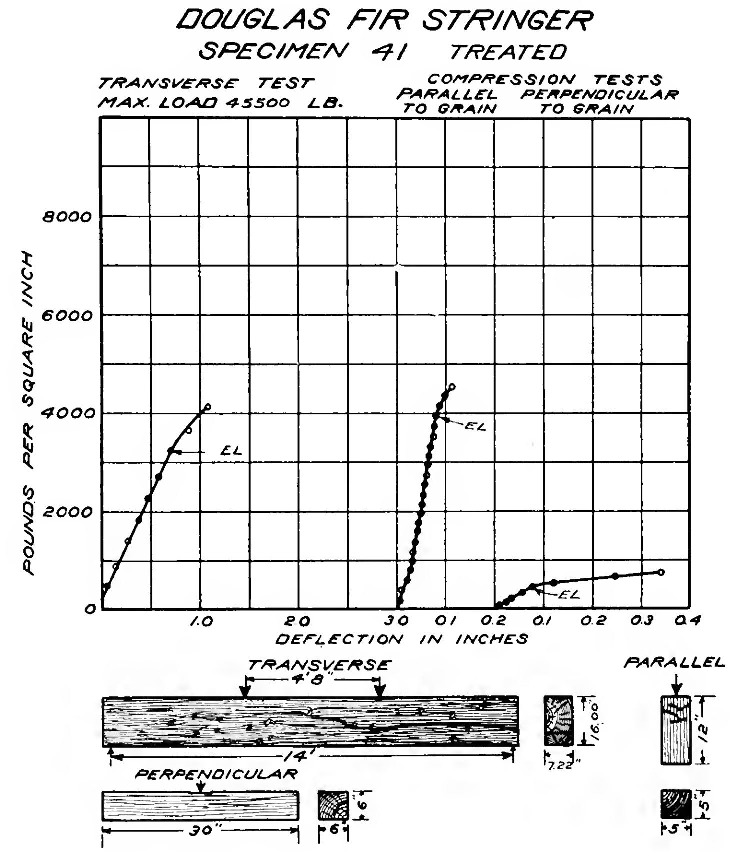

DOUGLAS FIR STRINGER
SPECIMEN 41 TREATED
TRANSVERSE TEST
MAX. LOAD 45500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.00"
7.22"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 124

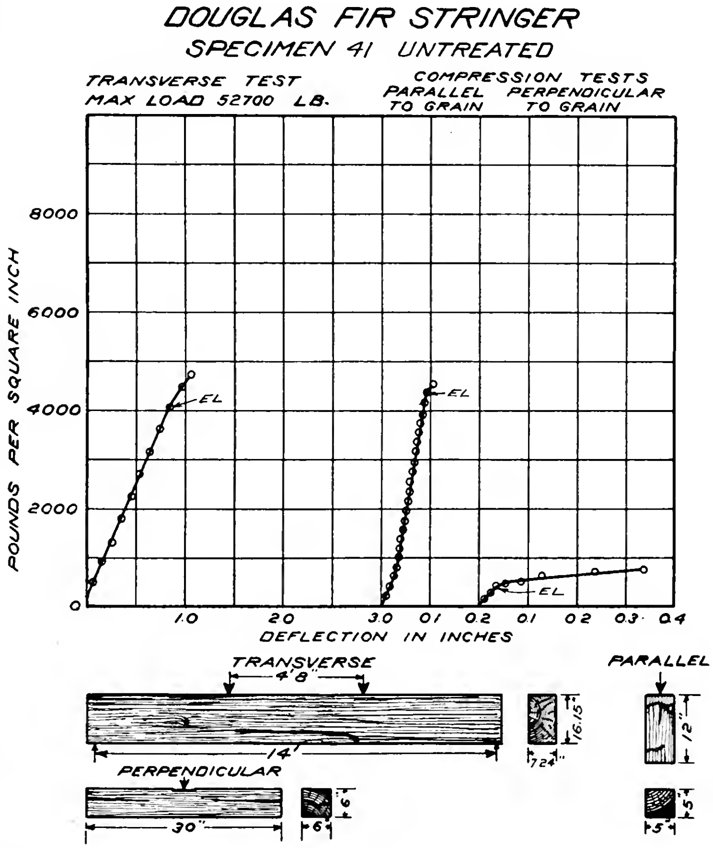

DOUGLAS FIR STRINGER
SPECIMEN 41 UNTREATED
TRANSVERSE TEST
MAX LOAD 52700 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.5"
724"
PARALLEL
12"
PERPENDICULAR
30"
6"
6
5"
5

FIG. 125

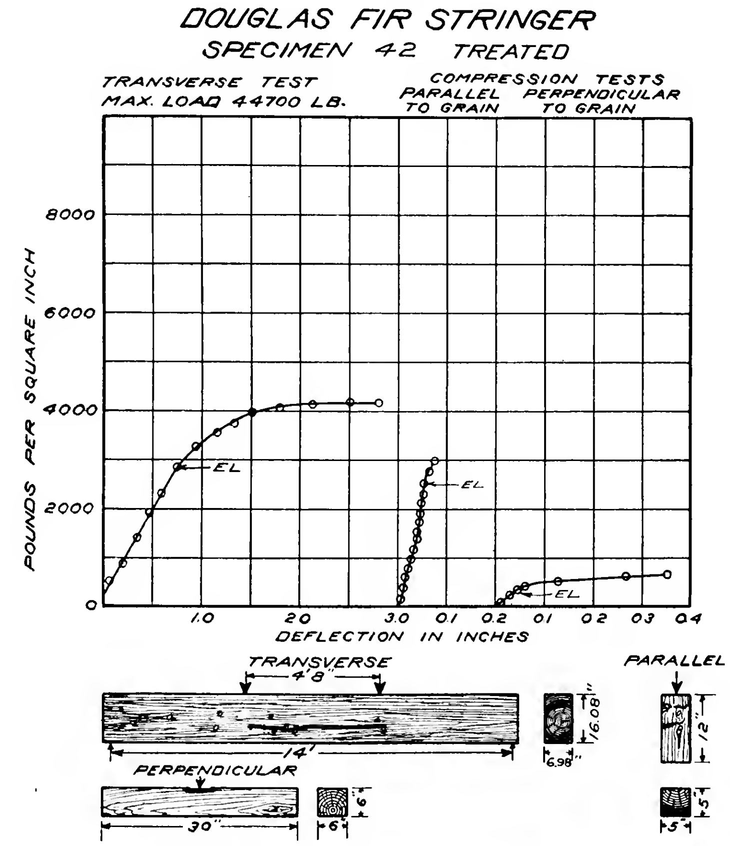

DOUGLAS FIR STRINGER
SPECIMEN 42 TREATED
TRANSVERSE TEST
MAX. LOAD 44700 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.08"
6.98"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 126

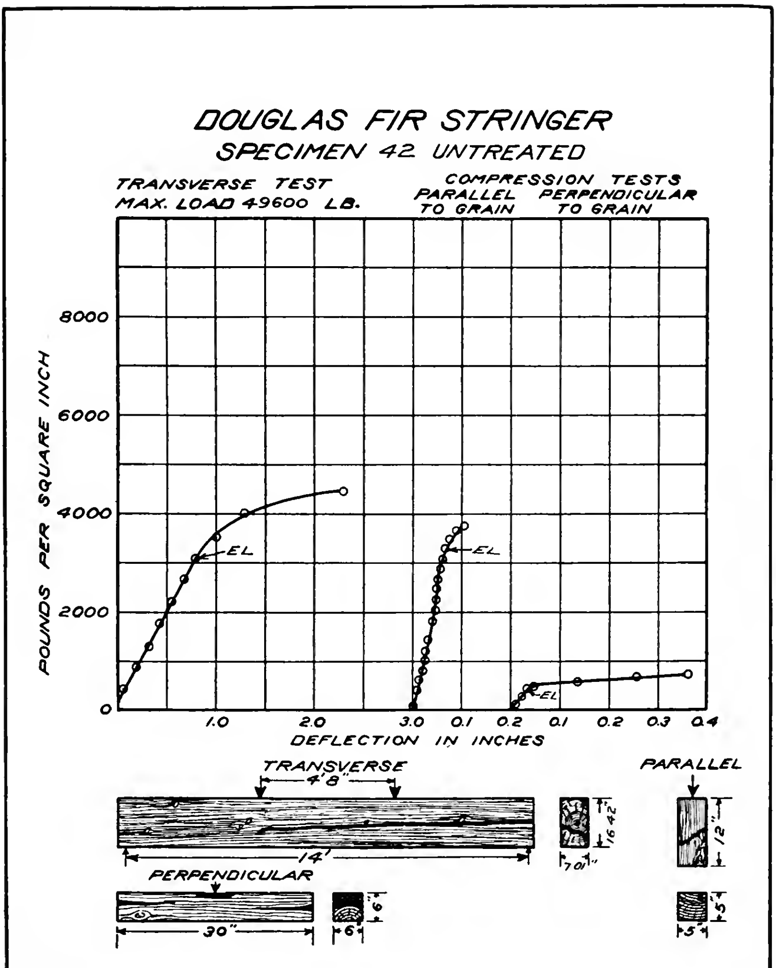

DOUGLAS FIR STRINGER
SPECIMEN 42 UNTREATED
TRANSVERSE TEST
MAX. LOAD 49600 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16 3/4"
7 0"
PARALLEL
12"
PERPENDICULAR
30"
6"
6
5"
5"

FIG. 127

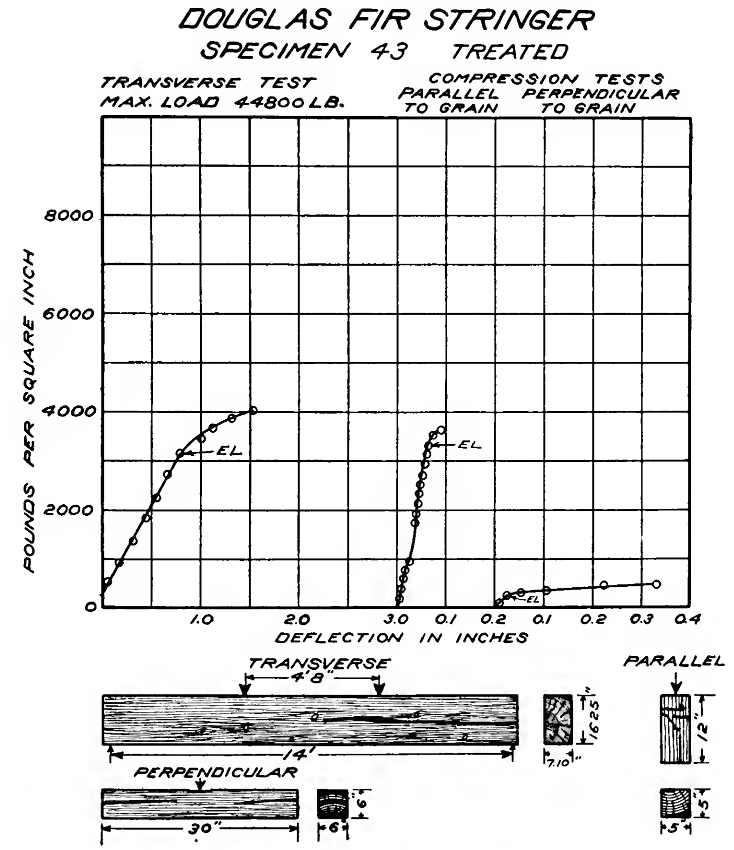

DOUGLAS FIR STRINGER
SPECIMEN 43 TREATED
TRANSVERSE TEST
MAX. LOAD 44800 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
EL
EL
EL
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
7.10"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 128

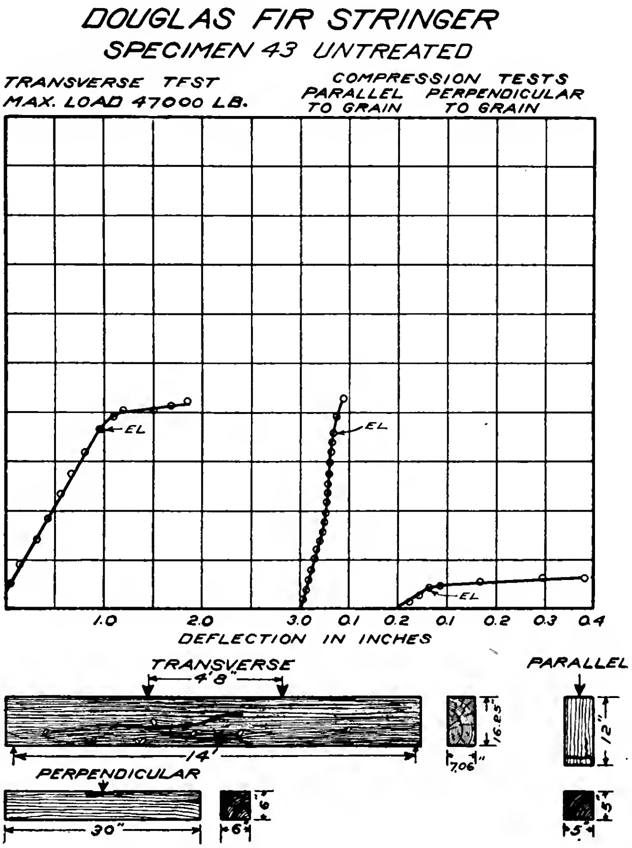

DOUGLAS FIR STRINGER
SPECIMEN 43 UNTREATED
TRANSVERSE TEST
MAX. LOAD 47000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.25"
7.06"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 129

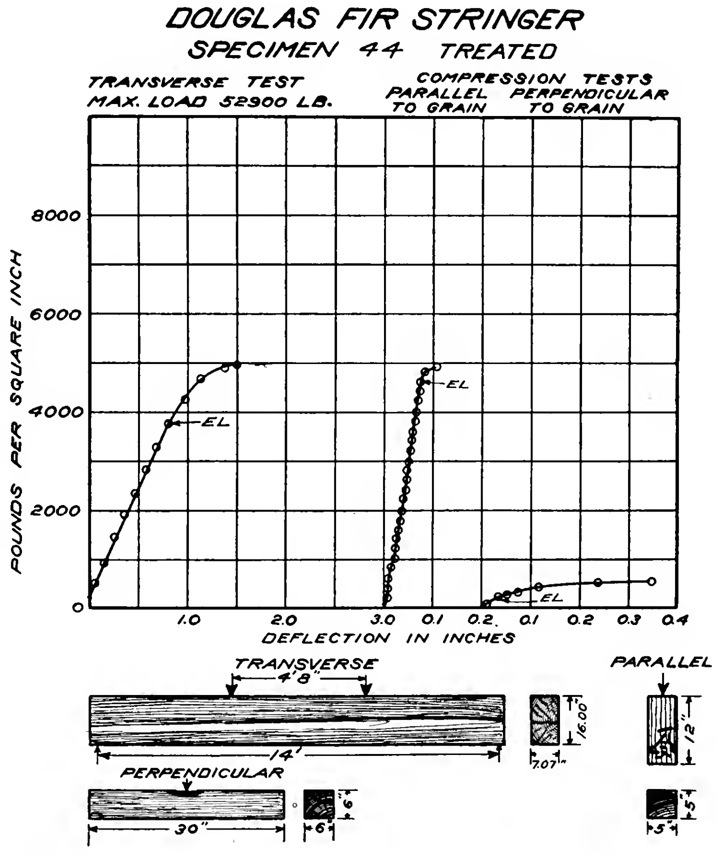

DOUGLAS FIR STRINGER
SPECIMEN 44 TREATED
TRANSVERSE TEST
MAX. LOAD 52900 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.00"
7.07"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 130

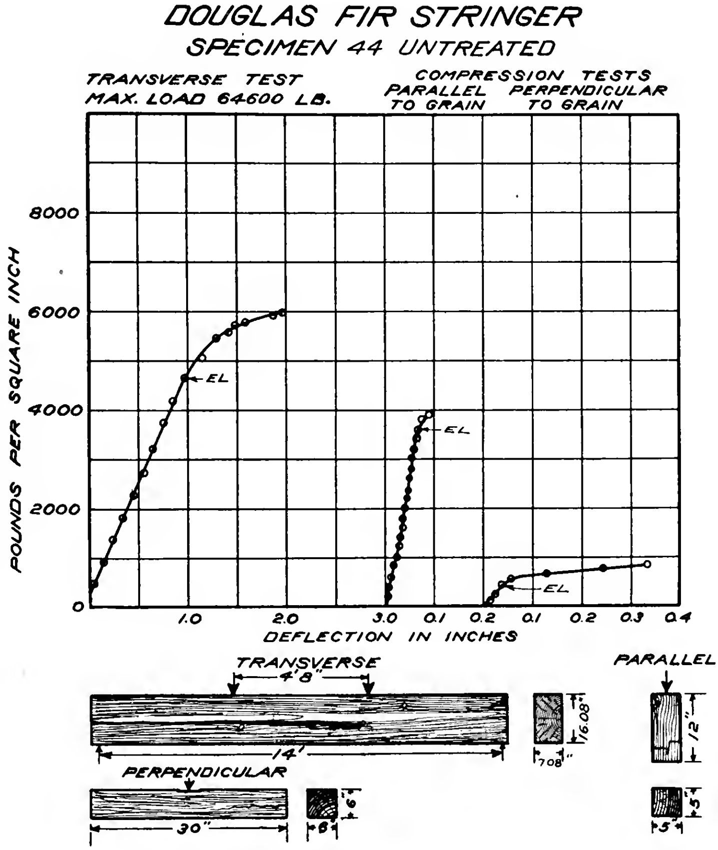

DOUGLAS FIR STRINGER
SPECIMEN 44 UNTREATED
TRANSVERSE TEST
MAX. LOAD 64600 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.08"
7.08"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 131

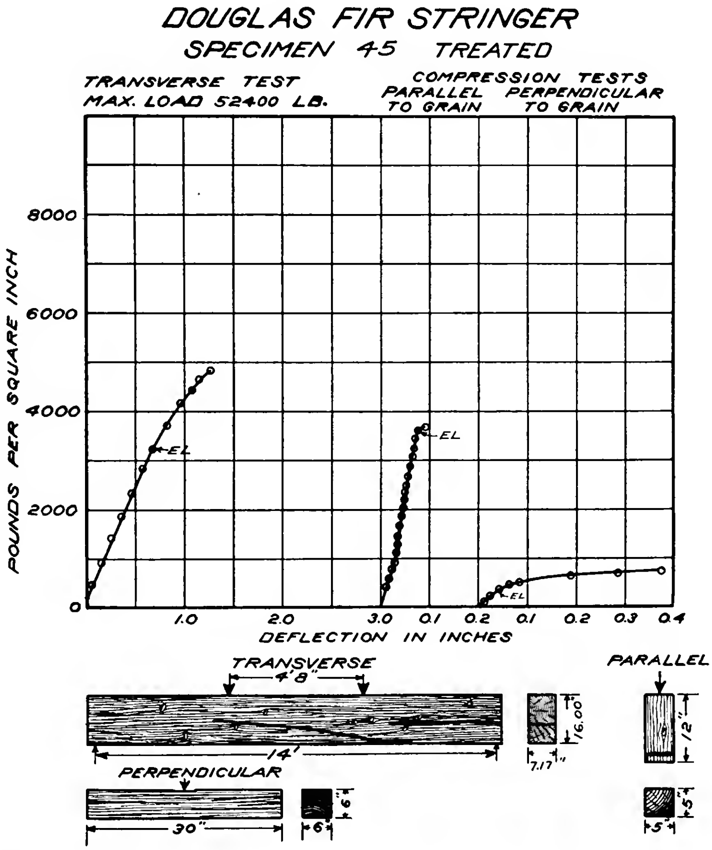

DOUGLAS FIR STRINGER
SPECIMEN 45 TREATED
TRANSVERSE TEST
MAX. LOAD 52400 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.00"
7.17"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 132

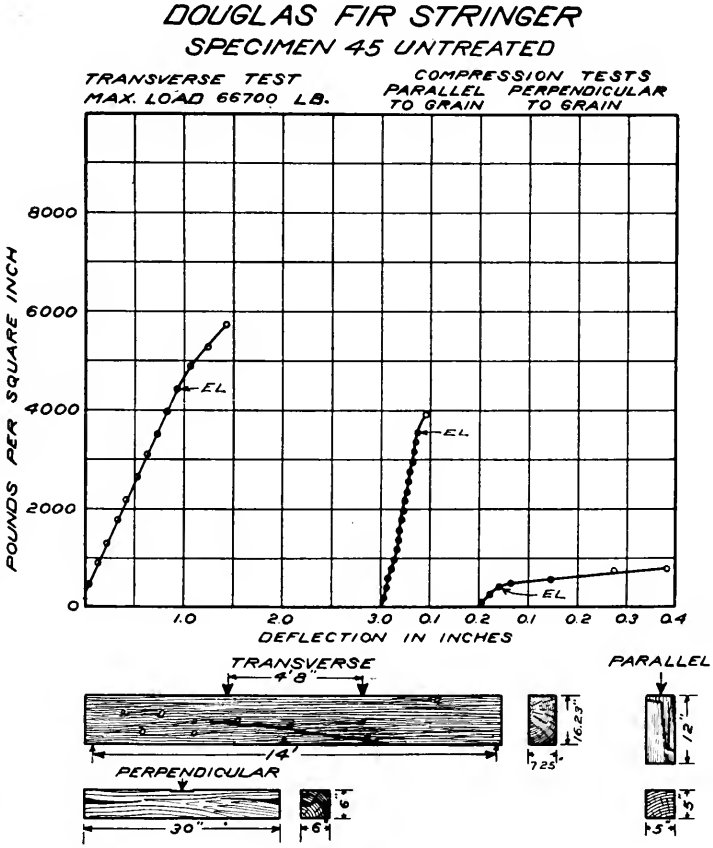

DOUGLAS FIR STRINGER
SPECIMEN 45 UNTREATED
TRANSVERSE TEST
MAX. LOAD 66700 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.23"
7.25"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 133

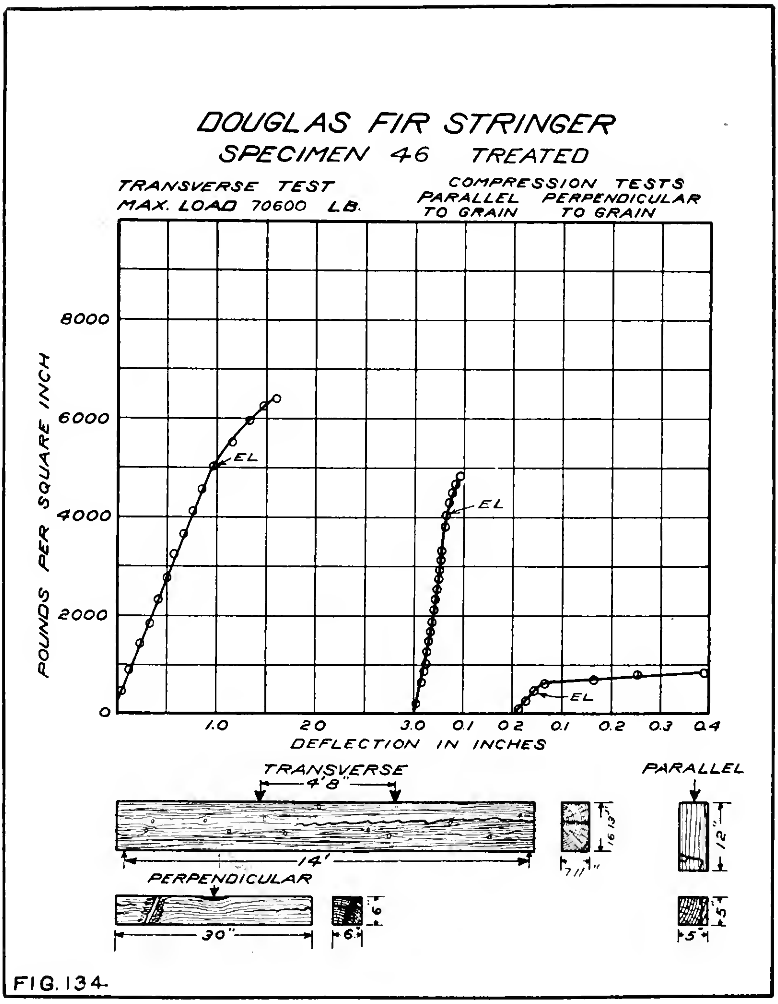

DOUGLAS FIR STRINGER
SPECIMEN 46 TREATED
TRANSVERSE TEST
MAX. LOAD 70600 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16 1/3"
7 1/2"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 134

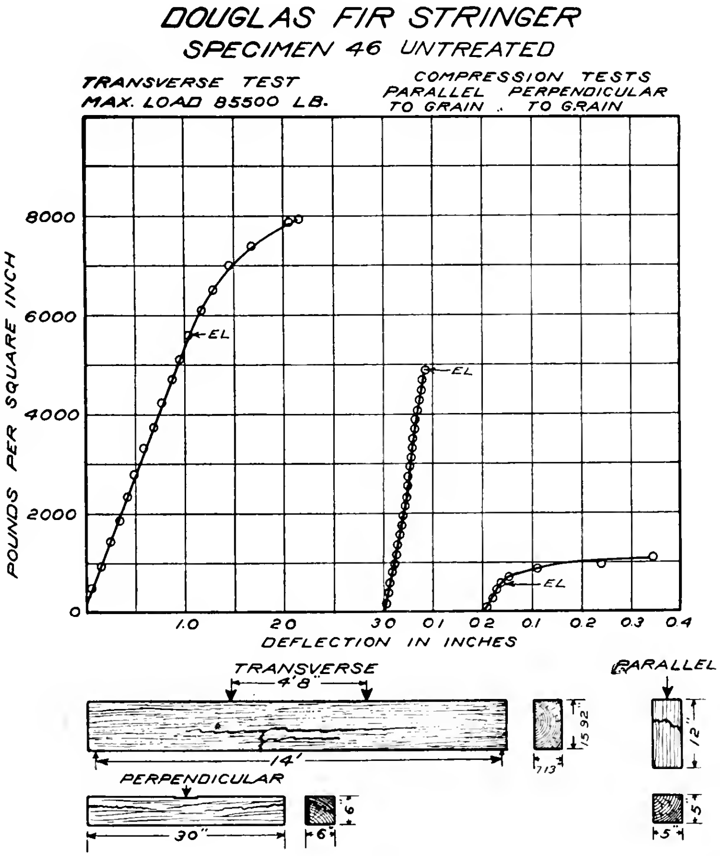

DOUGLAS FIR STRINGER
SPECIMEN 46 UNTREATED
TRANSVERSE TEST
MAX. LOAD 85500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
15.92"
7.13"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG 135

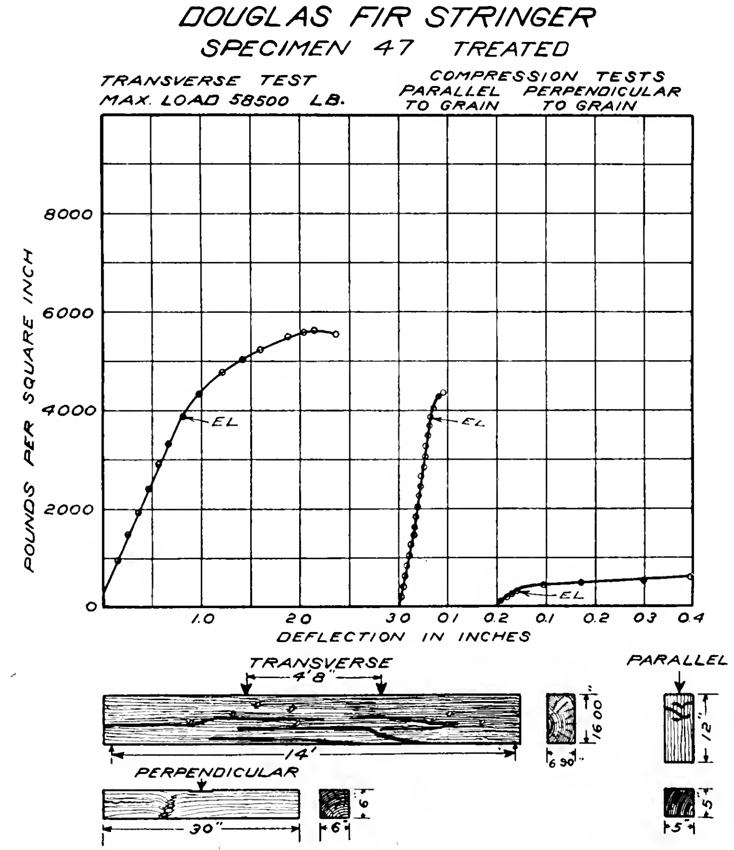

DOUGLAS FIR STRINGER
SPECIMEN 47 TREATED
TRANSVERSE TEST
MAX. LOAD 58500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.00"
6.90"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 136

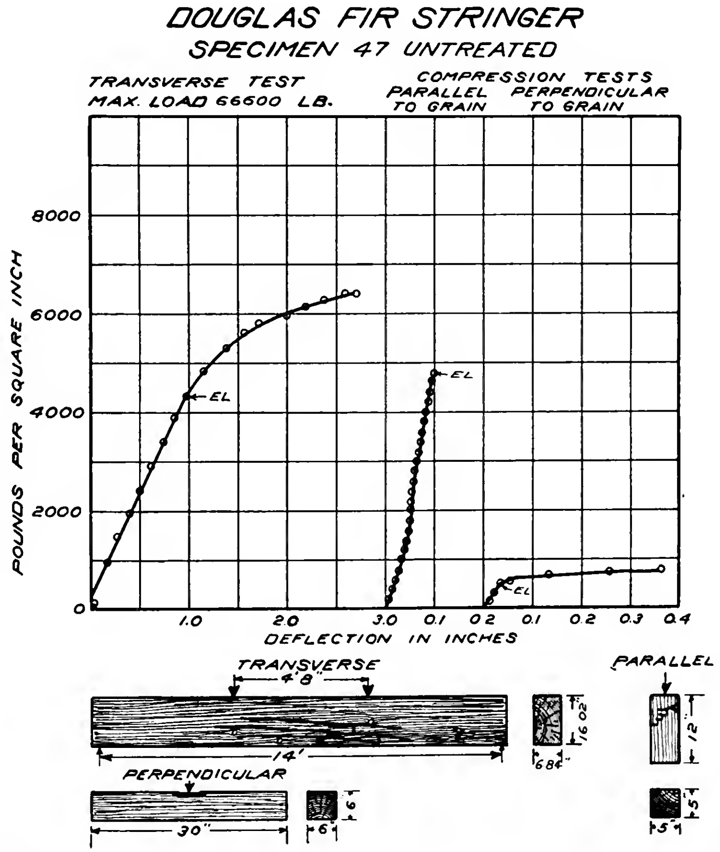

DOUGLAS FIR STRINGER
SPECIMEN 47 UNTREATED
TRANSVERSE TEST
MAX. LOAD 66600 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.02"
6.84"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 137

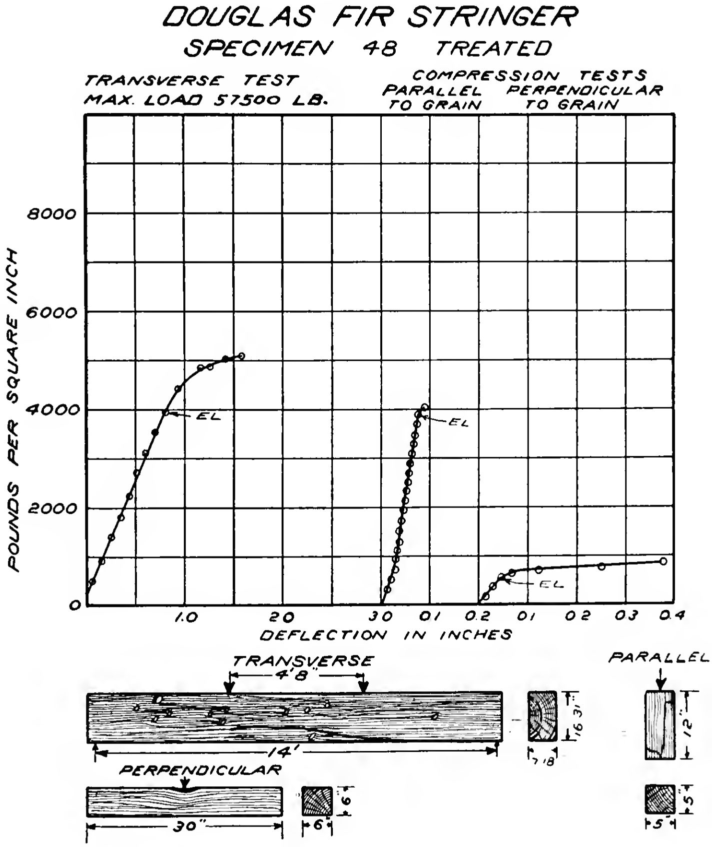

DOUGLAS FIR STRINGER
SPECIMEN 48 TREATED
TRANSVERSE TEST
MAX. LOAD 57500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16 3/8"
7 1/8"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 138

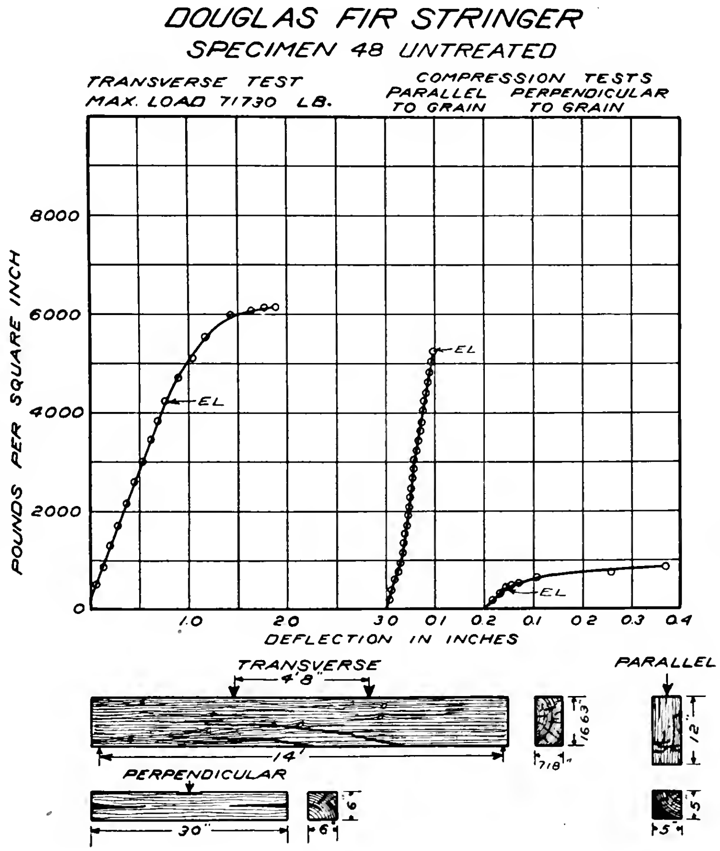

DOUGLAS FIR STRINGER
SPECIMEN 48 UNTREATED
TRANSVERSE TEST
MAX. LOAD 71730 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16⅝"
7⅞"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 139

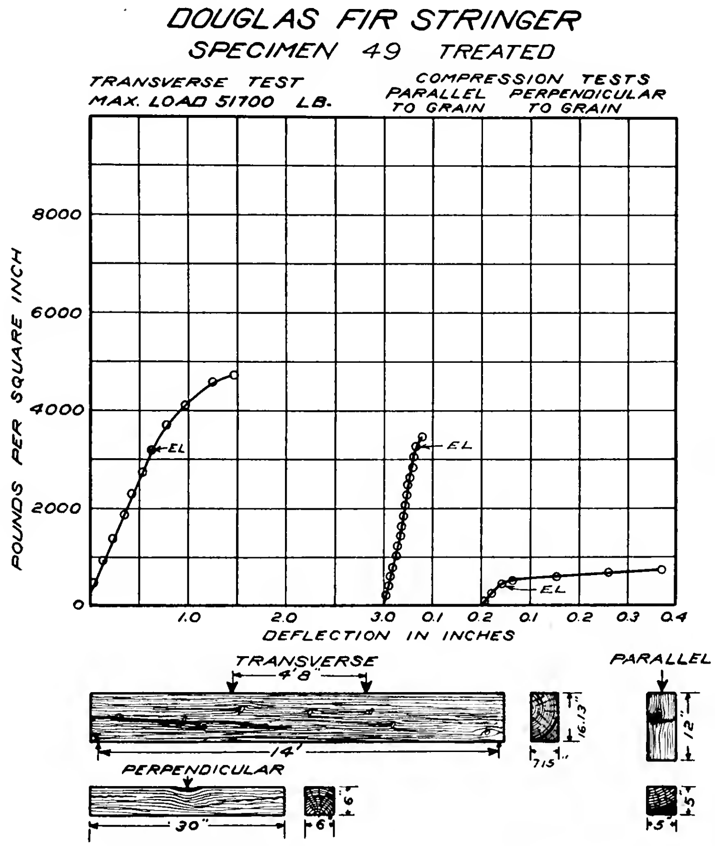

DOUGLAS FIR STRINGER
SPECIMEN 49 TREATED
TRANSVERSE TEST
MAX. LOAD 51700 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
E.L
E.L
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.13"
7.15"
PARALLEL
12"
5"
5
PERPENDICULAR
30"
6"
6

FIG. 140

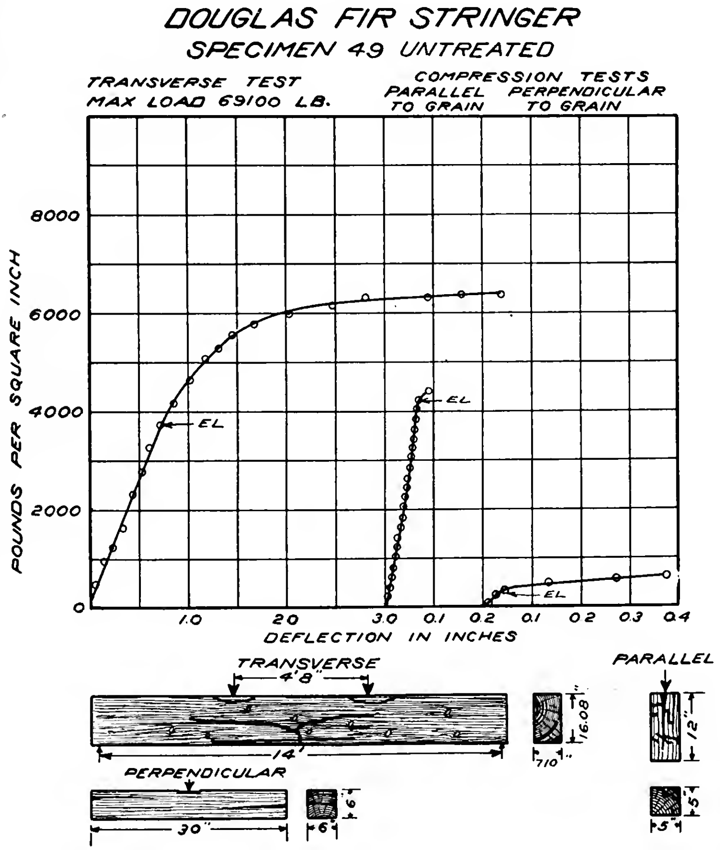

DOUGLAS FIR STRINGER
SPECIMEN 49 UNTREATED
TRANSVERSE TEST
MAX LOAD 69100 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.08"
7.10"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG 141

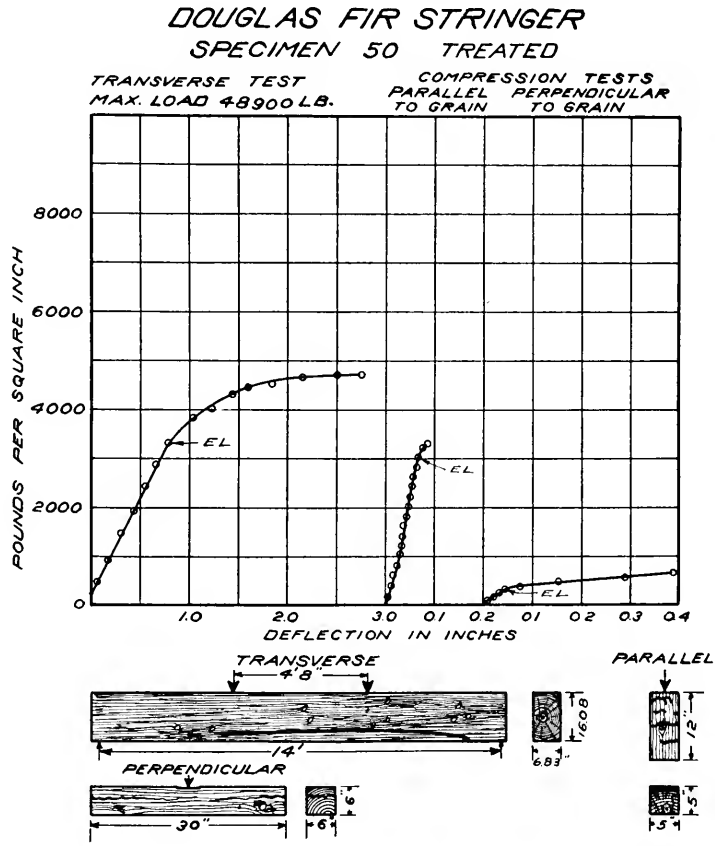

DOUGLAS FIR STRINGER
SPECIMEN 50 TREATED
TRANSVERSE TEST
MAX. LOAD 48900 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.08"
6.83"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 142

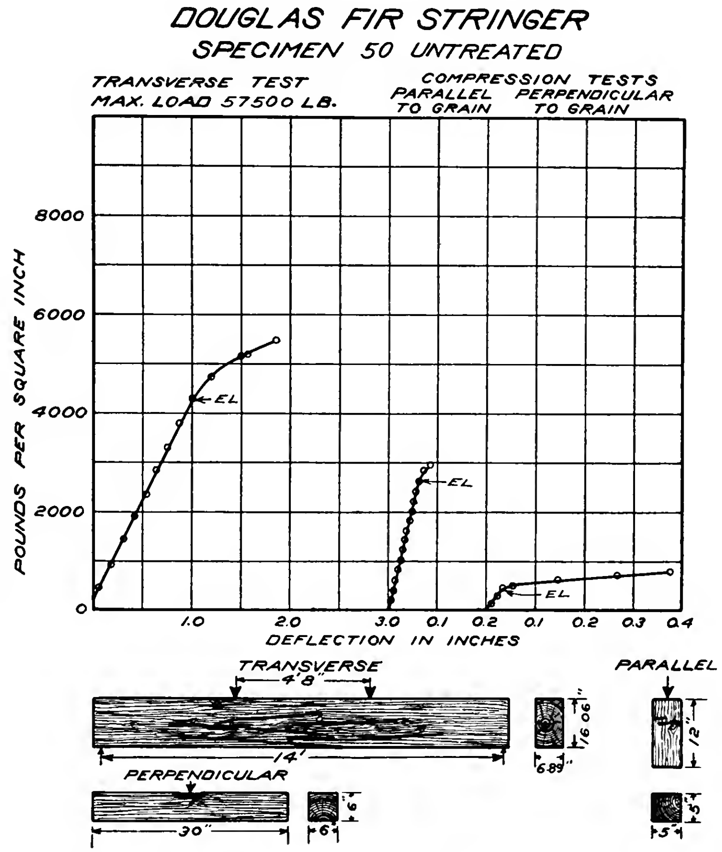

DOUGLAS FIR STRINGER
SPECIMEN 50 UNTREATED
TRANSVERSE TEST
MAX. LOAD 57500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.06"
6.89"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 143

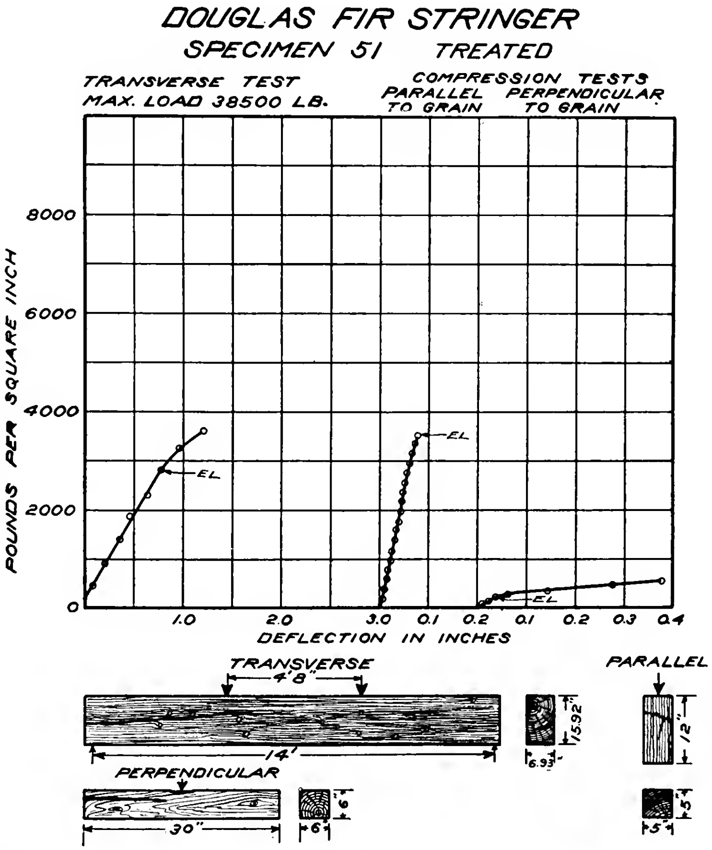

DOUGLAS FIR STRINGER
SPECIMEN 51 TREATED
TRANSVERSE TEST
MAX. LOAD 38500 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
15.92"
6.93"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 144

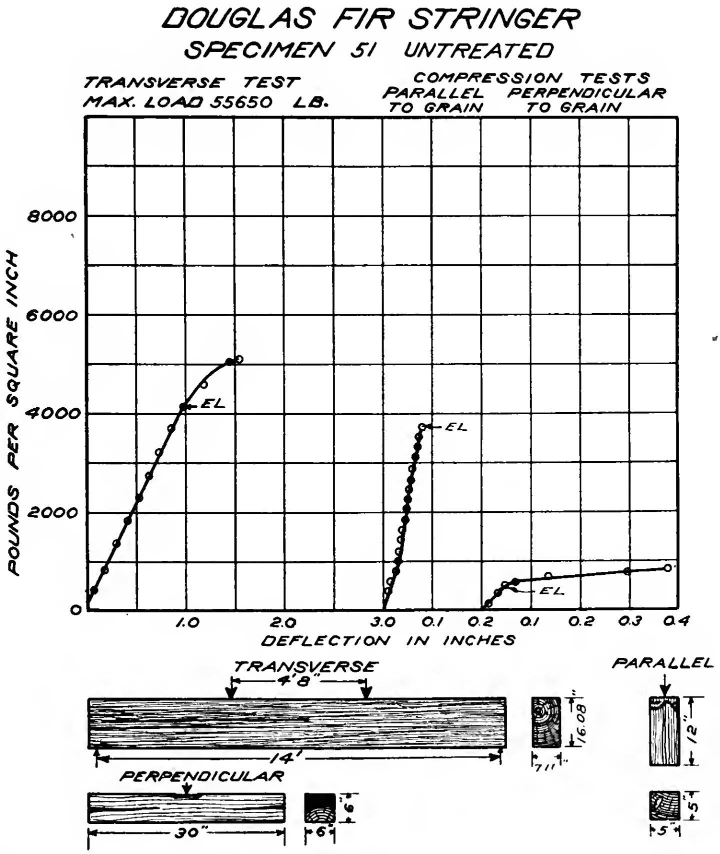

DOUGLAS FIR STRINGER
SPECIMEN 51 UNTREATED
TRANSVERSE TEST
MAX. LOAD 55650 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.08"
7"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 145

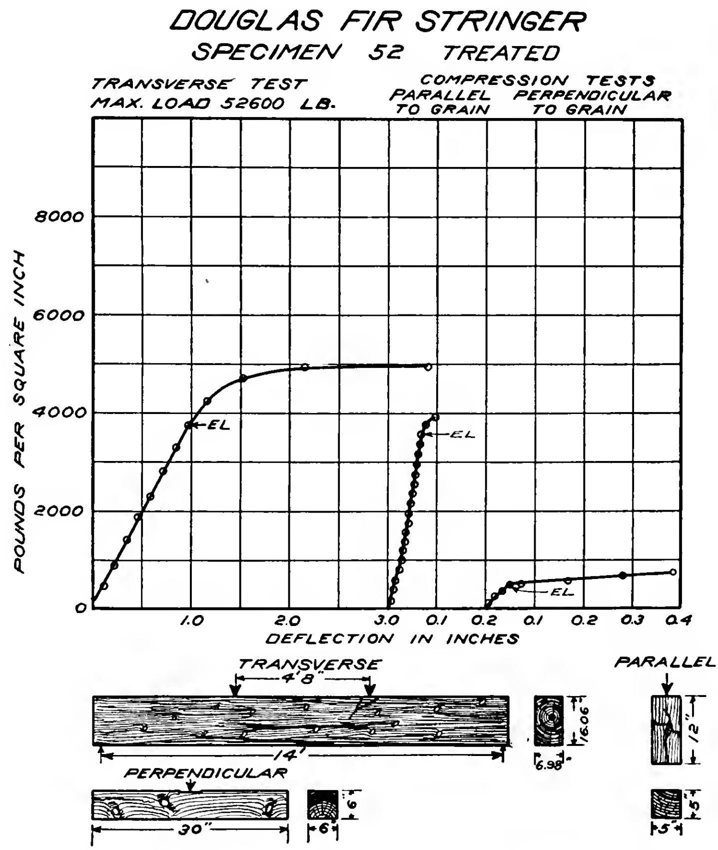

DOUGLAS FIR STRINGER
SPECIMEN 52 TREATED
TRANSVERSE TEST
MAX. LOAD 52600 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.06"
6.98"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 146

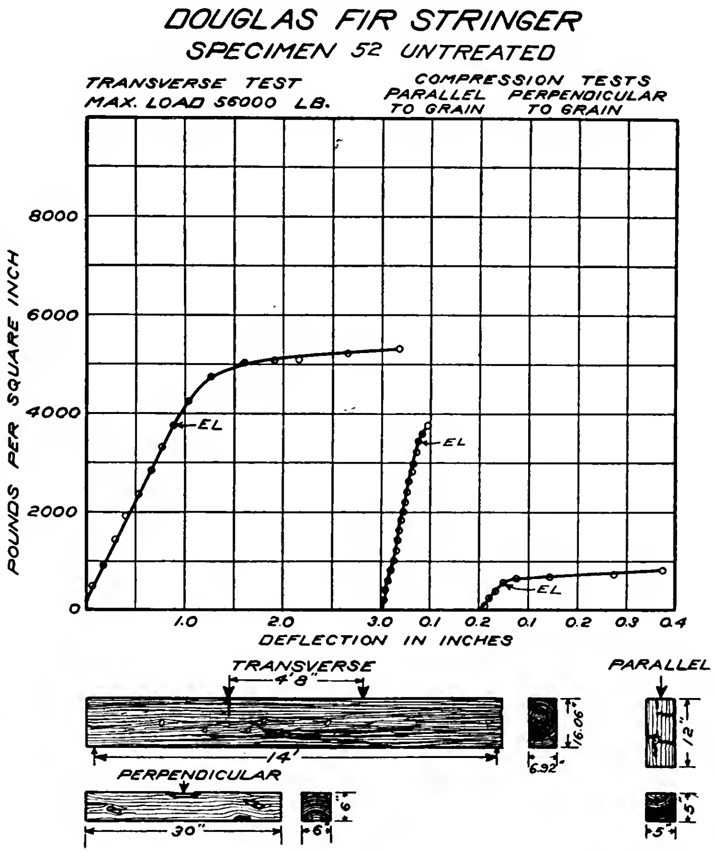

DOUGLAS FIR STRINGER
SPECIMEN 52 UNTREATED
TRANSVERSE TEST
MAX. LOAD 56000 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.06"
6.92"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG.147

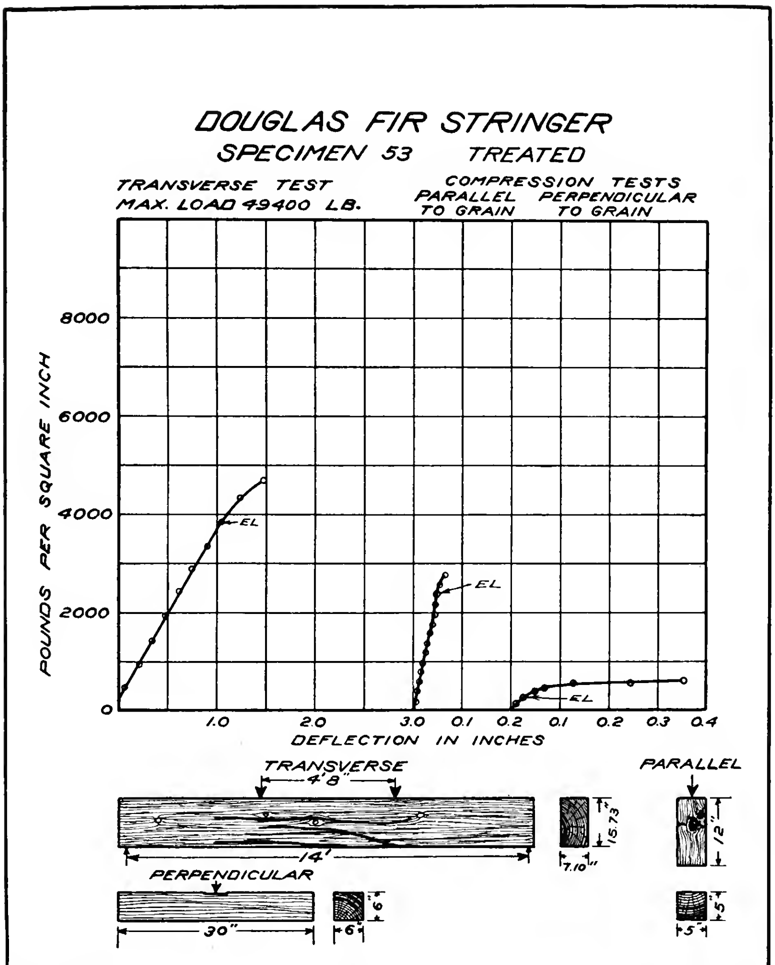

DOUGLAS FIR STRINGER
SPECIMEN 53 TREATED
TRANSVERSE TEST
MAX. LOAD 49400 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
15.73"
7.10"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 148

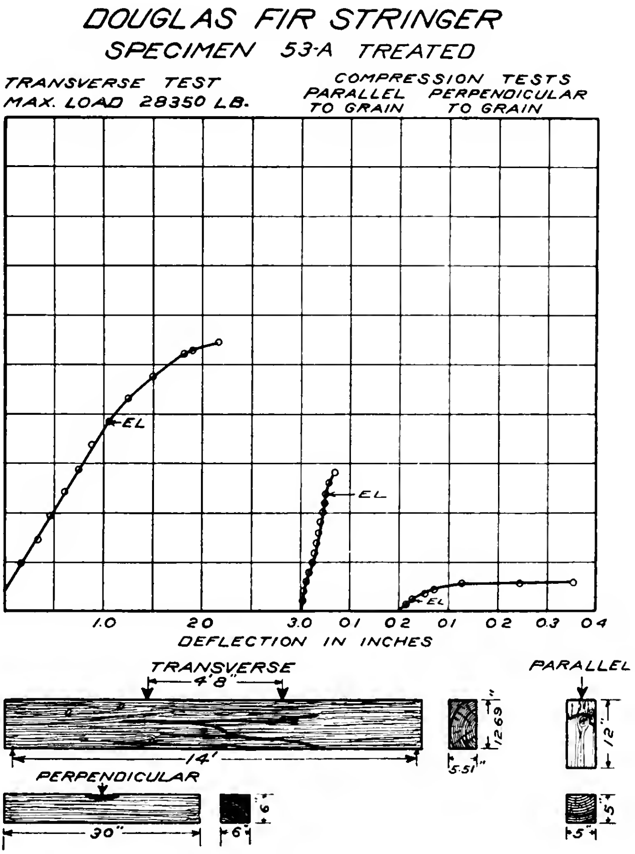

DOUGLAS FIR STRINGER
SPECIMEN 53-A TREATED
TRANSVERSE TEST
MAX. LOAD 28350 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
01
02
01
02
0.3
04
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
12.69"
5.51"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 149

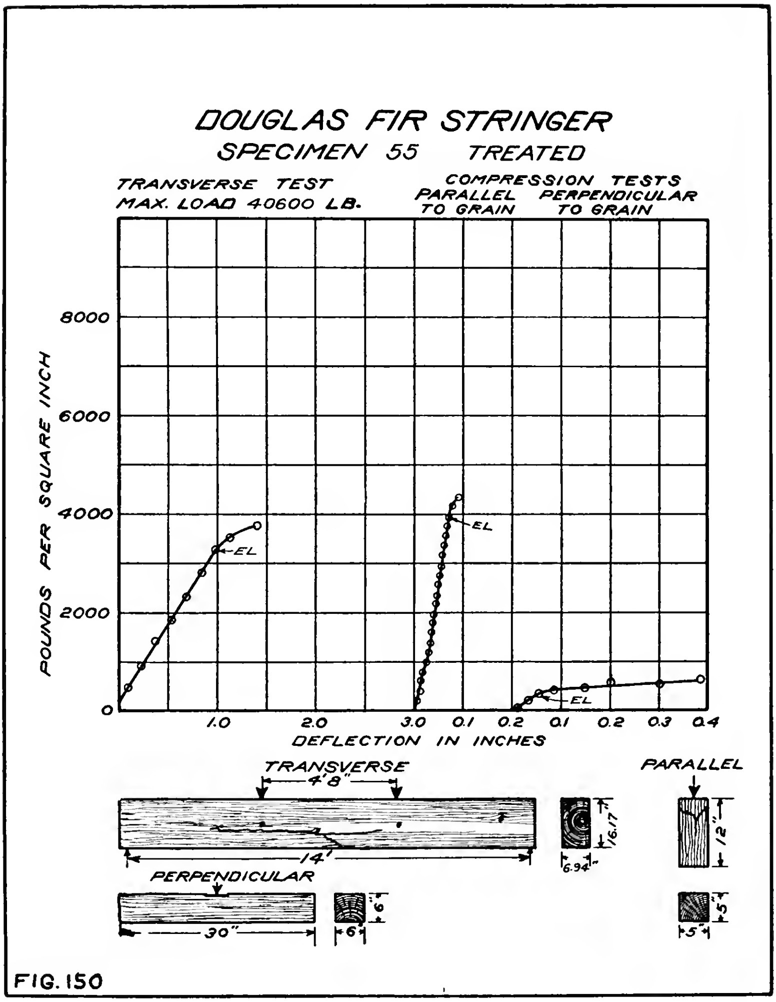

DOUGLAS FIR STRINGER
SPECIMEN 55 TREATED
TRANSVERSE TEST
MAX. LOAD 40600 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
16.7"
6.94"
PARALLEL
12"
5"
5"
PERPENDICULAR
30"
6"
6"

FIG. 150

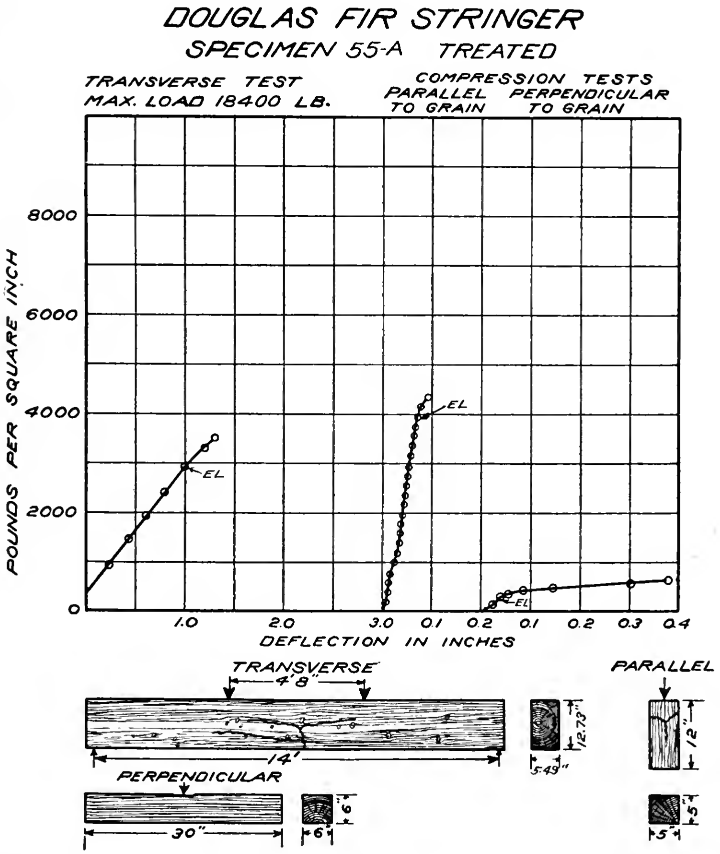
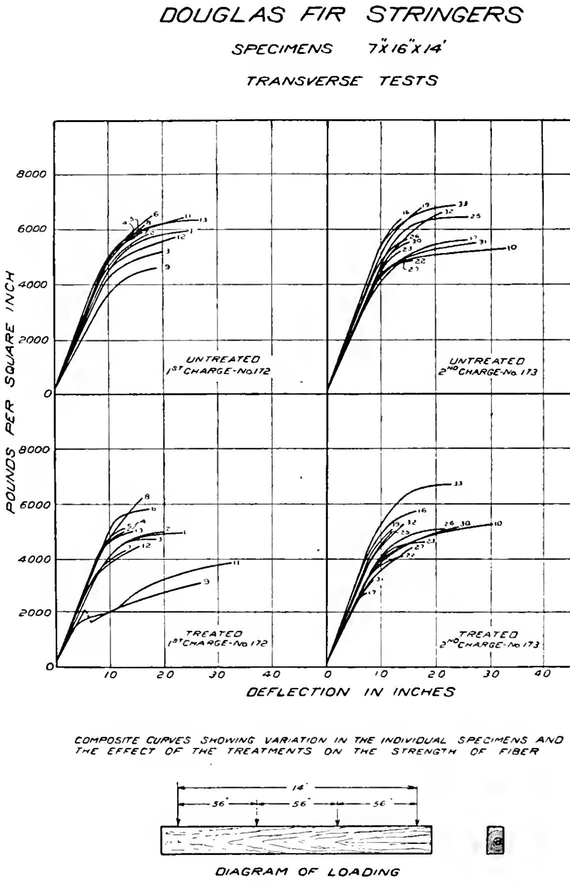

DOUGLAS FIR STRINGER
SPECIMEN 55-A TREATED
TRANSVERSE TEST
MAX. LOAD 18400 LB.
COMPRESSION TESTS
PARALLEL TO GRAIN
PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
6000
4000
2000
0
EL
EL
EL
1.0
2.0
3.0
0.1
0.2
0.1
0.2
0.3
0.4
DEFLECTION IN INCHES
TRANSVERSE
4'8"
14'
12.73"
5.49"
PARALLEL
12"
PERPENDICULAR
30"
6"
6"
5"
5"

FIG. 151



DOUGLAS FIR STRINGERS

SPECIMENS 7" x 16" x 14'

TRANSVERSE TESTS

COMPOSITE CURVES SHOWING VARIATION IN THE INDIVIDUAL SPECIMENS AND THE EFFECT OF THE TREATMENTS ON THE STRENGTH OF FIBER

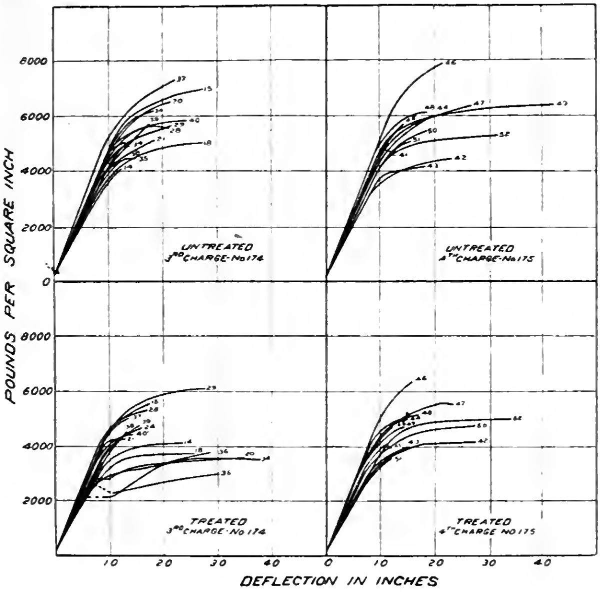
DIAGRAM OF LOADING

FIG. 152

DOUGLAS FIR STRINGERS

SPECIMENS 7"x16"x14'

TRANSVERSE TESTS



COMPOSITE CURVES SHOWING VARIATION IN THE INDIVIDUAL SPECIMENS AND THE EFFECT OF THE TREATMENTS ON THE STRENGTH OF FIBER

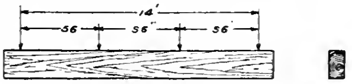


DIAGRAM OF LOADING

FIG. 153

Table 1. General Conditions. Treated Douglas Fir Stringers.

Spec. No.	Breadth, inches	Depth, inches	Length, ft.	in.	Weight pounds	Moisture per cent	Actual weight lb. per cu. ft.	Creosote per cu. ft. pounds	Dry weight lb. per cu. ft.	Rings per inch
1	7.11	16.15	15	5/8	543.0	23.7	45.3	12.2	26.8	11
2	6.98	16.17	14	11-5/8	530.0	22.9	45.2	10.5	28.2	9
3	7.07	16.25	15	3/8	507.5	22.7	42.3	14.1	23.0	7
4	7.17	16.04	14	11-5/8	562.0	26.1	47.0	14.2	26.0	12
5	7.04	16.33	14	11	561.0	27.1	47.1	12.6	27.1	20
6	7.09	15.99	15	0	620.0	20.4	52.5	17.2	29.3	10
7	7.11	16.25	15	5/8	562.0	29.9	46.6	12.2	26.5	10
8	7.04	16.18	14	11-1/4	581.0	25.0	49.2	11.3	30.3	12
9	6.95	16.15	15	0	520.0	24.2	44.5	15.4	23.4	6
10	6.86	16.00	15	1/4	516.0	29.1	45.1	13.9	24.2	9
11	6.94	16.13	15	1/2	591.0	27.5	50.6	15.8	27.3	11
12	7.17	16.13	14	11-1/4	518.0	24.8	43.2	11.4	25.5	8
13	7.09	15.83	14	11-3/8	544.0	26.1	46.7	12.3	27.3	9
14	7.06	16.40	14	10-3/4	465.0	25.0	38.8	8.3	24.4	27
15	7.03	16.25	14	11-3/4	595.5	27.2	50.1	13.7	28.6	14
16	7.10	16.15	14	11-1/8	570.0	27.0	47.9	9.5	30.2	11
17	7.03	16.00	15	5/8	553.5	34.7	47.1	15.4	23.5	11
18	7.01	16.23	14	11-5/8	434.0	25.2	36.7	6.5	24.1	21
19	7.03	16.13	15	3/8	557.0	21.2	47.1	14.1	27.2	10
20	7.05	16.25	15	0	617.5	25.3	51.8	14.5	29.8	11
21	7.07	16.04	14	11-3/8	606.5	23.8	51.6	14.7	29.8	15
22	6.96	16.17	15	1/4	524.0	25.8	44.6	12.3	25.7	13
23	7.27	16.25	15	7/8	602.0	27.2	48.7	9.8	30.6	19
24	7.23	16.29	15	1-1/8	545.0	27.8	44.2	11.9	25.3	11
25	7.04	16.19	15	1/2	550.0	22.9	46.2	11.3	28.4	7
26	7.04	16.19	15	1	548.0	30.2	45.9	9.9	27.7	11
27	6.93	16.17	15	1/2	495.0	26.1	42.3	9.3	26.2	25
28	7.13	16.00	15	0	521.0	27.1	43.9	13.3	24.1	10
29	7.00	16.17	15	1-1/2	523.0	28.6	44.0	11.2	25.5	12
30	7.09	16.42	15	0	510.0	24.2	42.1	8.9	26.7	13
31	7.17	16.25	15	0	490.0	28.2	40.4	9.9	23.8	13
32	7.13	16.29	15	1	531.0	21.6	43.7	11.7	26.3	19
33	7.07	15.98	15	7/8	548.0	21.2	46.4	10.0	30.0	11
34	7.17	16.35	14	10-3/4	605.0	28.4	49.9	12.0	29.5	14
35	7.01	16.17	15	3/4	471.0	31.1	39.7	3.5	27.6	12
36	7.01	16.00	15	1/4	490.0	28.2	42.9	5.5	29.2	11
37	7.08	16.25	15	5/8	607.0	26.0	50.5	10.1	32.1	15
38	7.07	15.94	15	5/8	573.0	29.2	48.6	15.9	25.3	8
39	7.02	16.15	15	0	540.0	28.3	45.7	8.5	29.0	13
40	7.00	16.21	15	1/2	567.0	25.4	47.8	11.7	28.8	8
41	7.22	16.00	15	1/4	558.0	26.2	46.3	8.5	30.0	14
42	6.98	16.08	14	11-1/4	473.5	30.0	40.6	9.3	24.1	10
43	7.10	16.25	15	0	497.5	25.5	41.4	12.3	23.2	13
44	7.07	16.00	15	5/8	536.5	26.8	45.4	13.2	25.4	17
45	7.17	16.00	15	0	584.0	25.0	48.8	10.2	30.9	12
46	7.11	16.13	15	3/4	587.5	26.4	49.0	5.8	34.4	11
47	6.90	16.00	14	11-3/4	491.0	28.8	42.8	12.5	23.5	13
48	7.18	16.31	14	11-3/4	588.5	19.0	48.3	13.1	29.6	13
49	7.15	16.13	14	11-3/4	523.0	27.8	43.6	8.6	27.4	12
50	6.83	16.08	15	2-3/8	475.0	27.1	41.0	9.2	25.0	10
51	7.11	15.90	15	1	448.0	30.6	37.9	9.8	21.5	12
52	6.98	16.06	15	0	503.0	22.3	43.0	11.0	26.2	13
Average	—	—	—	—	540.0	26.2	45.6	11.4	27.0	—
Maximum	—	—	—	—	620.0	34.7	52.5	17.2	34.4	—
Minimum	—	—	—	—	434.0	19.0	36.7	3.5	21.5	—
53	7.10	15.73	14	11-1/2	510.0	26.8	44.0	—	—	12
53a	5.51	12.69	15	0	262.0	--	36.0	—	—	—
55	6.94	16.17	15	0	445.0	29.1	38.1	—	—	6
55a	5.49	12.73	14	11-3/4	225.0	--	31.0	—	—	—

Table 2. General Conditions. Untreated Douglas Fir Stringers.

Spec. No.	Breadth, inches	Depth, inches	Length,		Weight, pounds	Moisture, per cent	Actual Weight lb. per cu. ft.	Dry Weight lb. per cu. ft.	Rings per inch
			ft.	in.					
1	7.03	16.31	14	9	438.5	39.4	37.3	26.8	11
2	7.06	16.23	14	9-1/2	454.0	36.8	38.5	28.2	9
3	7.05	16.25	14	8-5/8	384.0	42.5	32.7	23.0	7
4	7.05	16.25	14	8-1/2	414.0	36.1	35.3	26.0	12
5	7.00	16.27	14	10-3/8	440.0	37.7	37.4	27.1	20
6	7.11	15.98	14	9-1/8	464.0	36.0	39.8	29.3	10
7	7.04	16.21	14	8-3/4	433.5	39.9	37.1	26.5	10
8	7.04	16.29	14	10-3/8	477.5	33.2	40.3	30.3	12
9	6.95	16.17	14	9-5/8	383.0	42.0	33.2	23.4	6
10	6.96	16.04	14	8-3/4	390.0	41.0	34.1	24.2	9
11	6.98	16.21	14	8-3/8	444.0	40.6	38.4	27.3	11
12	7.17	16.30	14	9-1/4	432.0	40.9	36.0	25.5	8
13	7.08	15.96	14	8-3/4	452.5	43.1	39.1	27.3	9
14	6.94	16.35	14	10	401.5	41.0	34.4	24.4	27
15	7.09	16.33	14	10	476.0	39.3	39.9	28.6	14
16	7.14	16.19	14	9-3/4	500.0	39.0	42.0	30.2	11
17	7.01	16.15	14	8-7/8	396.5	45.4	34.2	23.5	11
18	6.97	16.23	14	9-1/8	404.5	44.7	34.9	24.1	21
19	7.11	16.21	14	8-3/4	455.0	41.7	38.6	27.2	10
20	7.14	16.17	14	9-3/8	497.0	40.6	41.9	29.8	11
21	7.06	16.13	14	9-3/8	477.0	37.1	40.8	29.8	15
22	7.00	16.35	14	9-5/8	415.0	37.4	35.3	25.7	13
23	7.36	16.31	14	8-5/8	511.5	36.0	41.7	30.6	19
24	7.00	16.29	14	8-1/8	401.0	36.3	34.5	25.3	11
25	6.99	16.25	14	8-5/8	466.0	39.0	40.1	28.4	7
26	7.09	16.25	14	9	465.0	42.3	39.4	27.7	11
27	6.96	16.15	14	8-1/4	418.0	38.7	36.4	26.2	25
28	7.08	16.23	14	8-3/4	407.5	43.6	34.7	24.1	10
29	7.06	16.31	14	8	407.5	36.1	34.8	25.5	12
30	7.15	16.25	14	9	446.0	40.4	37.5	26.7	13
31	7.10	16.23	14	9-3/8	391.0	39.1	33.1	23.8	13
32	6.97	16.25	14	8-1/2	425.0	39.8	36.7	26.3	19
33	7.18	16.00	14	8-5/8	488.5	38.4	41.6	30.0	11
34	7.21	16.33	14	10-1/8	505.0	41.0	41.6	29.5	14
35	7.08	16.15	14	8-1/2	426.0	31.9	36.5	27.6	12
36	7.13	15.92	14	9	471.0	38.4	40.5	29.2	11
37	7.11	16.27	14	8-5/8	506.0	33.1	42.8	32.1	15
38	7.09	16.25	14	8-5/8	397.0	33.3	33.7	25.3	7
39	7.05	16.08	14	8-3/4	454.0	34.9	39.2	29.0	13
40	6.94	16.25	14	9	457.0	37.2	39.6	28.8	8
41	7.24	16.15	14	10-3/4	495.0	36.2	40.9	30.0	14
42	7.01	16.42	14	11-3/8	408.0	41.3	34.1	24.1	10
43	7.06	16.25	14	9-1/8	379.0	38.7	32.2	23.2	13
44	7.08	16.06	14	8-1/2	433.0	47.0	37.3	25.4	17
45	7.25	16.23	14	10-3/4	503.0	33.6	41.3	30.9	12
46	7.13	15.92	14	9-1/8	520.0	29.8	44.7	34.4	11
47	6.84	16.02	14	8-3/4	410.5	55.5	36.6	23.5	13
48	7.18	16.63	14	7-7/8	498.5	38.6	41.0	29.6	13
49	7.10	16.08	14	10	451.5	40.1	38.4	27.4	12
50	6.89	16.06	14	9-1/4	400.0	41.1	35.2	25.0	10
51	7.11	16.08	14	10-1/4	395.0	55.7	33.5	21.5	12
52	6.92	16.06	14	10	407.5	35.8	35.6	26.2	13
Average	—	—	—	—	441.	39.4	37.6	27.0	—
Maximum	—	—	—	—	520.0	55.7	44.7	34.4	—
Minimum	—	—	—	—	379.0	29.8	32.2	21.5	—

Table 3. Results of Transverse Tests. Treated Douglas Fir Stringers.

Spec. No.	Elastic Limit lb. per sq. in.	Modulus of Rupture lb. per sq. in.	Deflection at Elastic Limit, inches	Deflection at Maximum Load, inches	Modulus of Elasticity lb. per sq. in.	Longitudinal Shear lb. per sq. in.	Type of Failure
1	3209	4985	0.68	2.50	1,728,800	357	Shear
2	3251	4875	0.72	2.40	1 657 200	349	Shear
3	4082	4640	1.00	2.50	1 496 300	334	Shear
4	4138	4980	0.84	1.86	1 826 300	354	Shear
5	4115	5060	0.78	3.40	1 898 000	361	Shear
6	5280	5725	1.05	2.00	1 892 100	400	Tension
7	3618	4280	0.85	2.00	1 556 000	307	Tension
8	4144	6315	0.84	1.64	1 808 000	453	Shear
9	2074	3075	0.53	3.12	1 429 500	219	Shear
10	3385	5110	0.76	3.25	1 889 300	362	Shear
11	1436	3990	0.36	4.10	1 442 200	285	Tension
12	3188	4420	0.64	1.52	1 826 500	316	Shear
13	4290	4900	0.83	2.13	1 942 300	344	Shear
14	3130	4050	0.86	2.35	1 314 000	294	Tension & Shear
15	3660	3840	0.69	3.70	1 938 700	397	Shear
16	4120	6635	0.73	1.64	2 078 500	410	Shear
17	2370	3490	0.55	6.60	1 783 000	247	Shear
18	2760	3705	0.79	3.00	1 276 700	266	Tension
19	4170	5070	0.79	2.25	1 945 800	276	Shear
20	2760	3575	0.65	3.50	1 539 400	255	Tension
21	4060	4290	0.90	1.72	1 671 100	304	Tension
22	3260	4115	0.78	2.10	1 538 300	295	Shear
23	3540	4580	0.79	2.02	1 637 500	329	Shear
24	3540	4700	0.82	3.03	1 574 200	339	Shear
25	3680	5045	0.76	2.60	1 776 100	362	Tension
26	3680	5120	0.83	2.20	1 626 700	362	Shear
27	3280	4440	0.82	3.65	1 468 900	318	Shear
28	4175	5300	0.87	1.75	1 786 100	376	Tension
29	4165	6075	0.91	2.80	1 684 200	436	Tension
30	3105	5060	0.68	3.00	1 649 500	369	Tension
31	3135	3365	0.78	1.10	1 467 100	242	Shear
32	4030	5220	0.84	2.40	1 752 000	384	Shear
33	4225	6690	0.74	2.80	2 126 400	475	Shear
34	1790	3590	0.38	6.00	1 694 000	259	Tension
35	2325	3020	0.56	4.75	1 520 800	216	Tension & Shear
36	2370.	3665	0.63	4.70	1 394 000	260	Shear
37	4530	5390	0.95	2.90	1 748 000	389	Shear
38	3310	4480	0.84	1.48	1 463 600	316	Tension
39	3710	4740	0.90	3.80	1 515 700	339	Shear
40	3230	4450	0.69	3.10	1 711 000	319	Shear
41	3220	4173	0.70	3.50	1 704 000	234	Tension & Shear
42	2825	4195	0.73	3.44	1 427 500	299	Crush & Shear
43	3170	4050	0.80	1.62	1 444 800	291	Shear
44	3750	4945	0.80	1.94	1 741 500	351	Shear
45	3240	4835	0.68	1.24	1 672 900	343	Tension & Shear
46	5035	6450	0.97	1.65	1 915 000	462	Shear
47	3840	5600	0.81	2.36	1 762 300	397	Shear
48	3990	5090	0.80	2.00	1 820 800	368	Tension
49	3645	4705	0.80	2.00	1 679 200	336	Shear
50	3360	4680	0.78	2.76	1 588 600	334	Tension
51	2840	3630	0.77	1.20	1 375 100	255	Shear
52	3770	4940	0.97	4.08	1 438 100	352	Crush & Shear
Average	3481	4680	0.77	2.71	1 666 200	333	
Maximum	5280	6690	1.05	6.60	2 126 400	475	
Minimum	1436	3020	0.36	1.10	1 276 700	216	
53	3860	4760	1.05	1.50	1 389 800	421	Tension
53a	3820	5400	1.05	2.15	1 705 000	304	Tension
55	3270	3790	0.99	1.40	1 214 100	263	Tension
55a	2860	3505	1.00	1.30	1 331 900	197	Tension

Table 4. Results of Transverse Tests. Untreated Douglas Fir Stringers.

Spec. No.	Elastic Limit lb. per sq. in.	Modulus of Rupture lb. per sq. in.	Deflection at Elastic Limit, inches	Deflection at Maximum Load, inches	Modulus of Elasticity lb. per sq. in.	Longitudinal Shear lb. per sq. in.	Type of Failure
1	4072	5930	0.88	2.48	1,693,000	430	Crush & Shear
2	4822	5730	1.02	2.34	1 639 000	413	Tension
3	4083	5165	0.93	2.00	1 613 000	373	Tension
4	4538	5890	0.89	1.45	1 873 900	426	Shear
5	4113	5735	0.81	1.53	1 859 000	415	Shear
6	5119	6510	1.07	3.28	1 787 500	462	Shear
7	4569	5905	0.92	1.60	1 828 000	425	Tension
8	4972	6090	1.12	1.60	1 627 200	441	Tension
9	3720	4600	0.99	2.50	1 386 100	330	Tension
10	4249	5300	0.88	3.36	1 794 200	378	Shear
11	4620	6440	0.89	2.32	1 906 000	476	Tension
12	4438	5655	1.00	2.60	1 624 500	409	Tension & Shear
13	4689	5990	0.91	2.65	1 925 100	457	Shear
14	3200	4105	0.86	1.20	1 349 200	396	Tension
15	5355	6930	1.15	2.80	1 707 400	503	Tension & Shear
16	4970	6400	0.85	1.38	2 153 800	460	Shear
17	3245	5540	0.67	2.95	1 863 000	394	Crush & Tension
18	3690	5055	0.95	2.80	1 425 000	364	Tension
19	5420	6770	0.97	1.72	2 060 000	490	Shear
20	4530	6470	0.97	2.14	1 724 600	464	Shear
21	3690	5190	0.80	2.30	1 701 300	371	Tension
22	4070	4925	0.88	1.56	1 686 000	360	Tension
23	4750	5335	1.08	3.20	1 605 100	362	Tension & Shear
24	4095	4850	0.97	3.23	1 545 800	351	Shear
25	5020	6540	1.02	2.60	1 788 300	473	Tension
26	4070	5610	0.78	1.45	1 913 000	405	Shear
27	3730	5010	0.82	3.00	1 678 600	359	Shear
28	4530	5590	1.00	2.06	1 665 500	403	Tension
29	4050	5740	0.94	2.16	1 575 200	416	Shear
30	4480	5600	0.93	2.00	1 849 500	404	Shear
31	3615	5470	0.83	4.16	1 600 700	394	Crush
32	4140	6600	0.89	2.40	1 207 400	477	Shear
33	5060	6990	0.98	2.37	1 924 900	497	Tension
34	3960	6150	0.78	2.54	1 851 000	446	Tension
35	3670	4435	0.87	1.43	1 555 700	318	Tension
36	4220	5070	0.87	2.40	1 812 500	358	Tension
37	4500	7325	0.79	2.45	2 084 700	530	Tension
38	3620	4405	0.90	2.50	1 473 900	318	Tension
39	3720	5055	0.85	2.00	1 618 500	361	Tension
40	4610	5790	0.98	4.10	1 728 600	418	Crush & Tension
41	4040	4725	0.83	1.44	1 792 500	338	Tension
42	3140	4435	0.80	2.28	1 418 900	323	Tension
43	3630	4260	0.96	1.84	1 387 400	299	Tension
44	4630	5970	0.99	1.92	1 735 000	420	Shear
45	4430	5905	0.94	1.41	1 730 500	425	Tension
46	5610	7990	1.03	2.14	1 946 400	565	Tension
47	4335	6400	0.99	2.67	1 630 900	456	Tension
48	4260	6100	0.78	1.90	1 957 300	451	Tension
49	3690	6355	0.74	4.25	1 751 500	486	Tension
50	4280	5460	1.00	2.43	1 294 800	320	Tension
51	4140	5115	0.99	1.53	1 548 700	365	Shear
52	3790	5300	0.88	3.30	1 599 300	378	Tension
Average	4269	5691	0.91	2.32	1 701 900	411	
Maximum	5610	7990	1.15	4.25	2 153 800	565	
Minimum	3140	4105	0.67	1.20	1 207 400	299	

Table 5. Results of Compression Tests Parallel to Grain.
Treated Douglas Fir Stringers.

Spec. No.	Elastic Limit lb. per sq. in.	Maximum Load lb. per sq. in.	Deflection at Elastic Limit, inches	Deflection at Maximum Load, inches	Modulus of Elasticity lb. per sq. in.	Type of Failure
1	3823	3983	0.076	0.090	607,200	Crush
2	3950	4325	0.072	0.084	653 500	Crush
3	2806	3168	0.064	0.080	525 000	Crush
4	3930	3930	0.094	0.094	502 000	Crush
5	4524	4524	0.071	0.071	773 000	Crush & Shear
6	3942	4376	0.075	0.110	634 500	Crush
7	3778	3778	0.070	0.070	648 000	Crush & Shear
8	4418	4820	0.078	0.095	690 000	Crush
9	2833	3160	0.060	0.089	570 500	Crush
10	4297	4297	0.080	0.080	649 500	Crush
11	3517	3907	0.060	0.070	705 000	Crush
12	2550	2901	0.066	0.085	409 500	Crush
13	3650	4000	0.083	0.105	528 000	Crush
14	3143	3340	0.071	0.108	539 000	Crush
15	4255	4255	0.090	0.090	571 000	Crush
16	3707	3707	0.085	0.085	527 000	Crush
17	3778	3979	0.095	0.124	478 300	Crush
18	2621	2822	0.064	0.080	497 500	Crush
19	4725	4881	0.078	0.090	730 000	Crush
20	3543	3938	0.072	0.096	583 300	Crush
21	3991	4511	0.080	0.107	600 500	Crush
22	4015	4215	0.073	0.090	660 000	Crush
23	4185	4300	0.090	0.106	559 000	Crush
24	4040	4080	0.074	0.090	663 300	Crush
25	3515	3670	0.067	0.079	632 500	Crush
26	3791	4310	0.073	0.096	631 500	Crush
27	3160	3320	0.072	0.089	533 500	Crush
28	3313	3509	0.072	0.079	556 500	Crush
29	2789	3187	0.057	0.070	623 500	Crush
30	3878	4000	0.070	0.090	673 000	Crush
31	2358	2593	0.057	0.084	501 000	Crush
32	3920	4000	0.071	0.082	667 000	Shear
33	5080	5235	0.088	0.100	674 000	Crush & Shear
34	4230	4430	0.063	0.078	814 500	Crush
35	2767	2846	0.070	0.093	477 500	Crush & Shear
36	2575	2772	0.058	0.070	540 000	Crush
37	4590	4750	0.084	0.104	650 000	Crush
38	3125	3633	0.069	0.089	527 000	Crush
39	3460	3537	0.073	0.092	577 300	Crush
40	2936	3288	0.058	0.077	614 000	Crush
41	3983	4540	0.082	0.117	582 500	Crush
42	2540	2930	0.055	0.071	554 000	Crush
43	3315	3587	0.064	0.089	632 500	Crush
44	4600	4880	0.077	0.103	716 500	Crush
45	3596	3631	0.076	0.086	579 000	Crush
46	4002	4802	0.068	0.096	704 000	Crush
47	3845	4330	0.066	0.090	702 000	Crush
48	3875	4070	0.075	0.087	627 500	Crush
49	3250	3415	0.062	0.077	790 000	Crush
50	3019	3300	0.067	0.092	511 500	Crush
51	3500	3500	0.075	0.075	564 500	Crush
52	3530	3803	0.070	0.098	608 500	Crush
Average	3629	3869	0.072	0.089	607 100	
Maximum	5080	5235	0.095	0.124	814 500	
Minimum	2358	2593	0.055	0.070	409 500	
53	2377	2772	0.051	0.068	566 500	Crush
55	3938	4330	0.070	0.090	590 000	Crush

Table 6. Results of Compression Test Parallel to Grain.
Untreated Douglas Fir Stringers.

Spec. No.	Elastic Limit lb. per sq. in.	Maximum Load lb. per sq. in.	Deflection at Elastic Limit, inches	Deflection at Maximum Load, inches	Modulus of Elasticity lb. per sq. in.	Type of Failure
1	4872	4872	0.085	0.085	687,000	Crush
2	4010	4459	0.078	0.108	623 500	Crush
3	3407	3487	0.099	0.114	413 000	Crush
4	3983	4420	0.079	0.118	605 500	Crush, Vertical
5	3752	4345	0.077	0.096	593 500	Crush & Shear
6	4425	4770	0.085	0.103	626 000	Crush
7	3585	4381	0.070	0.090	617 500	Crush
8	3609	4010	0.089	0.115	485 000	Crush
9	3358	3752	0.066	0.080	621 000	Crush
10	2960	2960	0.064	0.064	554 000	Crush
11	4760	4958	0.079	0.085	726 500	Crush
12	4580	4580	0.068	0.068	811 000	Crush & Shear
13	3752	3945	0.080	0.093	560 500	Crush
14	3352	3904	0.073	0.078	555 000	Crush
15	4740	5100	0.087	0.110	657 500	Crush
16	4948	5145	0.093	0.100	643 000	Crush
17	3155	3155	0.072	0.072	531 000	Crush
18	2976	2976	0.080	0.080	450 500	Crush
19	2630	2750	0.073	0.096	425 200	Crush
20	3245	3610	0.094	0.123	415 000	Crush
21	5109	5380	0.094	0.115	661 500	Crush
22	3372	3655	0.064	0.100	638 500	Crush
23	3878	4080	0.070	0.075	666 000	Crush & Shear
24	4128	4320	0.080	0.093	621 000	Crush
25	4490	4695	0.083	0.102	652 500	Crush
26	4345	4345	0.075	0.075	701 500	Crush
27	4025	4340	0.073	0.098	665 800	Crush
28	4322	4322	0.091	0.091	577 000	Crush
29	3358	3752	0.060	0.068	675 000	Crush
30	4200	4200	0.085	0.085	600 000	Crush
31	3441	3441	0.084	0.084	500 000	Crush
32	3960	4360	0.073	0.104	656 000	Crush
33	4535	4890	0.078	0.110	706 000	Crush
34	4564	4760	0.076	0.081	720 000	Crush
35	2806	3007	0.069	0.081	491 000	Crush
36	3007	3127	0.079	0.098	457 000	Crush
37	5332	5530	0.084	0.086	769 000	Crush
38	2611	3013	0.065	0.091	488 500	Crush
39	3778	3857	0.071	0.086	635 000	Crush & Shear
40	2765	3279	0.058	0.080	580 000	Crush
41	4330	4528	0.092	0.107	574 500	Crush
42	3225	3708	0.067	0.104	573 000	Crush
43	3538	4322	0.072	0.091	596 500	Crush
44	3600	3920	0.068	0.090	641 500	Crush
45	3550	3942	0.073	0.091	592 000	Crush
46	4828	4828	0.084	0.084	698 500	Crush & Shear
47	4770	4770	0.100	0.100	580 000	Crush
48	5173	5173	0.095	0.095	657 000	Crush & Shear
49	4260	4380	0.076	0.090	668 000	Crush
50	2611	2972	0.061	0.093	519 500	Crush
51	3695	3695	0.078	0.078	568 000	Crush
52	3570	3768	0.083	0.092	520 000	Crush
Average	3873	4114	0.078	0.092	601 000	
Maximum	5332	5530	0.100	0.123	811 000	
Minimum	2611	2750	0.058	0.064	413 000	

Table 7. Results of Compression Tests Perpendicular to Grain. Treated Douglas Fir Stringers.

Spec. No.	Elastic Limit lb. per sq. in.	Deflection at Elastic Limit, inches	Load in pounds per square inch for a deflection of,- 1/10-in.	3/16-in.	3/8-in.	Type of Failure
1	208	0.037	350	410	520	Crush & Split
2	277	0.037	470	500	580	Crush & Split
3	415	0.051	570	630	700	Crush
4	207	0.031	410	450	570	Crush & Split
5	206	0.040	350	420	560	Crush
6	413	0.036	630	740	890	Crush
7	275	0.057	400	460	570	Crush & Split
8	488	0.059	690	720	820	Crush & Split
9	346	0.046	580	530	620	Crush & Split
10	208	0.040	310	360	470	Crush & Split
11	413	0.044	600	680	790	Crush & Split
12	207	0.030	380	430	560	Crush
13	348	0.064	450	500	620	Crush & Split
14	278	0.066	400	430	530	Crush & Split
15	346	0.064	475	550	660	Crush & Split
16	413	0.056	560	620	750	Crush & Split
17	207	0.045	520	580	730	Crush
18	275	0.050	390	450	550	Crush & Split
19	412	0.052	570	630	770	Crush & Split
20	277	0.051	380	430	570	Crush & Split
21	277	0.043	430	540	700	Crush & Split
22	276	0.075	340	420	510	Crush & Split
23	206	0.040	440	510	570	Crush & Split
24	211	0.046	330	370	450	Crush & Split
25	615	0.064	740	790	900	Crush & Split
26	412	0.057	530	600	670	Crush & Split
27	207	0.028	400	470	620	Crush & Split
28	414	0.048	630	690	800	Crush & Split
29	347	0.057	470	500	580	Crush & Split
30	207	0.036	330	380	470	Crush & Split
31	207	0.044	340	380	490	Crush & Split
32	347	0.083	380	460	570	Crush & Split
33	417	0.065	550	600	750	Crush & Split
34	277	0.038	450	520	640	Crush & Split
35	276	0.034	310	480	630	Crush & Split
36	208	0.043	330	400	500	Crush & Split
37	278	0.039	470	520	640	Crush & Split
38	419	0.056	580	650	790	Crush & Split
39	210	0.031	440	460	550	Crush & Split
40	486	0.048	620	660	740	Crush & Split
41	414	0.080	510	570	730	Crush & Split
42	345	0.049	500	560	670	Crush
43	275	0.056	350	390	460	Crush & Split
44	207	0.036	430	470	550	Crush & Split
45	346	0.046	520	600	710	Crush & Split
46	478	0.047	670	730	850	Crush & Split
47	346	0.047	440	490	600	Crush & Split
48	550	0.047	660	720	830	Crush & Split
49	346	0.043	460	510	620	Crush & Split
50	275	0.048	410	470	610	Crush & Split
51	208	0.039	350	410	530	Crush & Split
52	417	0.050	530	600	720	Crush & Split
Average	322	0.048	470	530	640	
Maximum	615	0.080	740	790	900	
Minimum	206	0.028	310	360	450	
53	278	0.040	550	560	600	Crush & Split
55	277	0.039	460	510	590	Crush & Split

Table 8. Results of Compression Tests Perpendicular to Grain. Untreated Douglas Fir Stringers.

Spec. No.	Elastic Limit lb. per sq. in.	Deflection at Elastic Limit, inches	Load in pounds per square inch for a deflection of,-			Type of Failure
			1/10-in.	3/16-in.	3/8-in.	
1	413	0.037	740	820	930	Crush & Split
2	413	0.060	530	600	750	Crush & Split
3	484	0.042	620	650	750	Crush & Split
4	417	0.059	500	580	690	Crush
5	415	0.058	520	580	690	Crush
6	417	0.048	570	640	760	Crush & Split
7	414	0.037	630	670	790	Crush & Split
8	416	0.038	710	750	840	Crush & Split
9	420	0.051	510	560	680	Crush
10	415	0.043	540	580	660	Crush & Split
11	415	0.033	640	690	820	Crush
12	414	0.044	600	660	780	Crush & Split
13	411	0.059	520	580	720	Crush
14	413	0.054	530	590	680	Crush
15	415	0.048	600	660	820	Crush
16	484	0.053	600	710	890	Crush & Split
17	346	0.056	460	510	590	Crush
18	415	0.027	610	640	750	Crush & Split
19	412	0.042	600	650	760	Crush
20	414	0.048	550	600	710	Crush & Split
21	346	0.025	560	620	750	Crush
22	413	0.034	690	750	860	Crush
23	417	0.035	560	610	720	Crush & Split
24	422	0.050	510	550	660	Crush & Split
25	418	0.043	680	770	900	Crush & Split
26	415	0.034	630	690	820	Crush & Split
27	417	0.056	510	570	680	Crush & Split
28	415	0.044	630	670	790	Crush & Split
29	493	0.072	560	620	720	Crush & Split
30	417	0.048	540	600	700	Crush & Split
31	627	0.046	630	680	810	Crush & Split
32	417	0.045	590	640	770	Crush
33	481	0.042	700	770	900	Crush & Split
34	621	0.045	770	850	1060	Crush
35	485	0.037	600	650	780	Crush & Split
36	415	0.055	530	600	720	Crush & Split
37	417	0.037	620	680	810	Crush & Split
38	485	0.055	620	670	800	Crush & Split
39	625	0.047	690	740	850	Crush & Split
40	484	0.037	670	690	800	Crush & Split
41	415	0.035	610	670	820	Crush & Split
42	415	0.031	570	600	720	Crush & Split
43	416	0.063	510	570	640	Crush
44	418	0.039	650	710	810	Crush & Split
45	413	0.044	560	630	760	Crush & Split
46	485	0.035	870	940	1100	Crush & Split
47	483	0.035	640	680	780	Crush & Split
48	411	0.042	610	690	850	Crush
49	350	0.036	550	610	740	Crush & Split
50	417	0.035	565	630	760	Crush
51	411	0.040	660	710	820	Crush & Split
52	551	0.049	670	710	810	Crush
Average	438	0.044	603	659	780	
Maximum	627	0.072	870	940	1100	
Minimum	346	0.025	460	510	590	

Table 9. Weights and Moistures. Treated Douglas Fir Stringers.

	Weight at St. Helens, pounds			Actual weight at Laboratory, pounds	Weight per specimen, pounds			Moisture, per cent of dry wood		
Spec. No.	Before Treatment	After Treatment	Gain		Moisture	Creosote	Dry wood	Outside edge	Center line	Average
1	479	541	62	543	75	146	322	21.5	25.9	23.7
2	454	527	73	530	76	123	331	21.5	24.2	22.9
3	414	501	87	508	63	169	276	21.8	23.5	22.7
4	430	557	127	562	81	170	311	22.2	29.9	26.1
5	460	556	96	561	87	150	324	24.3	29.9	27.1
6	503	613	110	620	61	203	346	19.5	21.3	20.4
7	464	559	95	562	95	147	320	26.8	32.9	29.9
8	503	578	75	581	89	134	358	23.1	26.8	25.0
9	408	513	105	520	66	180	274	22.8	25.5	24.2
10	394	510	116	516	80	159	277	26.5	31.6	29.1
11	483	585	102	591	88	185	319	23.8	31.2	27.5
12	420	510	90	518	75	137	306	22.3	27.3	24.8
13	430	539	109	544	82	143	319	21.6	30.5	26.1
14	431	465	34	465	73	100	292	20.7	29.2	25.0
15	486	587	101	596	93	163	340	23.9	28.4	27.2
16	492	568	76	570	98	113	359	23.5	28.5	27.0
17	422	549	127	554	97	181	276	29.6	39.8	34.7
18	410	434	24	434	73	75	286	20.5	29.8	25.2
19	480	552	72	557	68	167	322	19.6	22.7	21.2
20	535	609	74	618	89	175	356	21.7	28.9	25.3
21	510	603	93	607	84	173	350	21.0	26.5	23.8
22	419	520	101	524	78	144	302	22.3	29.2	25.8
23	509	598	89	602	102	122	378	24.8	29.5	27.2
24	441	537	96	545	86	147	312	25.5	30.1	27.8
25	481	545	64	550	77	135	338	19.8	25.9	22.9
26	466	548	82	548	91	118	339	27.5	33.0	30.2
27	426	492	66	495	80	109	306	23.2	28.9	26.1
28	438	518	80	521	77	158	286	24.0	30.2	27.1
29	424	520	96	523	86	133	304	25.7	31.5	28.6
30	439	505	66	510	78	108	324	21.1	27.3	24.2
31	406	486	80	490	81	120	289	25.2	31.2	28.2
32	461	524	63	531	69	142	320	18.6	24.6	21.6
33	512	547	35	548	75	118	355	18.7	23.7	21.2
34	507	600	93	605	101	146	358	24.6	32.5	28.4
35	445	469	24	471	101	42	328	26.5	35.6	31.1
36	433	486	53	490	84	64	342	24.7	31.6	28.2
37	517	598	81	607	99	121	387	23.1	28.9	26.0
38	410	565	155	573	88	187	298	25.4	33.0	29.2
39	475	536	61	540	97	100	343	24.9	31.6	28.3
40	483	562	79	567	86	139	342	23.5	27.3	25.4
41	486	556	70	558	83	103	362	22.6	29.7	26.2
42	389	472	83	474	85	108	281	25.7	34.2	30.0
43	395	495	100	498	71	148	279	25.5	25.4	25.5
44	451	531	80	536	79	156	301	24.5	29.1	26.8
45	507	581	74	584	93	122	369	23.0	27.0	25.0
46	511	586	75	588	105	70	413	22.8	30.0	26.4
47	435	489	54	491	77	144	270	23.3	34.2	28.8
48	504	585	81	589	69	160	360	19.6	18.3	19.0
49	470	523	53	523	90	103	330	23.8	31.7	27.8
50	408	471	63	475	78	107	290	22.1	32.0	27.1
51	396	449	53	448	77	116	255	25.0	36.2	30.6
52	428	497	69	503	68	129	306	20.7	23.8	22.3
Aver.	454	534	80	542	83	135	322	23.2	29.1	26.2
Max.	535	613	155	620	105	203	413	29.6	39.8	34.7
Min.	389	434	24	434	61	42	255	18.6	18.3	19.0

Table 10. Weights and Moistures. Untreated Douglas Fir Stringers.

Spec. No.	Weight at St. Helens, pounds	Weight at Laboratory, pounds	Dry Weight, pounds	Moisture pounds	Moisture per cent Borings Outside edge	Moisture per cent Borings Center line	Moisture per cent Borings Average	Moisture per cent 1-inch section
1	436	439	315	124	39.3	39.5	39.4	36.4
2	462	454	332	122	37.7	36.0	36.8	34.6
3	391	384	270	114	41.1	44.0	42.5	36.3
4	423	414	305	109	35.8	36.5	36.1	34.8
5	442	440	319	121	39.1	36.4	37.7	32.2
6	475	464	342	122	35.0	37.0	36.0	33.1
7	444	434	307	127	39.8	40.1	39.9	35.2
8	487	478	359	119	32.9	33.6	33.2	31.4
9	390	383	270	113	42.2	41.9	42.0	34.6
10	396	390	277	113	40.2	41.8	41.0	35.0
11	443	444	313	131	39.2	42.0	40.6	34.5
12	429	432	305	127	39.9	42.0	40.9	45.6
13	457	453	314	139	41.8	44.4	43.1	34.2
14	412	402	286	116	40.3	41.7	41.0	36.4
15	487	476	346	130	41.0	37.6	39.3	42.6
16	506	500	360	140	38.4	39.7	39.0	37.3
17	401	397	273	124	45.3	45.6	45.4	40.6
18	412	405	279	126	44.3	45.2	44.7	47.0
19	463	455	320	136	40.6	42.8	41.7	34.3
20	501	497	353	144	43.2	38.1	40.6	49.1
21	486	477	349	128	37.9	36.3	37.1	34.0
22	423	415	305	110	39.3	35.6	37.4	34.1
23	510	512	376	136	35.5	36.5	36.0	33.3
24	411	401	295	106	36.1	36.5	36.3	35.4
25	473	466	331	135	37.6	40.4	39.0	34.4
26	478	465	327	138	42.0	42.7	42.3	35.3
27	426	418	301	117	39.5	37.9	38.7	32.1
28	420	408	283	125	44.9	42.3	43.6	36.4
29	410	408	299	109	38.1	34.1	36.1	31.4
30	457	446	318	128	40.7	40.2	40.4	34.1
31	398	391	281	110	38.3	40.0	39.1	33.0
32	435	425	305	120	38,7	40.9	39.8	33.0
33	491	489	353	136	37.8	39.0	38.4	31.7
34	506	505	358	147	43.1	38.9	41.0	35.8
35	428	426	323	103	31.6	32.3	31.9	33.7
36	466	471	340	131	37.5	39.4	38.4	35.8
37	519	506	380	126	35.0	31.2	33.1	32.9
38	405	397	303	92	33.9	32.7	33.3	32.9
39	459	454	336	118	36.1	33.8	34.9	35.6
40	458	457	333	124	38.2	36.3	37.2	36.0
41	497	495	363	132	35.4	37.1	36.2	31.4
42	402	408	288	120	41.9	40.7	41.3	31.7
43	378	379	273	106	40.7	36.7	38.7	30.5
44	437	433	295	138	54.6	39.5	47,0	31.0
45	501	503	377	126	34.8	32.4	33.6	32.2
46	522	520	400	120	27.6	32.0	29.8	30.8
47	410	411	264	147	71.1	40.0	55.5	33.6
48	502	499	360	139	37.9	39.4	38.6	33.0
49	447	452	322	130	40.1	40.2	40.1	36.1
50	400	400	284	116	39.2	43.0	41.1	37.5
51	393	395	254	141	37.0	74.4	55.7	41.2
52	409	408	301	107	35.0	36.7	35.8	33.7
Average	447	442	318	124	39.5	39.3	39.4	35.2
Maximum	522	520	380	147	71.1	74.4	55.7	49.1
Minimum	378	379	254	92	27.6	31.2	29.8	30.5

Table 11. Weight and Penetration of Creosote.
Treated Douglas Fir Stringers.

Spec. No.	Creosote per cu. ft. pounds	Creosote per sq. ft exposed area, pounds	Depth of Penetration - inches			Per cent of area penetrated by Creosote	Actual Weight per cu. ft. pounds
			Average	Maximum	Minimum		
1	12.2	2.44	0.40	1.50	0.10	15.80	45.25
2	10.5	2.05	0.75	1.00	0.35	28.70	45.18
3	14.1	2.82	0.55	0.80	0.40	21.60	42.34
4	14.2	2.84	0.79	1.50	0.50	30.20	47.00
5	12.6	2.52	0.70	1.20	0.40	27.20	47.05
6	17.2	3.42	0.89	1.50	0.50	34.60	52.50
7	12.2	2.44	0.60	1.00	0.40	23.20	46.55
8	11.3	2.26	0.70	1.50	0.40	27.00	49.20
9	15.4	3.08	0.57	0.90	0.40	22.20	44.48
10	13.9	2.78	0.65	0.90	0.30	25.20	45.08
11	15.8	3.16	0.55	0.70	0.30	21.60	50.55
12	11.4	2.28	0.50	0.85	0.30	19.60	43.22
13	12.3	2.46	0.65	1.00	0.50	25.20	46.67
14	8.3	1.66	0.40	0.65	0.10	15.80	38.80
15	13.7	2.74	0.73	1.00	0.50	28.00	50.10
16	9.5	1.90	0.51	0.90	0.30	20.00	47.94
17	15.4	3.08	0.57	1.10	0.10	22.20	47.05
18	6.3	1.26	0.30	0.90	0.10	12.00	36.68
19	14.1	2.82	0.49	0.60	0.40	19.40	47.05
20	14.5	2.90	0.58	1.00	0.10	22.70	51.75
21	14.7	2.94	0.66	1.10	0.20	25.00	51.55
22	12.3	2.46	0.51	0.80	0.25	20.00	44.60
23	9.8	1.96	0.57	1.00	0.30	22.20	48.65
24	11.9	2.38	0.60	0.80	0.50	23.30	44.15
25	11.3	2.26	0.52	0.80	0.30	20.20	46.20
26	9.9	1.98	0.57	1.20	0.40	22.20	45.90
27	9.3	1.86	0.48	1.20	0.20	18.90	42.30
28	13.3	2.66	0.56	0.80	0.30	21.80	43.85
29	11.2	2.24	0.48	0.90	0.20	18.90	43.95
30	8.9	1.78	0.34	0.80	0.10	13.60	42.05
31	9.9	1.98	0.48	0.70	0.25	18.90	40.35
32	11.7	2.34	0.41	0.95	0.10	16.00	43.65
33	10.0	2.00	0.32	0.70	0.10	12.75	46.35
34	12.0	2.40	0.44	1.30	0.50	17.50	49.87
35	3.5	0.70	0.20	0.70	0.10	12.00	39.72
36	5.5	1.10	0.40	0.80	0.10	15.80	41.87
37	10.1	2.01	0.60	1.20	0.30	23.30	50.45
38	15.9	3.18	0.73	1.20	0.60	28.00	48.63
39	8.5	1.70	0.49	1.00	0.10	19.30	45.68
40	11.7	2.34	0.51	1.10	0.25	20.00	47.80
41	8.5	1.70	0.44	1.00	0.10	17.50	46.30
42	9.3	1.86	0.46	0.80	0.30	18.10	40.60
43	12.3	2.48	0.54	0.80	0.30	21.20	41.40
44	13.2	2.64	0.50	0.70	0.30	19.60	45.35
45	10.2	2.04	0.65	1.00	0.30	25.20	48.83
46	5.8	1.16	0.42	1.20	0.20	16.20	48.95
47	12.5	2.50	0.33	0.50	0.20	13.00	42.76
48	13.1	2.62	0.37	1.40	0.30	14.60	48.32
49	8.6	1.72	0.40	0.50	0.20	15.80	43.55
50	9.2	1.84	0.38	0.80	0.10	15.10	40.97
51	9.8	1.96	0.34	0.60	0.20	13.60	37.85
52	11.0	2.20	0.50	0.80	0.30	19.60	43.03
Average	11.4	2.27	—	—	—	20.41	45.60
Maximum	17.2	3.42	—	—	—	34.60	52.50
Minimum	3.5	0.70	—	—	—	12.00	36.70

PHENOMENA OBSERVED IN TRANSVERSE TEST.

TREATED DOUGLAS FIR STRINGERS.

Specimen 1.—Straight grain; few medium-sized knots; average growth structure. Cracking began at load of 48,700 lbs. and continued until failure by longitudinal shear along line of pith center. Sharp cracking at final failure under maximum load of 54,600 lbs.

Specimen 2.—Straight grain; small knots; wide irregular growth rings, with large percentage of spring wood. Failed by longitudinal shear and large sliver broken at end under maximum load of 52,600 lbs. Dull cracking at final failure.

Specimen 3.—Grain four inches out of line of pith center. Small knots; wide growth rings, with large percentage of spring wood. Cracking began at load of 49,000 lbs. until failure by longitudinal shear, three inches below pith center under maximum load of 51,200 lbs. Loud cracking at final failure.

Specimen 4.—Straight grain; medium and small-sized knots; wide growth rings, with large percentage spring wood. No cracking until failure by longitudinal shear, along line of pith center, under maximum load of 54,300 lbs.

Specimen 5.—Grain of specimen one inch from line of pith center; small knots; bad check along pith center side of specimen; close growth rings, with small percentage spring wood, except near pith center. No cracking until failure by longitudinal shear, along growth rings, under maximum load of 55,400 lbs. Sharp cracking at final failure.

Specimen 6.—Grain three inches out of line of pith center; few small knots; abnormal growth structure, with small percentage of spring wood. Slight cracking just before failure by tension. Loud cracking at final failure under maximum load of 59,700 lbs.

Specimen 7.—Sawed 5 inches out of line of pith center, small knots; average growth structure. No cracking until failure by cross-grain tension. Sharp cracking at final failure under maximum load of 47,400 lbs.

Specimen 8.—Straight grain, large knots and close growth rings with fairly large percentage of spring wood. Dull cracking began at load of 45,000 lbs. Sharp cracking at final failure by slivering tension, under maximum load of 68,800 lbs.

Specimen 9.—Straight grain, average and small sized knots, very wide growth rings; large percentage spring wood and very rank growth. Shear failure and cracking began at load of 22,000 lbs., and continued until failure by tension under maximum load of 32,800 lbs.

Specimen 10.—Straight grain; average sized knots; very wide growth rings, around pith center. Small percentage spring wood. Cracking began just before failure by longitudinal shear, under maximum load of 53,000 lbs. Sharp cracking at final failure.

Specimen 11.—Straight grain; small knots; growth rings varying from wide to very close with large percentage of spring wood. Dull cracking began at load of 10,000 lbs. Shear failure by tension under maximum load of 42,500 lbs.

Specimen 12.—Straight grain; small knots; growth rings varying from wide to close, with large percentage of spring wood. Very rank growth at pith center. Slight cracking at load of 43,000 lbs. before final failure by longitudinal shear under maximum load of 48,700 lbs. Dull cracking at final failure.

Specimen 13.—Sawed four inches out of line of pith center. Small and average sized knots, with average growth structure, and large percentage of spring wood in wide rings portion. Failed by longitudinal shear along line of pith center. Dull cracking at final failure under maximum load of 51,400 lbs.

Specimen 14.—Straight grain, small and average sized knots; very close growth structure. Loud cracking before final failure by longitudinal shear and cross-grain tension under maximum load of 45,400 lbs.

Specimen 15.—Straight grain; small knots; very close growth rings, with average percentage of spring wood. No cracking until failure by longitudinal shear, along line of pith center and growth rings under maximum load of 60,400 lbs.

Specimen 16.—Straight grain; several small knots; heavy summer growth. Cracking began at a load of 59,400 lbs. and final failure was by longitudinal shear along line of pith center. Loud cracking at final failure under maximum load of 62,700 lbs.

Specimen 17.—Grain four inches out of line of pith center; small knots and deep checks along one side; wide growth rings, with large percentage of spring wood. Dull cracking and shear failure began at load of 28,000 lbs. and continued until failure by longitudinal shear under maximum load of 37,000 lbs.

Specimen 18.—Straight grain, many small knots; close growth rings, with large percentage of spring wood around pith center. Sharp cracking began at load of 38,400 lbs. and continued until failure by slivering tension under maximum load of 40,400 lbs.

Specimen 19.—Straight grain, small knots, abnormal growth structure, with fairly small percentage of spring wood. No cracking before failure by longitudinal shear under maximum load of 41,000 lbs. Dull cracking at final failure.

Specimen 20.—Straight grain, medium-sized knots; close growth rings, with fairly large percentage of spring wood. Cracking began at load of 30,000 lbs. and continued until final shear at line of pith center, under maximum load of 39,000 lbs.

Specimen 21.—Sawed four inches out of line of pith center; small knots; close growth rings, with heavy summer growth. Cracking began at load of 43,500 lbs. and continued until failure by cross grain and slivering tension under load of 46,000 lbs.

Specimen 22.—Sawed three inches out of line of pith center; small and average sized knots. Growth rings varying from wide to narrow with large percentage of spring wood. Dull cracking began at load of 40,000 lbs. and continued until final failure by horizontal shear, under maximum load of 43,200 lbs.

Specimen 23.—Straight grain, medium-sized knots, irregular growth, with small percentage of spring wood. Internal cracking began at load of 49,300 lbs. and continued until failure by longitudinal shear under maximum load of 51,900 lbs.

Specimen 24.—Straight grain; one average sized knot; close growth rings with average growth structure. Dull cracking began at load of 47,900 lbs. and continued until failure by longitudinal shear, under maximum load of 53,200 lbs.

Specimen 25.—Straight grain; small and average sized knots, rank growth, with small percentage of spring wood. No cracking before final failure by longitudinal shear. Sharp cracking at final failure under maximum load of 44,600 lbs.

Specimen 26.—Straight grain; small and average sized knots; average growth rings, changing to very close, with very small percentage of spring wood. Failure by longitudinal shear along line of pith center. Loud cracking at final failure under maximum load of 55,000 lbs.

Specimen 27.—Straight grain, except for slight dip, small and average sized knots, abnormal growth rings, changing abruptly from wide to very close, with small percentage of spring wood and bad checks along sides. Dull cracking before failure by longitudinal shear, along checks under maximum load of 47,500 lbs.

Specimen 28.—Straight grain; several small knots; growth rings wide, changing abruptly to very close, with large percentage of spring wood. Cracking began at load of 53,900 lbs. and continued until failure by longitudinal shear along line of pith center under maximum load of 57,200 lbs.

Specimen 29.—Straight grain; small knots; average growth structure; slight cracking began at load of 50,000 lbs. Loud cracking at final failure by tension at center, under maximum load of 65,800 lbs.

Specimen 30.—Straight grain; small and average sized knots. Close growth rings with average growth structure. Cracking began at load of 56,600 lbs. Loud cracking at final failure by tension, under maximum load of 57,200 lbs.

Specimen 31.—Straight grain; average sized knots; wide growth rings, with large percentage of spring wood. Dull cracking before and at failure by longitudinal shear, under maximum load of 37,550 lbs.

Specimen 32.—Straight grain, small and average sized knots. Growth rings varying, with average percentage of spring wood. Dull cracking at load of 45,000 lbs., and final failure by longitudinal shear and slivering tension under maximum load of 59,500 lbs.

Specimen 33.—Straight grain, small knots, irregular structure, with large percentage spring wood, near pith center. Cracking began at load of 70,700 lbs. and continued until failure by longitudinal shear. Sharp cracking under maximum load of 71,500 lbs.

Specimen 34.—Straight grain; average sized knots; bad checks along line of pith center; irregular growth, with close growth rings and small percentage of spring wood. Cracking began at load of 20,000 lbs. and continued until failure by slivering tension and longitudinal shear along line of pith center under maximum load of 40,500 lbs.

Specimen 35.—Straight grain; many small and average sized knots; irregular growth with large percentage of spring wood. Failure by shear and tension began at load of 28,000 lbs. Continued cracking due to shear around knots at final failure under maximum load of 32,600 lbs.

Specimen 36.—Grain three inches out of line of pith center, large number of average sized knots. Specimen badly checked along pith center. Wide growth rings with large percentage of spring wood. Cracking began at load of 29,900 lbs. and continued until failure by longitudinal shear, in check at end and by slivering tension under maximum load of 38,800 lbs.

Specimen 37.—Straight grain, small knots, close growth rings, with small percentage of spring wood. Specimen slivered at load of 53,150 lbs., before failure by longitudinal shear, under maximum load of 59,600 lbs. Sharp cracking at failure. Section shelled out at bottom.

Specimen 38.—Straight grain; small and average sized knots; growth rings wide, rank growth, with large percentage of spring wood. No cracking before failure by slivering tension, under maximum load of 47,500 lbs. Sharp cracking at final failure.

Specimen 39.—Straight grain, medium sized knots, abnormal growth rings, with average percentage of spring wood. Failed with little preliminary cracking by longitudinal shear above line of pith center under maximum load of 51,200 lbs.

Specimen 40.—Straight grain. Many small and average sized knots; rank growth structure. Failed by longitudinal shear. Dull cracking at failure under maximum load of 48,300 lbs.

Specimen 41.—Many small knots, medium growth rings with a large percentage of summer wood and grain four inches out of line with pith center. Cracking culminating in cross-grain longitudinal shear failure began at a maximum load of 45,500 lbs.

Specimen 42.—Straight grain; with several large knots; rank growth structure, with a large percentage of spring wood. Failure by shear and crushing, at maximum load of 44,700 lbs. along neutral axis at center of specimen.

Specimen 43.—Straight grain, with several small and average sized knots. Close growth rings with a fairly large percentage of spring wood. Dull cracking at load of 38,400 lbs., with failure by longitudinal shear. Sharp cracking at final failure under maximum load of 44,800 lbs.

Specimen 44.—Straight grain, containing several small knots and average growth structure. Dull cracking at load of 52,200 lbs., and failure by longitudinal shear along neutral axis. Sharp cracking at final failure under maximum load of 52,900 lbs.

Specimen 45.—Straight grain; specimen sawed four inches out of line with pith center, and contained small and average sized knots, with small percentage of spring wood. Failure by shear along line of pith center, and slivering near center under maximum load of 52,400 lbs.

Specimen 46.—Straight grain, with several small knots and structure showing irregular growth conditions. Cracking began under load of 68,800 lbs. Sharp cracking at final failure by horizontal shear along line of pith center under maximum load of 70,600 lbs.

Specimen 47.—Straight grain, with several small and average sized knots; average growth with large percentage of spring wood. Several cracks before failure by horizontal shear. Sharp cracking at final failure under maximum load of 58,500 lbs. In addition to horizontal shear, specimen showed cross grain shear failure, resulting from knots on one side.

Specimen 48.—Straight grain, with specimen sawed four inches out of line with pith center. Several small knots; irregular growth, showing average percentage of spring and summer wood. Cracking began at load of 54,800 lbs., with final tension failure at maximum load of 57,500 lbs.

Specimen 49.—Straight grain, with several small knots; average growth showing large percentage of spring wood. Failure by horizontal shear along neutral axis at center of specimen under maximum load of 51,700 lbs.

Specimen 50.—Straight grain, with several small and average sized knots, showing rank growth around pith center; large percentage of spring wood. Initial failure by slivering tension under load of 46,400 lbs. Sharp cracking at failure under maximum load of 48,900 lbs.

Specimen 51.—Dip grain with many small knots, showing abnormal growth conditions. Dull cracking at failure by horizontal shear under maximum load of 38,500 lbs.

Specimen 52.—Straight grain with several small and average sized knots; structure showed rank growth at pith center, with a large percentage of spring wood. Dull cracking under load of 52,500 lbs. and final failure by shearing and crushing along neutral axis at center of specimen, under load of 52,600 lbs.

Specimen 53.—Straight grain; small and average sized knots. Average growth rings with large percentage of spring wood. Specimen slivered at 45,000 lbs. Sharp cracking at final failure, by tension at maximum load of 49,400 lbs.

Specimen 53-*A*.—Straight grain, with several medium-sized knots. Cracking occurred under load of 27,300 lbs. and final failure by slivering and cross-grain tension with little cracking occurred under maximum load of 28,350 lbs.

Specimen 55.—Specimen sawed with grain four inches out of line of pith center; several large knots; rank growth with large percentage of spring wood. Dull cracking began at 30,000 lbs. and continued to final failure by tension at maximum load of 40,600 lbs.

Specimen 55-*A*.—Straight grain with several average sized knots, rank growth structure with large percentage of spring wood. Sharp cracking at initial failure by slivering tension, at elastic limit under load of 15,000 lbs. Loud cracking at final failure by tension under maximum load of 18,400 lbs.

PHENOMENA OBSERVED IN TRANSVERSE TEST.

UNTREATED DOUGLAS FIR STRINGERS.

Specimen 1.—Straight grain; several medium-sized knots; average growth structure. Cracking began under load of 35,000 lbs. and continued until failure by crushing and longitudinal shear, under load of 65,750 lbs.

Specimen 2.—Straight grain; small knots; wide irregular growth rings, with large percentage of spring wood. Cracking began under load of 50,000 lbs. and continued until failure by slivering tension, at load of 63,100 lbs.

Specimen 3.—Straight grain, many small knots, wide growth rings, with large percentage of spring wood. Little cracking took place until failure by slivering tension, under maximum load of 57,000 lbs.

Specimen 4.—Straight grain, few small knots, wide growth rings, with large percentage of spring wood. No cracking until failure by longitudinal shear along line of pith center under load of 65,000 lbs.

Specimen 5.—Straight grain, small knots, close growth rings, with small percentage of spring wood, except near pith center. Cracked in tension under load of 58,000 lbs. Loud cracking at final failure by longitudinal shear, under load of 62,900 lbs.

Specimen 6.—Straight grain; small knots; abnormal growth structure, with small percentage of spring wood. Dull cracking began at load of 55,000 lbs. and continued until failure by longitudinal shear, along growth rings at load of 70,000 lbs.

Specimen 7.—Straight grain, small knots, average growth structure. No cracking until failure by cross grain and slivering tension under load of 64,700 lbs.

Specimen 8.—Straight grain; small and average sized knots; growth rings close, with fairly large percentage of spring wood. Dull cracking began under load of 63,900 lbs. Sharp cracking at failure by slivering tension under maximum load of 67,400 lbs.

Specimen 9.—Grain three inches out of line with pith center throughout length of specimen; average sized knots; growth rings very wide, with large percentage of spring wood; very rank growth. Dull cracking began under load of 47,500 lbs. and continued until failure by tension along growth rings. Sharp cracking at final failure.

Specimen 10.—Grain one inch out of line throughout length of specimen; small and average sized knots, growth rings very wide around pith center; small percentage of spring wood. Cracking began at load of 50,000 lbs. and continued until failure by longitudinal shear at base under maximum load of 56,200 lbs.

Specimen 11.—Straight grain; few small knots; growth rings varying from wide to very close, with large percentage of spring wood.

Cracking began at load of 64,100 lbs. and failure was by tension under load of 71,800 lbs.

Specimen 12.—Straight grain, small knots; wide growth rings, with large percentage of spring wood. Cracking began just before maximum load was reached and failure took place by slivering tension and longitudinal shear under load of 63,800 lbs.

Specimen 13.—Straight grain; small knots; growth rings varying from very wide to very narrow; large percentage of spring wood in the wide rings portion. Bearing plates crushed into fiber at load of 66,700 lbs. and failure was by longitudinal shear. Sharp cracking at final failure under maximum load of 68,900 lbs.

Specimen 14.—Straight grain; many small knots on one side; very close growth rings with small percentage spring wood. No cracking until failure by slivering tension under maximum load of 45,000 lbs.

Specimen 15.—Straight grain; few small knots; growth rings very close, with an average percentage of spring wood. Slight cracking began at load of 74,700 lbs. and failure took place by shear along line of pith center and tension under maximum load of 77,700 lbs. Shear failure influenced by crushing of plates under load points into wood.

Specimen 16.—Straight grain; few small knots; heavy summer growth. No cracking took place before failure by shelling out along growth rings, under maximum load of 70,900 lbs.

Specimen 17.—Sawed four inches out of line of pith center; few small knots; wide growth rings, with a large percentage of spring wood. Dull cracking began at load of 59,700 lbs., and failure took place by crushing and shear, at maximum load of 60,000 lbs., shearing from crushed portion under plates at load points.

Specimen 18.—Straight grain; many small knots; close growth rings, with a large percentage of spring wood. Cracking began at load of 54,200 lbs. and continued until failure by slivering tension, and crushing of fiber under bearing plates, at maximum load of 54,900 lbs. Position of knots influencing tension failure.

Specimen 19.—Straight grain; few small knots; abnormal growth structure; with fairly small percentage of spring wood. No cracking took place before failure by longitudinal shear two inches below pith center, under load of 75,350 lbs.

Specimen 20.—Sawed four inches out of line of pith center; grain dips four inches throughout length of specimen. Two small knots; close growth rings, with fairly large percentage of spring wood. Cracking began at load of 66,100 lbs., and failure was by longitudinal shear, through the entire length of specimen. Sharp cracking at final failure under maximum load of 71,500 lbs.

Specimen 21.—Straight grain; two small knots; abnormal growth rings; varying wide and narrow; very small percentage of spring wood. Cracking began at load of 40,000 lbs. and continued until failure by slivering tension and crushing fiber under bearing plates, under maximum load of 54,400 lbs.

Specimen 22.—Straight grain; small knots; growth rings varying from wide to narrow, with large percentage of spring wood. Dull cracking began under load of 45,500 lbs. and continued until failure under maximum load of 54,200 lbs. Sharp cracking at final failure.

Specimen 23.—Sawed three inches out of line with pith center; small knots; growth rings varying from wide to narrow, with small percentage of spring wood. Dull cracking began at load of 50,000 lbs. and failure was by longitudinal shear. Loud cracking at final failure, under maximum load of 58,000 lbs.

Specimen 24.—Straight grain; free from knots; close growth rings, with average percentage of spring wood. No cracking before failure by longitudinal shear, near top of specimen at maximum load of 53,000 lbs.

Specimen 25.—Had slight dip in grain, one large and several small knots; wide growth rings with small percentage of spring wood. Little cracking before failure by slivering tension under load of 71,700 lbs.

Specimen 26.—Straight grain; small knots; average growth rings; changing to very close, with very small percentage of spring wood. Loud cracking before failure by longitudinal shear, at maximum load of 62,200 lbs.

Specimen 27.—Straight grain; knots small and average; growth rings changing abruptly from very wide to very narrow, with small percentage of spring wood. Dull cracking began at load of 52,600 lbs. and continued until failure by longitudinal shear, under maximum load of 53,800 lbs. Sharp cracking at final failure.

Specimen 28.—Straight grain, few small knots; wide growth rings, changing abruptly to very narrow, with large percentage of spring wood. Cracking began at load of 51,800 lbs. and continued until failure by tension at maximum load of 61,750 lbs.

Specimen 29.—Straight grain, few small knots; growth rings close, with average percentage of spring wood. Dull cracking began at load of 35,000 lbs. and continued until failure by longitudinal shear at maximum load of 63,900 lbs.; bearing plates under load points crushing into wood.

Specimen 30.—Specimen sawed three inches out of line with pith center; small and average knots; growth rings close, with average percentage of spring wood. Dull cracking began at load of 50,000 lbs. and continued until failure by longitudinal shear, and slivering tension at maximum load of 62,600 lbs.

Specimen 31.—Straight grain; small and average knots; growth rings wide, with a large percentage of spring wood; rank growth. Cracking began at load of 57,700 lbs. and continued until failure by crushing of bearing plates into wood under load points and slight tension at maximum load of 60,600 lbs.

Specimen 32.—Straight grain; small knots; growth rings varying, with average percentage of spring wood. Sharp cracking at failure by longitudinal shear along growth rings, under maximum load of 72,000 lbs. Plates under load points crushed into wood.

Specimen 33.—Straight grain, few small and one large knot, at bottom near center. Average growth rings, with a large percentage of spring wood near pith center. Dull cracking began at load of 60,000 lbs. and continued to failure by slivering tension at maximum load of 76,100 lbs.

Specimen 34.—Straight grain; one large knot near bottom at center, and three small scattered knots. Close growth rings with small percentage of spring wood. Cracking at failure by slivering tension at maximum load of 70,000 lbs.

Specimen 35.—Straight grain; many small and average knots. Growth rings wide, with large percentage of spring wood. Cracking began at load of 44,800 lbs. and continued until failure by tension, under maximum load of 48,400 lbs.

Specimen 36.—Straight grain; small and average knots; wide growth rings, with a large percentage of spring wood. Dull cracking began at load of 50,000 lbs. and continued until failure by slivering tension under maximum load of 54,200 lbs. Sharp cracking at final failure. Failure influenced by knots.

Specimen 37.—Straight grain, small knots; growth rings close, with a small percentage of spring wood. Dull cracking began at load of 75,000 lbs., continuing until failure by slivering tension, and longitudinal shear at maximum load of 81,700 lbs., partly along growth rings.

Specimen 38.—Straight grain; many large and small knots. Growth rings wide, with a large percentage of spring wood. Rank growth. Dull cracking began at load of 25,000 lbs. and continued until failure by tension, under maximum load of 48,800 lbs. Sharp cracking at final failure.

Specimen 39.—Straight grain; few medium-sized knots; abnormal growth rings; average percentage of spring wood. Failure by slivering tension, with sharp cracking at maximum load of 54,500 lbs.

Specimen 40.—Straight grain; many average sized knots. Rank growth structure. Dull cracking began just before final failure, which was by slivering tension at maximum load of 62,800 lbs. Plates under load points crushed into wood.

Specimen 41.—Straight grain, few average sized knots, varying growth rings, with a small percentage of spring wood. Sharp cracking at failure by cross-grain tension, under load of 52,700 lbs.

Specimen 42.—Straight grain, average sized knots. Growth rings very wide, with a large percentage of spring wood. Cracking began at load of 40,000 lbs. and continued until failure by slivering tension at maximum load of 49,600 lbs.

Specimen 43.—Straight grain, average sized knots. Growth rings close, with a fairly small percentage of spring wood. Cracking began at load of 43,000 lbs. and continued until failure by slivering tension at maximum load of 47,000 lbs.

Specimen 44.—Straight grain, small and average sized knots, close growth rings, with average percentage of spring wood. Cracking began just before failure by longitudinal shear. Sharp cracking at final failure under maximum load of 64,600 lbs.

Specimen 45.—Straight grain; average sized knots, close growth rings with a small percentage of spring wood. Failure without warning, by cross-grain tension at maximum load of 66,700 lbs. Position of knots influenced failure.

Specimen 46.—Straight grain; not sawed square; many small knots. Growth rings varying from wide to narrow. Average percentage of spring wood. Cracking began just before failure under load of 85,500 lbs. First indication of failure was by cracking along line of pith center.

Specimen 47.—Straight grain; few small knots; close growth rings; with a large percentage of spring wood. Slight cracking before failure by tension. Loud cracking before final failure, at maximum load of 66,600 lbs.

Specimen 48.—Slight dip in grain of specimen. Few small knots; growth rings close, with average percentage of spring and summer wood. Much slivering of wood before failure by shear and cross-grain tension at maximum load of 71,730 lbs.

Specimen 49.—Specimen sawed with grain four inches out of line of pith center. Small and average sized knots. Average growth rings with a large percentage of spring wood. Little cracking before failure by cross-grain tension with sharp report at maximum load of 69,100 lbs.

Specimen 50.—Straight grain, very small and average sized knots. Growth rings varying from wide to narrow with a large percentage of spring wood. Little cracking took place before failure by tension at maximum load of 57,500 lbs.

Specimen 51.—Dip grain, sawed three inches out of line of pith center; few knots; abnormal growth rings, varying from wide to narrow, with a large percentage of spring wood. Dull cracking began at load of 45,000 lbs., and continued until failure by longitudinal shear along pith center, under maximum load of 55,650 lbs.

Specimen 52.—Straight grain; many average sized knots; growth rings wide, with a large percentage of spring wood. Dull cracking began at load of 52,900 lbs. and continued until failure by slivering tension. Sharp cracking at final failure under load of 56,000 lbs. Position of knots influenced failure.

DISCUSSION.

Physical Structure.—Inasmuch as the material had been treated less than two months before physical tests were made, it was almost entirely free from season checks. The material passed the requirements for service as bridge stringers and was, therefore, free from injurious defects, such as large, loose knots, bad checks, shakes, etc.

The stringers were sawed from the heartwood of the log and contained very little sap wood. The lot tested contained 33 per cent. box heart, and 67 per cent. side cuts, as compared with 36 per cent. box hearts and 64 per cent. side cuts, in the entire lot treated.

Treatment.—It is generally conceded that green or watersoaked timber cannot be satisfactorily treated until the moisture has been removed below a certain point in order to get the material in a receptive condition for creosoting. In creosoting processes, where temperatures of 240 degrees to 350 degrees Fahrenheit are used in removing the moisture, the fiber is weakened, due to the high temperature. When boiling under vacuum at a much lower temperature, of only 180 degrees to 190 degrees Fahrenheit, less injury, if any, may be expected.

How much moisture is removed and how much oil can be pressed into the fiber is shown by the following summary of the Plant inventory covering the treatment of the lot:

Charge No.	Plant No.	Retort.	Cu. Ft. Timber Treated.	Total Moisture Removed Pounds.	Total Oil—Pounds. Used.	Total Oil—Pounds. Required.*
1	172	E	2,448	10,760	30,400	29,350
2	173	F	2,154	7,040	23,450	25,650
3	174	F	1,695	7,140	22,850	20,300
4	175	E	1,675	6,840	23,000	20,100
Total			7,972	31,780	99,700	95,400

These data show the removal of 4 lbs. of moisture and a treatment of 12.5 lbs. of creasote per cubic foot of timber.

The condition of the timber as to moisture and creosote before and after treatment in pounds per cubic foot is shown by the following table:

			Moisture				
Charge No.	Plant No.	Retort.	Before Treatment.	After Treatment.	Moisture Removed.	Moisture and Creosote.	Creosote.
1	172	E	10.3	6.6	3.7	19.9	13.3
2	173	F	10.7	7.0	3.7	18.2	11.2
3	174	F	10.3	7.4	2.9	18.1	10.7
4	175	E	10.8	7.0	3.8	17.3	10.3

The moisture content in the treated specimens was slightly greater at the time of test than just after treatment, as shown by difference in weights at St. Helens and at Topeka.

The removal of moisture, either by air drying or by artificial drying, constitutes the seasoning of timber. Former laboratory tests have shown a slight increase in the physical strength of treated Douglas Fir, due to seasoning.

Effect of Treatment.—The transverse tests show that the effect of treatment on the strength of Douglas Fir stringers is as follows: weighs at St. Helens and at Topeka.

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*To give treatment of 12.0 lbs. of creosote per cubic foot.

	Pounds per Square Inch. Maximum.	Minimum.	General Average.	Per Cent.
Elastic Limit:				
Treated	5,280	1,430	3,481	82
Untreated	5,610	3,140	3,269	100
Modulus of Rupture:				
Treated	6,690	3,020	4,680	82
Untreated	7,990	4,105	5,691	100
Modulus of Elasticity:				
Treated	2,136,400	1,276,700	1,666,200	98
Untreated	2,153,800	1,204,400	1,701,900	100
Longitudinal Shear:				
Treated	475	216	333	81
Untreated	565	299	411	100

These data show in the transverse tests that the elastic limit and modulus of rupture are decreased 18 per cent. due to this treatment; the modulus of elasticity is decreased only 2 per cent., and the shearing strength is decreased 19 per cent.

A general classification of number of failures in transverse tests for treated and untreated specimens follows:

	Longitudinal Shear.		Tension.		Miscellaneous.	
	No. of Failures.	Per Cent. of Total.	No. of Failures.	Per Cent. of Total.	No. of Failures.	Per Cent. of Total.
Treated	32	62	14	27	6	11
Untreated	16	31	29	56	7	13

From this table it is seen that for the treated specimens a majority failed by longitudinal shear, while of the untreated specimens, the majority failed by tension.

Treated Specimens 9, 17, 34 and 35 showed peculiar shear failures along the line of pith center as shown by the graphs. These specimens showed an early failure by shear and later failed by tension, under a higher load. In all other shear failures the shearing took place at the maximum load.

The predominate type of shear failure was through the pith center in the box heart cuts, and near the line of pith center in the side cuts. From a total of 48 shear failures in the treated and untreated stringers, 33 specimens, or 69 per cent., were directly along the line of pith center.

Specimen 16, untreated, side cut, failed by shearing entirely along the growth rings, five inches from the pith center. Specimens 6 and 37, untreated, and 5 and 31, treated, failed by shearing along the growth rings for a short distance, and then across the grain.

The compression tests parallel to the grain show that the effect of treatment on the strength of Douglas Fir is as follows:

	Pounds per Square Inch.			
	Maximum.	Minimum.	General Average.	Per Cent.
Elastic Limit:				
Treated	5,080	2,358	3,629	94
Untreated	5,173	2,611	3,873	100
Maximum Load:				
Treated	5,235	2,590	3,869	94
Untreated	5,530	2,750	4,114	100
Modulus of Elasticity:				
Treated	814,500	409,500	607,110	101
Untreated	811,000	413,000	601,020	100

This table shows that in compression, the strength of this material is decreased 6 per cent. at the elastic limit and 6 per cent. at the maximum load, due to treatment. The modulus of elasticity shows the treated material 1 per cent. stiffer than the untreated material. The specimens for this test were sawed from the material after transverse test, and had a part of the area of the treated specimens penetrated by creosote.

The compression tests perpendicular to the grain show that the effect of treatment on the strength of Douglas Fir is as follows:

	Pounds per Square Inch.			
	Maximum.	Minimum.	General Average.	Per Cent.
Elastic Limit:				
Treated	615	206	322	74
Untreated	627	346	438	100
Load for Deflection of ⅜-inch:				
Treated	900	450	640	82
Untreated	1,100	590	780	100

This table shows that the strength of this material in compression was decreased due to treatment, by 26 per cent. at the elastic limit and by 18 per cent. at a load which caused ⅜-in. deflection.

SPECIAL TESTS.

A special test was made to determine the effect of the area penetrated by creosote on the physical strength of treated stringers, as compared with the area not penetrated.

Treated stringers 53 and 55, each 30 feet long, were cut in 15-foot lengths. One-half of each stringer was numbered 53 and 55 and the other half of each stringer 53-A and 55-A, respectively. Specimens 53-A and 55-A were planed on the sides and edges, so as to remove the area penetrated by the creasote, prior to transverse tests. The results of transverse test were as follows:

Specimen.	Sectional Area Sq. In.	Elastic Limit Lbs. per Sq. In.	Modulus of Rupture Lbs. per Sq. In.	Modulus of Elasticity Lbs. per Sq. In.	Weight per Cu. Ft.	
					Actual	Creosoted Area Planed Off.
53	111.7	3,860	4,760	1,389,800	44.0	
53A	70.0	3,820	5,400	1,705,000	36.0	57.4
55	112.0	3,270	3,790	1,214,100	38.1	
55A	70.0	2,860	3,505	1,331,900	31.0	50.3

The above table shows a slight increase in the modulus of rupture for Specimen 53-A over Specimen 53, while it shows a slight decrease in elastic limit and modulus of rupture for Specimen 55-A over Specimen 55. The average of the above data shows that the modulus of elasticity is the only property which is appreciably increased by removing the creosoted portion.

The weight per cubic foot of the area actually penetrated by creosote in the above specimens is approximately twice the weight of dry wood.

Penetration of Creosote.—A table showing the absorption of creosote and the area of penetration is as follows:

	Creosote—Pounds		Average Depth of Penetration Inches.	Per Cent. of Area Penetrated by Creosote.
	Per Cu. Ft.	Per Sq. Ft. of Exposed Area.		
Average	11.4	2.27	..	20.4
Maximum	17.2	3.42	0.89	34.6
Minimum	3.5	0.70	0.20	12.0

The maximum value in the above table is for specimen 6 and the minimum value for specimen 35. Specimen 6 had a large percentage of summer wood and was of a very compact structure, as is shown by photograph, Fig. 6. Specimen 35 had a large percentage of spring wood, as shown by photograph, Fig. 21. The summer wood in this specimen was of a spongy, open structure. A study of the structure and the creosote per cubic foot shows that the structure having a large percentage of summer wood has a high value for creosote per cubic foot, and that the structure having a high percentage of spring wood has a low value for creosote per cubic foot. This is due to the fact that the soft, spongy fiber of the spring wood offers greater resistance to the penetration of creosote than the structure of the summer wood. Specimens 14, 18 and 27, which have 21 or more growth rings per inch, show values for creosote per cubic foot which are below the average value.

CONCLUSIONS.

The results of these tests indicate the following conclusions relative to the boiling under vacuum process of creosoting Douglas Fir Bridge Stringers:

1. The moisture may be successfully removed by boiling under vacuum for the proper treatment of the material. Moisture determinations show that on an average 35 per cent. of the total moisture was removed by this process.

2. The removal of moisture by the boiling under vacuum process, preliminary to creosoting, decreases the physical strength of the material.

3. The weight of creosote per unit of volume for treated material is dependent on the structure of the specimen. The spring wood offers greater resistance to treatment than the summer wood.

4. Special test of treated stringers 53 and 55 indicate that the decrease in physical strength due to treatment· is not confined to the area penetrated by creosote, but that the entire structure is affected.

6. The compressive strength parallel to the grain was decreased 6 per cent., due to boiling under vacuum process.

7. The compressive strength perpendicular to the grain was decreased 26 per cent., due to the boiling under vacuum process.

8. Although the average strength of the treated material is appreciably decreased, its stiffness, as measured by the modulus of elasticity, is not affected.

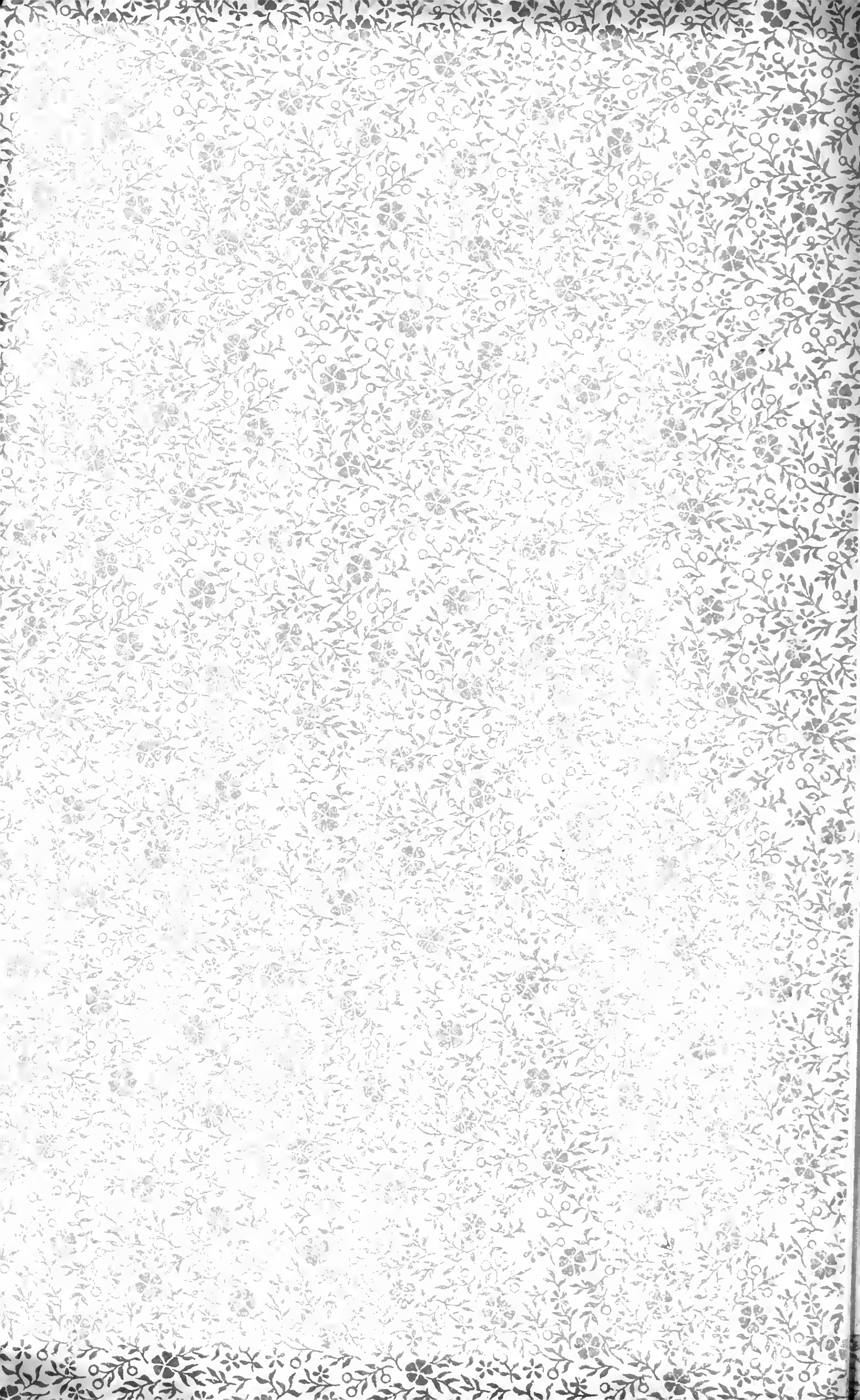
9. In general, the average strength of Douglas Fir Bridge Stringers, subjected to the boiling under vacuum process of creosoting, was five-sixths of its original strength.

INDEX

PART 1.

PART 2.

(**For Sheets and Plates illustrating Text**, see pages 603-748.)



CK.

'er ct fArea f head braded to total area f head	Years in Service	In Joint	Defects in Quality of Material and Road Bed											Material Fair	Reference Numbers
			Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Steel Pres.	Frozen Roadbed	Miscellaneous		
			Badly	Somewhat		in Head	in web								
10.3	12												Hardness low	●	1N
14.9	12			●											1S
7.1	12							●							2N
10.6	12			●	●			●							2S.
11.5	17												Hardness low	●	3N.
9.7	17												Very soft		3S.
86	15			●									Very soft		4N
92	15												Soft		4S
9.2	15		●			●	●	Hard in Web Irregular					Low C heat		5N
97	15		●			●		Hard in Web					Very irregular		5S
9.4	14												Very soft	●	6N
94	14			●				S somewhat high					Somewhat soft		6S.
8.4	14												Somewhat soft	●	7N.
9.7	14													●	7S.

of head

Sheet 1

PENNSYLVANIA LINES WEST OF PITTSBURGH.

STUDY OF 14 RAILS WHICH HAVE GIVEN GOOD SERVICE IN THE MAIN TRACK.

OFFICE OF CHIEF ENGR M of W SEPT 9

Reference No	Weight of Rail lbs per yd	Rail Sec	Mfr	Year of Rolling	Bessemer or O.H.	[illegible]	[illegible]	Rail	Carbon Head	Carbon Web	Carbon Base	Manganese Head	Manganese Web	Manganese Base	Phosphorus Head	Phosphorus Web	Phosphorus Base	Silicon Head	Silicon Web	Silicon Base	Sulphur Head	Sulphur Web	Sulphur Base
Indianapolis Divn – West of [illegible] 6 miles west of Columbus O																							
N	85	ASCE	Car	899	B			N	48	46	49	74	73	73	097	093	097	089	099	097	029	030	031
S	"	"	"	"				S	52	57	5	91	95	92	101	119	099	136	136	136	016	023	015
2N	"	"	"	"	"			N	58	58	60	92	92	93	099	102	101	127	127	127	020	025	022
2S	"	"	"		"			S	55	65	54	93	97	92	195	23	087	132	127	132	016	025	017
Indianapolis Divn – East of Centerville O																							
3N	85	PRR	Car	1894	B			N	48	45	48	90	77	80	5	06	2	059	059	061	045	034	036
3S	"			"	"			S	44	39	43	70	68	69	114	097	111	047	050	053	033	028	030
Indianapolis Divn – West of Dunreith Ind																							
4N	85	PRR	Car	896	B	Unknown		N	37	40	39	67	67	66	099	9	106	047	047	047	013	016	015
4S			"					S	44	4	44	77	77	77	098	097	100	095	103	088	021	021	022
5N	"		"					N	38	59	46	71	79	74	084	92	113	06	064	06	016	049	024
5S	"	"			"			S	43	61	44	96	94	95	083	66	092	094	092	094	016	044	019
Indianapolis Divn – East of Greenfield Ind																							
6N	85	PRR	I	897	B			N	43	4	44	82	82	83	087	081	099	55	66	155	259	053	056
6S	"		"	"				S	48	54	49	01	101	00	069	01	092	183	191	183	055	069	058
7N		"	"	"				N	49	47	48	100	01	100	088	084	088	197	202	197	045	047	045
7S	"	"			"			S	50	50	52	96	94	95	083	083	083	172	165	163	043	045	044

Reference No	Tensile Strength Lbs per sq inch	Elastic Limit Lbs per sq inch	Elongation per cent in 2"	Reduction of area per cent of Orig Sec	Drop Test Supports 2' apart, Test Piece at "D" Blows at 5 Ft	Blows at 10 Ft	Blows at 15 Ft	Initial Deflec	Accumulated Ft Lbs	50 lb Tup, Test Piece at E, Blows at 3 Ft	Blows at 6 Ft	Blows at 10 Ft	Initial Deflec	Accumulated Ft Lbs
Indianapolis Divn – West of [illegible] 6 miles west of Columbus O														
N	105600	60100	20 5	32 5	5	5	40	5/8	33750	5	5	38	1 1/4	2 250
S	120250	64950	17 25	25 65	5	5	34	1/2	29250	5	5	32	1 3/16	18250
2N	130900	68290	12 5	17 5	5	5	30	2	26250	No Material				
2S	101650	67700	3 25	3 31	5	1		2	750	5	5		8	2250
Indianapolis Divn – East of Centerville O														
3N	107200	66405	22 5	36 62	5	5	41	5/8	34500	5	5	50	1 3/8	27250
3S	96120	47345	25	43 86	5	5	50	6	37500	No Material				
Indianapolis Divn – West of Dunreith Ind														
4N	96175	52500	18 75	26 2	5	5	69	1/2	55500	5	5	38	1 5/16	21250
4S	97950	46770	23 75	40 47	5	5	62	11/16	50250	5	5	46	1 1/16	25250
5N	102390	54540	10 8	9 69	5	5		6	3750	5	5		1 1/8	2250
5S	100135	62790	8 25	8 12	1				250	5	5	46	1 5/16	25250
Indianapolis Divn – East of Greenfield Ind														
6N	99490	52095	23 5	39 8	5	5	66	3/4	53250	5	5	26	5/16	15250
6S	109850	56170	9 25	31 94	5	5	53	11/16	43500	5	5	52	1 5/8	28250
7N	109850	60005	21 75	35 2	5	5	52	5/8	42750	5	5	31	1 5/16	17750
7S	112700	52140	8 5	29 8	5	5	66	5/8	53250	5	5	18	1 3/16	11250

Reference No	Brinell Hardness*	Per cent of Area of Metal Abraded to total area of head	Years in Service	[illegible]	Defects in Quality of Material and Road Bed: Segregated Badly	Segregated Somewhat	Brittle	Somewhat Brittle in Head	Somewhat Brittle in Web	Hard	Rolling Seams	Slag Present	Rolling Stresses	Frozen Roadbed	Miscellaneous	Worn [illegible]	Reference Numbers
Indianapolis Divn – West of [illegible] 6 miles west of Columbus O																	
N	212	10 3	12												hardness low	●	1N
S	235	14 9	12			●											1S
2N	254	7 1	12							●							2N
2S	241	10 6	12			●	●			●							2S
Indianapolis Divn – East of Centerville O																	
3N	220	5	17												hardness low	●	3N
3S	187	9 7	17												Very soft		3S
Indianapolis Divn – West of Dunreith Ind																	
4N	183	8 6	15			●									Very soft		4N
4S	188	9 2	15												Soft		4S
5N	209	9 2	15		●			●	●	Hard [illegible] sulphur					Low Carbon		5N
5S	207	9 7	15		●			●		hard in web					Very irregular		5S
Indianapolis Divn – East of Greenfield Ind																	
6N	188	9 4	14												Very soft	●	6N
6S	209	9 4	14			●				[illegible] somewhat high					Somewhat soft		6S
7N	217	8 4	14												Somewhat soft	●	7N
7S	221	9 7	14													●	7S

NOTES –

Alignment – tangent
Ballast – Gravel
Average Chemical Analysis of all Carnegie rail received 899 – C 474 P 093 Mn 838 Si 083 S 030
" " " " " Illinois " 1897 – C 474 P 08 Mn 92 Si 129 S 057

*Ave. of head

Sheet 2

SBURGH

S

Broken Rails

o.	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed											Material Fair	Reference Numbers
½" ×1"			Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Steel Pres.	Frozen Road bed	Miscellaneous		
Accumul. Foot Lbs.			Badly	Somewhat		in Head	in Web								
39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
26750	198											●	Possible flaw		1
21250	212	●										●			2
16750	192												Soft. Much worn		3
18250	206	●											Hardness low		4
23750	199	●	●									●	Hard in neck. Irreg		5
–	167											●	Soft		6
25750	212	●										●	Line & surface fair	●	7
24750	236			●		●		●				●			8
8250	241							●			●	●	Flaw. Ties fair		9
35750	211	●	●			●						●	Line & surface fair		10
8750	226											●	Line & surface fair	●	11
—	189												Little soft		12
28250	216	●										●	Possible flaw	●	13
–	217											●	C. little high	●	14
12750	241							●				●	Line & surface fair		15
1950	240	●		●			●	●				●			16
2750	256	●		●	●			●							17
1050	275				●			●	●	●		●			18
10250	261							●				●	Low ductility		19
10250	224											●	Flaw		20
18750	235			●					Split base			●	Hardness high		21
—	217								●			●	Split base	●	22
19750	218	●		●				Considerably worn					Flaw in base		23
14750	236	●						●				●	Crack in head		24
3750	225		●		●			Hard in web				●	Crack in head		25
27750	245							●				●	Flat wheel		26
—	241			●				●					Low ductility		27
—	185											●	Soft. Irregular		28
–	208	●	●			●							Split head		29
–	202			●		●					●		Split head		30
19250	242	●	●			●		●				●			31
17250	250							●				●			32
17750	225											●	Split base		33
17750	200											●	P. a little high		34
15250	217											●	P. a little high		35
24250	223	●										●	P. & S. high		36
16250	222												Flaw		37
16250	213													●	38
23750	220									●		●	P. high		39
·5750	251	●				●		●				●	Flaw. Struc. poor		40
—	242	●		●	●			●				●	Flaw		41

PENNSYLVANIA LINES WEST OF PITTSBURGH

STUDY OF RAIL FAILURES IN MAIN TRACKS

Bessemer Process

March-1913

Broken Rails

Reference Number	Wt. of Rail Lbs. Yd.	Section	Manufacturer	Year Rolled	Position in Ingot	Years in Service	Kind of Joint	Ballast	Chemical Analysis of Rail															Tensile Strength	Elastic Limit	Elongation Per Cent in 2 In.	Reduction of Area Per Ct. of Orig. Sect.	Character of Fracture	Drop Test – Supports 12" apart – 50 Lb. Tup										Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed												Material Fair	Reference Numbers
									Carbon			Manganese			Phosphorus			Silicon			Sulphur			Lbs. per Sq. In.					Test Piece at D					Test Piece at E							Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seams	Slag Present	Foreign Substances	Frozen Road Bed	Miscellaneous		
									Head	Web	Base	Head	Web	Base	Head	Web	Base	Head	Web	Base	Head	Web	Base						Blows at 5 Ft.	Blows at 10 Ft.	Blows at 15 Ft.	Total Deflec.	Accum. Foot Lbs.	Blows at 3 Ft.	Blows at 6 Ft.	Blows at 10 Ft.	Total Deflec.	Accum. Foot Lbs.			Badly	Somewhat		In Head	In Web								
1	85	PRR	Ill S W	1897	–	16 Yr. 8 Mo.	T	G	44	41	45	89	89	89	.092	.087	.099	.169	.169	.174	.016	.033	.038	104950	53330	22.5	41.44	S	5	5	64	27/32	51750	5	5	49	1 7/16	25750	198											●	[illegible]		1
2			"		–	16 6	"		42	43	45	92	91	91	.095	.104	.105	.183	.174	.188	.034	.042	.036	101150	55820	23.0	32.92	—	5	5	69	5/8	55500	5	5	38	1 9/32	21250	212	●										●			2
3	"		Carnegie		–	16 6	L		40	40	42	73	73	72	.097	.095	.102	.056	.066	.059	.022	.024	.027	97995	64750	19.0	38.44	GBS	5	5	54	23/32	44250	5	5	29	1 1/8	16750	192												Soft Much worn		3
4			Ill S W		–	15 0	T		42	42	42	1.03	1.00	99	.096	.094	.092	.197	.207	.197	.040	.039	.030	107850	60000	23.0	42.79	S	5	5	78	9/16	62250	5	5	32	1 1/8	8250	206	●											Hardness low		4
5			Carnegie	1896	–	16 0		"	42	65	44	70	77	68	.088	.183	.108	.103	.094	.103	.010	.033	.043	100120	50860	17.0	30.7	FgBS	5	5	26	3/4	23250	5	5	43	1 1/4	23750	199	●	●									●	Hard in rock [illegible]		5
6	"			"	–	15 10	"		37	36	38	63	64	63	.096	.091	.086	.075	.075	.075	.020	.021	.022	85095	40675	26.75	46.83	S	5	5	82	11/16	65250	—	—	—	—	—	67											●	Soft		6
7			Ill S W	1897	–	14 10			47	48	47	93	95	92	.092	.099	.092	.136	.135	.136	.038	.042	.041	108400	57500	19.25	34.95	FgBS	5	5	55	9/32	45000	5	5	47	1 7/32	25750	212	●										●	Line & surface fair	●	7
8			Carnegie	1898	–	13 9	"	"	54	58	57	1.01	1.02	1.02	.100	.116	.106	.132	.113	.132	.024	.027	.026	123775	60385	12.25	13.9	G	5	5	—	17/32	3750	5	5	45	1 5/32	24750	236			●		●		●				●			8
9	"			"	–	13 9		"	54	49	53	1.03	1.04	1.06	.111	.094	.108	.093	.103	.098	.021	.017	.018	120050	63625	15.75	26.3	FgBS	5	5	43	5/8	36000	5	5	12	1 3/32	8250	24							●			●	●	Flaw Ties fair		9
10	"		"	"	–	13 7	"	"	46	60	50	92	94	92	.096	.160	.104	.094	.094	.094	.021	.047	.027	108550	57295	13.25	6.58	G	5	5	—	17/32	3750	5	5	67	1 1/4	35750	21	●	●			●						●	Line & surface [illegible]		10
11				"	–	13 6			53	49	53	92	94	91	.10	.102	.107	.103	.120	.103	.028	.022	.027	115250	60680	17.5	26.62	FgBS	5	5	33	9/16	28500	5	5	13	1 3/32	8750	226											●	Line & surface fair	●	11
12	"	"	"	"	–	13 2	"		44	41	43	71	72	71	.106	.092	.100	.094	.094	.094	.029	.027	.028	98625	49440	24.5	42.45	S	5	5	43	25/32	36000	—	—	—	—	—	89												Little soft		12
13	"			"	–	12 10	"	"	51	47	50	90	91	90	.103	.098	.104	.118	.118	.118	.021	.019	.019	109800	54720	20.25	33.0	FgBS	5	5	59	5/8	46000	5	5	52	1 7/16	28250	216	●										●	Possible flaw	●	13
14	100	ASCE	"	1906	–	6 Yr. 0 Mo.	L	"	59	57	59	1.10	1.08	1.11	.096	.097	.094	.099	.103	.099	.037	.030	.035	185700	63915	14.75	22.30	"						—	—	—	—	—	217											●	C little high	●	14
15			"	"	–	5 7	T	S	49	48	48	1.25	1.04	1.03	.099	.101	.101	.127	.127	.127	.031	.033	.037	110300	50100	18.75	30.75	"	5	5	54	19/32	44250	5	5	21	1 5/16	2750	241							●				●	Line & surface fair		15
16			"	"	–	5 7	"	"	59	53	58	1.17	1.15	1.17	.103	.094	.099	.118	.118	.118	.031	.023	.029	125050	65410	14.5	20.61	Fg	5	5	66	15/32	53250	5	4	—	1 7/32	1950	240	●		●			●	●				●			16
17			"	"	–	3 0		"	60	63	60	1.19	1.20	1.20	.083	.093	.093	.100	.088	.117	.034	.043	.038	115750	81085	3.25	1.4	Gran	4	—	—	3/8	1000	5	5	1	13/16	2750	256	●		●	●			●							17
18			"	1907	–	4 9			68	63	68	1.51	1.37	1.51	.098	.089	.098	.160	.155	.160	.035	.023	.032	144500	68170	9.5	8.65	"	5	4	—	11/32	3250	5	1	—		1050	275				●			●	●	●		●			18
19			"	"	–	4 8	"	"	59	55	58	1.61	1.52	1.62	.092	.085	.091	.136	.136	.132	.027	.031	.036	134750	73680	12.5	17.70	"	5	5	2	15/32	5250	5	5	16	5/8	10250	261							●				●	Low ductility		19
20				"	–	4 8		"	55	53	54	1.03	1.05	1.04	.096	.086	.094	.137	.118	.103	.035	.033	.035	117100	62420	17.0	27.30	FgBS	5	5	52	9/16	42750	5	5	16	1 5/32	10250	224											●	Flaw		20
21				"	–	4 6	"	G	61	55	57	1.16	1.13	1.14	.102	.095	.099	.047	.052	.052	.041	.037	.04	122950	60690	15.25	25.48	GBS	5	5	17	19/32	16500	5	5	23	1 1/16	18750	235			●					Split base			●	Hardness high		21
22			"	"	–	4 6		"	51	49	50	1.10	1.12	1.12	.096	.088	.092	.080	.106	.080	.037	.028	.032	112400	55610	20.5	36.02	FgBS	5	5	69	5/8	55500	—	—	—	—	—	217								●			●	Split base	●	22
23	"		"	"	–	3 0	"	S	54	47	47	94	91	92	.099	.099	.100	.056	.038	.047	.050	.042	.038	112050	79570	18.25	28.20	GBS	—	—	—	—	—	5	5	35	1"	19750	218	●		●				Considerably worn					Flaw in base		23
24	85	"	"	1899	–	12 Yr. 9 Mo.		G	54	55	53	94	95	92	.103	.114	.103	.150	.132	.150	.024	.028	.022	120500	60950	16.0	22.7	FgBS	5	5	45	5/8	37500	5	5	25		14750	236	●						●				●	Crack in head		24
25	"			"	–	12 9	"	"	54	73	59	69	75	72	.129	.192	.136	.080	.089	.089	.021	.047	.023	116100	63130	10.5	14.0	Fg	5	1	—	9/16	1750	5	5	3	1 9/32	3750	225		●		●			Hard in web				●	Crack in head		25
26	"	"	National	—	–	11 5	L		53	54	53	97	97	98	.101	.101	.102	.108	.108	.106	.030	.029	.030	119750	81125	14.5	27.55	G	5	5	42	19/32	25250	5	5	50	1"	27750	245							●				●	Flat wheel		26
27	"		Carnegie	1900	–	11 3	T		53	57	55	96	97	97	.105	.121	.104	.165	.169	.165	.025	.029	.026	105155	58955	4.5	3.82	Fg	5	5	17		16533	—	—	—	—	—	241			●				●					Low ductility		27
28	"		"	"	–	8 0	"	"	46	42	45	75	74	75	.082	.087	.090	.084	.075	.094	.038	.025	.038	97254	56796	24.0	21.0	S&G	—	—	—	—	—	—	—	—	—	—	185											●	Soft Irregular		28
29	"	"	"	"	–	8 0	"	"	45	61	46	67	74	70	.078	.154	.080	.054	.052	.050	.026	.059	.026	101000	63250	18.0	22.84	"	1	—	—	—	250	—	—	—	—	—	208	●	●			●							Split head		29
30			"	1901	–	7 0		"	55	57	54	99	1.03	1.02	.102	.107	.102	.080	.108	.101	.057	.053	.056	98240	59890	6.75	3.3	G	—	—	—	—	—	—	—	—	—	—	202			●		●					●		Split head		30
31			"	1902	–	10 3		"	54	66	53	1.05	1.08	1.06	.100	.144	.113	.047	.052	.052	.032	.057	.036	99920	65810	4.0	3.18	Fg	5	5	—	1/2"	3750	5	5	34	1 3/32	19250	242	●	●			●		●				●			31
32	"			"	–	10 2	"	"	56	56	57	1.13	1.09	1.09	.114	.118	.115	.080	.071	.071	.035	.035	.036	124190	65795	16.0	25.03	"	5	5	23	9/16	21000	5	5	30	1 11/32	17250	250							●				●			32
33			"	"	–	10 0	H		55	52	54	98	99	99	.103	.097	.100	.113	.118	.118	.041	.035	.038	118650	64210	17.75	27.93	FgBS	5	5	62	9/16	50250	5	5	31	1 1/8	17750	225											●	Split base		33
34	"				–	9 6	T	"	51	45	46	86	87	87	.119	.100	.128	.075	.089	.085	.034	.030	.030	101400	48860	21.5	36.4	S	5	5	49	11/16	40500	5	5	31	1 11/16	17750	200											●	P a little high		34
35					–	9 6	"	"	49	49	49	99	98	97	.117	.115	.119	.042	.052	.042	.057	.057	.054	108300	57140	9.5	35.83	FgBS	5	5	53	1/2"	43500	5	5	26	1 7/16	15250	217											●	P a little high		35
36				"	–	9 6		"	53	53	52	88	90	88	.114	.120	.118	.075	.076	.061	.070	.061	.073	110880	60920	15.0	23.1	G	5	5	44	21/32	36750	5	5	44	1"	24250	223	●										●	P & S high		36
37			"	"	–	9 4	H		53	49	50	82	83	83	.105	.084	.102	.071	.080	.071	.034	.032	.034	113335	59370	18.75	29.7	G&S	5	5	22	9/16	20250	5	5	28	1 5/32	16250	222												Flaw		37
38			"	"	–	9 4	T	—	49	50	50	69	70	70	.104	.109	.107	.066	.068	.066	.045	.052	.048	106425	51270	18.5	26.3	Fg.	5	5	9	5/8	10500	5	5	28	1 5/16	16250	213													●	38
39	"		"	"	–	9 4		G	51	49	52	99	99	98	.126	.125	.123	.108	.108	.107	.030	.027	.030	114500	59415	19.0	30.4	FgBS	5	5	55	5/8"	45000	5	5	43	1 3/32	23750	220									●		●	P high		39
40	"		"	"	–	9 4	"	"	63	63	61	1.10	1.10	1.12	.120	.125	.119	.061	.061	.071	.050	.052	.050	134250	67860	13.75	19.39	Fg	3	—	—	1/2	750	5	5	7	1 3/16	5750	251	●				●		●				●	Flaw Struc poor		40
41					–	9 4	"		56	62	57	1.08	1.10	[illegible]	[illegible]	.137	.144	.036	.035	.061	.049	.063	.053	94310	61500	2.5	2.3	"	4	—	—	9/16	1000	—	—	—	—	—	242	●		●	●			●				●	Flaw		41

SBURGH

Broken Rails

p. 2"x1" ccumul. oot lbs.	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed											Material Fair	Reference Numbers
			Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Steel Pres.	Frozen Road bed	Miscellaneous		
			Badly	Somewhat		in Head	in Web								
6250	246	●						●				●	C. high		42
1350	233		●		●			●					Crack in head		43
600	226		●				●				●	●	Hard in web		44
7250	252	●	●					●				●	Ductility low		45
28250	206											●	C. high		46
4750	219									Ties	fair		Line & surface fair	●	47
6750	265						●	●				●			48
20750	235			●								●	Split base		49
11750	237								●			●	Hard in web		50
—	268		●		●			●					Split head		51
—	207					●				Ties	fair	●	Line & surface fair		52
18250	208												Hard spot on head	●	53
21750	243	●	●					●				●	C. & S. high		54
19250	250	●		●				●					Split base		55
1350	269			●	●			●		Split	head	●	C., P. & S. high		56
31250	237											●		●	57
5250	220	●		●						C. high			Defect in head		58
—	179	●										●	Soft. Abnormal		59
15750	218											●	Line & surface fair	●	60
12250	263							●				●	Split base		61
6250	251			●		●		●				●	Line & surface fair		62
12750	246	●						●	●	Ties	fair	●	Line & surface fair		63
—	271							●				●	Ductility low		64
22250	236									Split	base	●	Line & surface fair	●	65
3250	260							●				●	Line & surface fair		66
23250	238		●									●	Hard in web		67
9750	235	●										●	Weber joint	●	68
24250	249					●		●				●			69
	258							●				●	Two breaks		70
3250	259					●		●					Line & surface fair		71
—	222				●							●			72
20750	246							●		Ties	bad		Line & surface fair		73
9250	232											●	Line & surface fair	●	74
1950	194											●	Split base	●	75
21250	228											●	Split base	●	76
2750	256			●	●			●				●	Split base		77
6250	249							●				●			78
17750	239			●			Little hard			Split	base	●	Line & surface fair		79
18750	235									Split	base	●	Line & surface fair	●	80
12750	231											●		●	81
4250	298							●		Ties	fair	●	C. & Mn. high		82

Sheet 3

PENNSYLVANIA LINES WEST OF PITTSBURGH
STUDY OF RAIL FAILURES IN MAIN TRACKS

Bessemer Process

March – 1913

Broken Rails

Reference Number	Wt of Rail Lbs. Yd.	Rail Section	Manufacturer	Year of Rolling	Position in Ingot	Years in Service		Position on Tangent or Curve	Ballast	Chemical Analysis of Rail: Carbon Head	Carbon Web	Carbon Base	Manganese Head	Manganese Web	Manganese Base	Phosphorus Head	Phosphorus Web	Phosphorus Base	Silicon Head	Silicon Web	Silicon Base	Sulphur Head	Sulphur Web	Sulphur Base	Tensile Strength Lbs per Sq In	Elastic Limit Lbs per Sq In	Elongation in 2 inches	Reduction of Area	Character of Fracture	Drop Test – Supports 2' apart – 50 Lb Tup: Test Piece at D, Blows at 5 Ft	10 Ft	15 Ft	Total Deflec.	Accum. Foot Lbs	Test Piece at E, Blows at 3 Ft	6 Ft	9 Ft	Total Deflec.	Accum. Foot Lbs	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed: Segregated Badly	Segregated Somewhat	Very Brittle	Somewhat Brittle in Head	Somewhat Brittle in Web	Hard	Rolling Seam	Slag Present	Foreign Steel	Frozen Road bed	Miscellaneous	Material Fair	Reference Numbers
42	85	A.S.C.E.	Carnegie	1902	–	9 Yr	4 Mo	L	G	60	59	58	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	96600	60455	3.5	18.47	Fg	5	5	4	7/8	14500	5	5	8	15/16	6250	246	●						●				●	C high		42
43				1903	–	8	1			53	87	60	1.00	1.6	1.03	.064	.260	.14	.035	.075	.075	0.8	.068	.026	115450	59395	6.75	6.25	G	2	–	–	9/16	500	5	2	–	1 1/8	1350	233		●		●			●					Crack in head		43
44					–	8	11			5.	67	5.	.93	.95	.9	.03	.454	.1	.07	.07	.07	.25	.229	.016	116900	62860	0.0	.20		5	5	27	24/32	24000	4	–	–	1 1/2	600	226		●				●				●	●	Hard in web		44
45					–	8	10			53	60	55	1.08	1.8	1.12	.10	.19	.17	.22	.136	.41	.249	.371	.052	123450	65830	8.0	19.7	Fg	5	5	4	5/8	14250	5	5	30	1 5/32	17250	252	●	●					●				●	Ductility low		45
46					–	8	7			60	55	56	.74	.74	.74	.089	.080	.082	.061	.06	.061	.024	.029	.031	108500	55400	18.75	30.9	Fg B.S.	5	5	55	19/32	45000	5	5	52	1 1/8	28250	206											●	C high		46
47					–	8	7			54	50	55	.90	.89	.91	.104	.1	.11	.07	.075	.075	.027	.035	.026	114650	56560	19.25	30.2		5	5	52	1/2	42750	5	5	25	1 1/32	14750	219									Ties fair			Line & surface fair	●	47
48					–	8	5	H		58	55	59	1.2	1.10	1.12	.01	.086	.105	.18	.18	.18	.034	.036	.034	127560	65210	15.0	22.5	Fg	5	5	45	9/16	37500	5	5	9	1 3/16	6750	265						●	●				●			48
49			Cambria		–	8	4	T	G	51	57	54	1.14	1.16	1.15	.103	.121	.110	.075	.075	.075	.050	.063	.051	124000	63335	16.25	25.28	Fg B-S	5	5	36	9/16	33750	5	5	37	1 1/4	20750	235			●								●	Split base		49
50			Carnegie		–	7	11			53	51	52	1.15	1.15	1.15	.101	.090	.097	.118	.122	.122	.030	.027	.028	120000	64920	18.25	29.34		5	5	71	1/2	57000	5	5	19	1 1/32	11750	237								●			●	Hard in web		50
51					–	6	0			60	75	62	.89	.97	.91	.086	.15	.097	.103	.103	.101	.020	.037	.021	101150	74550	3.75	2.67	G	5	1	–	7/16	1750	–	–	–	–	–	268		●		●			●					Split head		51
52			Ill S W	1904	–	8	2			50	47	49	.88	.90	.89	.093	.084	.092	.034	.085	.085	.050	.049	.05	105535	52115	20.75	34.53	Fg B S	5	3	–	19/32	2750	–	–	–	–	–	207					●				Ties fair		●	Line & surface fair		52
53			Carnegie		–	8	0			47	44	48	.82	.83	.83	.096	.086	.086	.07	.075	.075	.041	.037	.041	102250	50025	21.0	36.68		5	5	39	9/16	33000	5	5	22	1 5/8	8250	208												Hard spot on head	●	53
54					–	8	0			57	62	57	.94	.96	.94	.04	.24	.106	.07	.05	.106	.050	.073	.059	120500	63585	6.5	11.6	G	5	5	57	9/16	46500	5	5	39	1 1/8	21750	243	●	●					●				●	C & S high		54
55					–	7	9	L		59	63	62	1.17	1.4	1.18	.107	.113	.112	.122	.122	.122	.037	.041	.038	133800	71105	12.5	17.98	Fg B-S	5	5	9	7/16	10500	5	5	34	1 1/32	9250	250	●		●				●					Split base		55
56					–	7	8	"	"	68	72	60	1.32	1.34	1.23	.32	.139	.098	.108	.108	.111	.13	.121	.083	127200	68790	6.75	6.8	G	4	–	–	1/2	1000	5	1	0		1350	269			●	●			●		Split head		●	C P & S high		56
57					–	7	6	T		56	55	56	1.10	1.13	1.12	.088	.089	.087	.119	.113	.113	.028	.023	.030	123400	65105	17.0	20.79	Fg B S	5	5	86	5/8	68250	5	5	58	1 1/16	31250	237											●		●	57
58					–	7	2		–	57	61	56	.85	.88	.85	.088	.102	.087	.089	.089	.085	.027	.040	.037	118300	59790	15.25	23.22	"	5	3	–	7/32	2750	5	5	6	1 1/32	5250	220	●		●						C high			Defect in head		58
59			"		–	5	0			55	54	57	.90	.90	.91	.089	.096	.096	.111	.094	.105	.054	.052	.053	96845	30804	24.0	20.0	G	5	5	46	7/32	38250	–	–	–	–	–	179	●										●	Soft Abnormal		59
60			Ill S W		–	0	1			50	47	50	.98	.95	.97	.103	.097	.101	.136	.127	.136	.056	.048	.051	105855	54010	19.0	33.7	S	5	5	39	5/8	33000	5	5	27	1 3/16	15750	218											●	Line & surface fair	●	60
61			Carnegie	1905	–	6	9			63	61	63	1.35	1.31	1.31	.092	.085	.093	.18	.41	.146	.044	.041	.043	134550	79900	12.0	21.8	Fg	5	5	33	7/8	28500	5	5	20	1	12250	263							●				●	Split base		61
62					–	6	9			59	61	61	1.09	1.09	1.09	.10	.106	.107	.113	.108	.113	.024	.020	.025	122650	57750	5.5	6.11	G	5	3	–	9/16	2750	5	5	28	7/32	16250	251			●		●		●				●	Line & surface fair		62
63					–	6	8		S	58	58	62	1.07	1.06	1.07	.085	.094	.101	.132	.132	.132	.029	.032	.028	125650	60250	18.5	31.0	Fg B S	5	5	39	19/32	33000	5	5	21	31/32	12750	246	●						●	●	Ties fair		●	Line & surface fair		63
64					–	6	8		G	65	67	66	1.20	1.21	1.21	.092	.087	.087	.099	.094	.103	.038	.044	.035	136025	77320	8.0	11.8	G	5	5	12	1/2	12750	–	–	–	–	–	271							●				●	Ductility low		64
65					–	6	5			52	52	54	1.05	1.04	1.04	.096	.084	.089	.113	.118	.092	.034	.029	.034	115460	54740	17.0	31.7	Fg B S	5	5	52	19/32	42750	5	5	40	1 3/16	22250	236									Split base		●	Line & surface fair	●	65
66					–	6	4	H		61	60	61	1.06	1.09	1.06	.102	.092	.093	.098	.27	.27	.027	.023	.028	128590	70210	12.0	22.8		5	5	44	19/32	36750	5	5	22	1 1/32	19250	260							●				●	Line & surface fair		66
67					–	6	4	T		58	65	59	1.10	1.10	1.08	.094	.121	.098	.085	.085	.085	.046	.061	.043	126000	64385	13.0	15.56	Fg	5	5	53		48000	5	5	42	1 5/8	23250	238		●									●	Hard in web		67
68					–	6	3			55	55	55	.93	.93	.91	.098	.093	.093	.061	.064	.066	.024	.025	.024	118800	62715	15.25	28.35	G B S	5	5	45	1/2	37500	5	5	15	1 1/32	9750	235	●										●	Weber joint	●	68
69					–	6	3			56	53	55	1.17	1.20	1.19	.094	.086	.093	.073	.085	.085	.041	.035	.035	120970	61940	16.0	28.8	Fg B S	5	3	–	9/16	2750	5	5	44	1 1/8	24250	249					●		●				●			69
70					–	6	3			62	60	63	1.11	1.11	1.09	.094	.093	.096	.094	.094	.089	.030	.032	.032	129450	64630	15.5	21.85	"	5	5	38		41250						258							●				●	Two breaks		70
71					–	6	2	H	S	64	62	64	1.22	1.20	1.20	.097	.098	.096	.095	.094	.094	.043	.038	.037	128100	65580	11.0	14.92	Fg	5	3	–	7/16	2750	5	5	42	7/8	23250	259					●		●					Line & surface bad		71
72					–	6	2	T	G	62	64	60	1.15	1.15	1.14	.107	.113	.115	.075	.082	.066	.040	.051	.038	118900	62610	5.0	3.82	G	5	3	–	1/2	2750	–	–	–	–	–	222				●							●			72
73					–	6	0			58	57	59	1.22	1.20	1.22	.091	.082	.088	.089	.085	.089	.040	.037	.035	131100	71310	14.25	21.6	G B S	5	5	14	1/2	14250	5	5	27	7/8	20750	246							●		Ties bad			Line & surface fair		73
74				1906	–	6	0	H	"	55	53	54	1.20	1.19	1.20	.093	.094	.093	.13	.108	.108	.034	.037	.038	118900	62200	17.25	28.67	Fg B S	5	5	68	17/32	54750	5	5	14	1 1/32	9250	232											●	Line & surface fair	●	74
75					–	6	0			54	49	52	.98	1.01	.99	.096	.081	.090	.08	.136	.108	.037	.029	.036	110800	56520	18.25	30.63		5	5	64	9/16	51750	5	4	–	1 1/4	950	194											●	Split base	●	75
76					–	6	0	T		56	55	58	1.05	1.05	1.05	.103	.095	.102	.071	.071	.068	.050	.048	.052	12.850	58480	15.75	24.87	G B S	5	5	75	3/8	60000	5	5	38	13/32	21250	228											●	Split base	●	76
77					–	6	0	L		63	62	62	1.09	1.06	1.10	.102	.118	.099	.118	.122	.108	.041	.051	.039	121050	64290	6.0	6.12	G	5	3	–	9/16	2750	5	5	1	1 1/8	2750	256			●	●			●				●	Split base		77
78					–	6	0	T		63	57	61	1.10	1.12	1.10	.106	.097	.109	.122	.122	.123	.034	.034	.037	129800	66500	16.0	24.8	Fg B S	5	5	45	9/16	37500	5	5	28	1 1/8	16250	249							●				●			78
79					–	6	0	L		56	52	56	1.05	1.04	1.05	.104	.102	.098	.108	.113	.103	.035	.035	.035	120500	62040	18.0	28.44	"	5	5	28	17/32	22250	5	5	31	1 3/16	17750	239			●			Little hard			Split base		●	Line & surface fair		79
80					–	6	0			54	50	51	1.02	1.02	1.01	.104	.102	.102	.136	.127	.135	.035	.031	.033	116800	62390	18.5	30.22	"	5	5	67	9/16	64000	5	5	33	1	18750	235									Split base		●	Line & surface fair	●	80
81					–	5	11	T		55	48	53	.98	.96	.98	.088	.087	.088	.108	.108	.108	.034	.034	.029	117850	70340	17.0	27.1	"	5	5	41	5/8	34500	5	5	21	1 7/32	12750	231											●		●	81
82					–	5	11			69	68	70	1.36	1.39	1.37	.088	.088	.082	.141	.146	.146	.025	.021	.025	145010	70630	10.0	14.9	Fg	5	5	22	7/16	20250	5	5	4	1 1/16	4250	298							●		Ties fair		●	C & Mn high		82

BURGH

Sheet 4

Broken Rails

" .	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed												Material Fair	Reference Numbers
ul. bs.			Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Steel Pres.	Frozen Road bed	Broken Wheel	Miscellaneous		
			Badly	Somewhat		in Head	in Web									
	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	
50	243							●				●		C.high		83
50	251							●				●		C.high		84
50	239											●		Little hard		85
50	222											●		Split base	●	86
50	227									Split base		●		Line & surface fair	●	87
50	217											●			●	88
0	249						●	●				●				89
	257							●				●		Crack in head		90
50	255		●		●			●		Ties fair		●		Line & surface fair		91
50	241							●				●				92
50	248						●	●				●				93
0	270						●	●	Possible flaw			●		C & Mn. high		94
50	240											●		Somewhat hard	●	95
50	262							●				●			●	96
50	251						●	●				●		Split base		97
0	256							●				●				98
50	224							Split base. Ties poor						Line & surface fair	●	99
0	275						●	●	2 breaks. Ties fair			●		Line & surface fair		100
50	255							●	Ties fair			●		Line & surface fair		101
0	279					●		●				●				102
50	241											●		Somewhat hard		103
0	222								●			●		Defect in head		104
50	259							●	S. rather high			●		Ductility low		105
50	218			●		●		Hardness irregular				●		Considerably worn		106
50	267							●				●				107
0	255							●	●			●				108
50	241							●	Broken base			●		S. rather high		109
50	246							●	●			●	●			110
50	233											●	●		●	111
50	206											●		Split base	●	112
50	212											●	●		●	113
50	208											●	●	Hardness low	●	114
0	222											●	●		●	115
0	236					●						●	●	Somewhat hard		116
0	208											●	●	Hardness low	●	117
0	203								2 breaks			●	●	Hardness low	●	118
0	226											●	●		●	119
0	205											●	●	Hardness low	●	120
0	242							●				●		Split base		121
2	261	●				●	●	●				●				122
	257							●				●				123

Sheet 4

PENNSYLVANIA LINES WEST OF PITTSBURGH
STUDY OF RAIL FAILURES IN MAIN TRACKS

Bessemer Process

March - 1913

Broken Rails

Reference Number	Wt of Rail Lbs. per Yd	Rail Section	Manufacturer	Year of Rolling	Position of Rail in Ingot	Years in Service	High or Low Rail on Tangent	Ballast	Chemical Analysis of Rail: Carbon Head	Carbon Web	Carbon Base	Manganese Head	Manganese Web	Manganese Base	Phosphorus Head	Phosphorus Web	Phosphorus Base	Silicon Head	Silicon Web	Silicon Base	Sulphur Head	Sulphur Web	Sulphur Base	Tensile Strength Lbs per Sq In	Elastic Limit Lbs per Sq In	Elongation Percent in 2 Inches	Reduction of Area in Percent of Original Section	Character of Fracture	Drop Test - Supports 12" apart - 50 lb. Tup: Test Piece at D: Blows at 5 Ft	10 Ft	15 Ft	Initial Deflection	Accumul. Foot Lbs	Test Piece at E: Blows at 3 Ft	6 Ft	10 Ft	Initial Deflection	Accumul. Foot Lbs	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed: Segregated Badly	Segregated Somewhat	Very Brittle	Somewhat Brittle in Head	Somewhat Brittle in Web	Hard	Rolling Seam	Slag Present	Foreign Substances	Frozen Road Bed	Broken Wheel	Miscellaneous	Material Fair	Reference Numbers
83	85	ASCE	Carnegie	1906	–	5 Yr 11 Mo	T	G	62	59	61	109	111	110	.096	.096	.092	.11	.118	.118	.026	.025	.025	126600	61830	130	2474	G&S	5	5	28	23/32	29750	5	5	31	1 1/16	27750	243							●				●		C high		83
84					–	5 10 "	"	"	60	60	60	109	109	110	.09	.089	.092	.132	.136	.139	.036	.035	.034	125700	67975	1475	266		5	5	50	1/2"	41250	5	5	30	1"	17250	251							●				●		C high		84
85					–	5 10 "			55	54	56	111	113	110	.101	.094	.091	.130	.165	.124	.033	.042	.041	117500	60100	160	310	Fg&S	5	5	39	9/16	33000	5	5	30	1 3/16	17250	239											●		Little hard		85
86			Cambria	"	–	5 10 "	L		49	44	50	93	91	93	.090	.087	.094	.071	.071	.071	.038	.032	.037	115750	61605	.90	3077	"	5	5	65	7/8"	52500	5	5	41	1 1/8	22250	222											●		Split base	●	86
87			"	"	–	5 10 "	H		54	51	55	95	95	96	.101	.097	.094	.033	.038	.038	.060	.057	.060	121200	58230	175	2742		5	5	65	1/2	52500	5	5	24	1 1/2"	14250	227									Split base		●		Line & surface fair	●	87
88			Carnegie		–	5 9 "	T	"	54	51	50	102	102	101	.084	.086	.091	.096	.13	.098	.040	.036	.039	109600	56215	200	3316	"	5	5	57	5/8"	46500	5	5	25	1 1/4"	14750	217											●			●	88
89					–	5 8			56	57	59	93	93	94	.102	[illegible]	.101	.098	.094	.107	.035	.035	.035	122700	63595	155	2442		5	5	4	1/2"	6750	1	—	—	—	150	249						●	●				●				89
90				1905	–	5 8 "	H	"	59	59	59	113	112	112	.103	.107	.106	.118	.103	.113	.032	.032	.031	125240	63820	150	238	Fg	5	5	39	7/32	33000	—	—	—	—	—	257							●				●		Crack in head		90
91	"	"		1906	–	5 8 "	T	"	55	68	56	106	112	106	.079	.129	.083	.118	.118	.118	.024	.046	.027	103630	62690	30	51	G	3	—	—	9/16"	750	5	5	13	1 1/2"	8750	255		●		●			●		Ties fair		●		Line & surface fair		91
92	"	"	"	"	–	5 6 "	"		62	59	59	107	107	106	.100	.094	.098	.118	.118	.113	.036	.035	.041	127050	63575	155	2335	Fg&S	5	5	44	1/2"	36750	5	5	32	21/32	18250	24							●				●				92
93	"				–	5 6 "	"	"	59	55	59	95	97	99	.089	.085	.082	.132	.127	.127	.031	.025	.031	126250	51940	140	253	"	5	5	38		32250	1	—	—	—	150	248						●	●				●				93
94					–	5 6 "			64	62	62	126	128	127	.100	.094	.097	.122	.113	.123	.046	.049	.042	130750	68230	150	2024	Fg	5	5	2	1/2"	5250	5	1	—	15/16	1050	270						●	●	Possible flaw			●		C & Mn high		94
95	"		"		–	5 6 "	L	"	56	54	57	114	118	114	.100	.089	.104	.113	.113	.115	.038	.038	.038	119830	60510	170	2905	Fg&S	5	5	47	9/16	39000	5	5	28	1 1/16"	16250	240											●		Somewhat hard	●	95
96			"		–	5 5 "	T	"	61	60	61	115	116	116	.097	.092	.089	.099	.106	.108	.044	.042	.044	126900	66180	1475	2325	G	5	5	45	1/2	37500	5	5	27	1 1/16	15750	262							●				●			●	96
97			"		–	5 5 "	"	"	58	57	63	105	107	107	.083	.077	.085	.132	.136	.127	.047	.041	.046	122330	60310	160	281	Fg&S	5	5	41	13/32	34500	5	2	—	1 1/8"	1350	251						●	●				●		Split base		97
98			"	"	–	5 5 "	"	"	60	59	61	132	134	134	.096	.093	.093	.132	.122	.118	.051	.044	.044	127500	64795	155	279		5	5	40	1/2	33750	5	5	18	1 1/16	11250	256							●				●				98
99	"			"	–	5 4 "	"	"	57	52	56	108	109	107	.093	.091	.096	.106	.132	.103	.033	.029	.030	119500	60130	175	307	"	5	5	57	9/16	46500	5	5	38	[illegible]	21250	224							Split base	Ties poor					Line & surface fair	●	99
100			"		–	5 4 "	L	"	63	60	63	119	122	119	.085	.076	.089	.122	.122	.118	.035	.034	.033	134560	66940	130	198	G	5	5	38	1/2"	32250	5	1	—	7/8	1050	275						●	●	2 breaks Ties fair			●		Line & surface fair		100
101		"			–	5 3	T		64	60	65	107	118	107	.056	.087	.096	.122	.127	.122	.037	.034	.033	129125	65990	1425	226	G&S	5	5	44	15/32	35750	5	5	44	1"	24250	255							●	Ties fair			●		Line & surface fair		101
102	"		"		–	5 3 "	"	"	63	60	63	146	147	137	.093	.084	.092	.075	.085	.075	.032	.034	.032	95950	48320	.40	171	Fg	3	—	—	5/8"	750	5	5	19	9/16	11750	279					●		●				●				102
103					–	5 1 "		"	58	55	61	120	120	123	.096	.086	.092	.103	.103	.103	.049	.051	.050	122400	62005	160	2765	Fg&S	5	5	73	1/2	58500	5	5	34	1 1/8	19250	241											●		Somewhat hard		103
104	"				–	5 1 "	"	"	62	60	62	94	93	92	.098	.086	.096	.080	.078	.080	.044	.035	.045	122200	60800	155	2162	"	5	5	58	1/2	47250	5	5	39	1 3/16	21750	222								●			●		Defect in head		104
105	"		"	1907	–	5 0 "			61	61	61	113	112	113	.103	.111	.105	.075	.078	.075	.054	.064	.050	129160	67380	90	119	Fg	5	5	43	17/32	36000	5	5	4	1 5/16	4250	259							●	S rather high			●		Ductility low		105
106					–	4 10 "	L		49	53	49	79	81	79	.106	.126	.104	.047	.047	.047	.037	.041	.038	105550	68990	35	458		5	1	—	5/8	1750	5	5	36	1 9/32	20250	218			●		●			Hardness irregular			●		Considerably worn		106
107				"	–	4 10 "	T	"	63	58	61	130	133	135	.098	.087	.092	.118	.120	.120	.036	.034	.035	128255	71955	130	271	G&S	5	5	46	15/32	38250	5	5	22	29/32	13250	267							●				●				107
108					–	4 10 "	"		58	56	56	118	115	118	.137	.107	.125	.094	.094	.094	.043	.043	.042	12 550	61810	1775	2755	Fg&S	5	5	30	9/16	26250	5	5	3	1 7/32	3750	255							●	●			●				108
109			–		–	4 9 "	"	"	61	57	58	117	125	123	.095	.089	.091	.146	.165	.146	.061	.057	.060	127150	64760	1575	2783	"	5	5	67	7/16"	54500	5	5	33	1 1/32	18750	241							●	Broken base			●		S rather high		109
110		"	"	"	–	4 9	"	"	59	58	59	107	109	108	.10	.098	.100	.107	.113	.103	.039	.038	.037	127750	64450	1575	2382		5	5	49	13/32	40500	5	5	20	1 1/8	2250	246							●	●			●	●			110
111	"				–	4 9 "	"		54	55	54	85	85	87	.107	.109	.110	.085	.085	.094	.033	.041	.034	116270	59860	1725	2704	"	5	5	38		33000	5	5	37	1 1/16	20250	233											●	●		●	111
112			"		–	4 9	"	"	55	54	54	88	86	88	.113	.106	.094	.075	.075	.080	.029	.049	.039	117650	58710	180	2802	"	5	5	17	17/32	16500	5	5	13	1 1/4"	8750	206											●		Split base	●	112
113	"		"		–	4 9 "	"	"	50	48	51	87	89	88	.100	.092	.109	.066	.071	.071	.035	.035	.037	106700	54460	210	3227	"	5	5	17	9/16	16500	5	5	32	1 3/16	18250	212											●	●		●	113
114	"		"		–	4 9 "	"		50	48	51	90	91	89	.096	.088	.090	.080	.094	.080	.026	.027	.026	107450	53000	2125	3329	S	5	5	11	4/16	12000	5	5	49	1 5/32	26750	208											●	●	Hardness low	●	114
115	"		"	"	–	4 9 "	"		54	52	54	92	91	92	.100	.100	.097	.108	.108	.103	.028	.029	.024	115800	57750	192	3163	Fg&S	5	5	42	3/4"	35250	5	5	27	1 3/16	15750	222											●	●		●	115
116		"			–	4 9 "	"		57	60	60	101	102	102	.109	.107	.106	.099	.094	.108	.034	.036	.033	123600	61990	160	241	Fg	5	5	—	17/32	3750	5	5	19	1 1/16	11750	236					●						●	●	Somewhat hard		116
117	"	"	"	"	–	4 9 "	"	"	48	48	52	84	84	83	.103	.102	.097	.085	.075	.075	.044	.045	.041	103900	50360	210	349	Fg&S	5	5	48	5/8"	39750	5	5	18	1 1/16	11250	208											●	●	Hardness low	●	117
118	"				–	4 9 "	"		51	50	51	80	78	79	.103	.109	.106	.098	.099	.103	.042	.038	.04	110400	54300	195	2885		5	5	30	7/16"	26250	5	5	18	1 5/16	11250	203									2 breaks		●	●	Hardness low	●	118
119	"		"		–	4 9 "	"		54	52	55	92	94	93	.089	.084	.091	.101	.120	.122	.027	.027	.029	115025	57550	1625	2855	"	5	5	5		7500	5	5	21	15/16	12750	226											●	●		●	119
120			"		–	4 9		"	53	52	54	96	95	97	.102	.098	.107	.103	.094	.094	.046	.043	.044	116400	60280	165	274	"	5	5	53	13/16	43500	5	5	30	1 1/8"	17250	203											●	●	Hardness low	●	120
121		"	"		–	4 8	"	"	63	59	63	121	123	123	.101	.096	.103	.108	.118	.113	.041	.038	.043	126250	66280	150	2449	Fg	5	5	19	7/16	18000	5	5	59	13/16	31750	242							●				●		Split base		121
122		"	"		–	4 7 "	L	"	63	61	62	117	117	117	.106	.087	.102	.099	.099	.099	.047	.054	.044	132480	66710	110	165	"	5	1	—	5/16"	1750	5	5	7	1"	5750	25	●				●	●	●				●				122
123					–	4 6 "	T		62	60	60	115	115	113	.113	.107	.111	.094	.089	.094	.038	.036	.035	129450	65565	150	2245	"	5	5	41	1/2"	34500	—	—	—	—	—	257							●				●				123

Broken Rails

"x1" cumul. tal Lbs. 39	Brinell Hardness 40	In Joint 41	Defects in Quality of Material and Road Bed: Segregated Badly 42	Segregated Somewhat 43	Very Brittle 44	Somewhat Brittle in Head 45	Somewhat Brittle in Web 46	Hard 47	Rolling Seam 48	Slag Present 49	Foreign Steel Pres. 50	Frozen Road bed 51	Miscellaneous 52	Material Fair 53	Reference Numbers 54
1730	232								●	Ties	poor	●	Line & surface poor	●	124
20750	257	●						●				●		●	125
7750	234											●	Split base	●	126
2750	241					●		●				●	Broken base		127
7750	230											●		●	128
250	255					●	●	●				●			129
9750	222											●	Broken base	●	130
2250	210				Broken wheel				●			●	Split base		131
5750	228	●		●		●							Hard in neck		132
9250	213	●										●	Line & surface fair	●	133
5750	216											●		●	134
4250	229											●		●	135
78250	235	●	●									●	Hard in web		136
9750	231								Split base			●	Hard in head	●	137
4750	222	●												●	138
3750	255	●		●		●	●	●				little			139
—	250							●			●		Mn & S. high		140
7750	273	●	●			●	●	●					S. high		141
5750	219	●											Line & surface fair	●	142
—	224													●	143
6750	231	●	●			●							Hard in neck		144
5250	225								●				Line & surface fair	●	145
2250	231						●						Split base		146
4750	227												Split base	●	147
9250	237	●										●	Somewhat hard		148
7250	232								Split base			●	Line & surface fair		149
7750	231											●	S. somewhat high		150
350	217								Split base			●	Line & surface fair	●	151
0750	227											●	Broken wheel	●	152
8250	242	●	●			●		●				●	Surface poor		153
2250	255		●					●					Hardness irreg		154
5750	257					●		●							155
1250	211								●			●		●	156
—	220	●		●						●		.	Flaw. S. high		157
6750	206	●	●										Mn & S high in web		158
—	223			●											159
4250	209												Line & surface fair	●	160
0750	239							Broken wheel				●	Somewhat hard		161
3750	214					Broken base. Ties fair						●	Line & surface fair	●	162
3750	237	●	●			●						●	Very hard in neck		163
7250	259					●		●				little			164

PENNSYLVANIA LINES WEST OF PITTSBURGH

STUDY OF RAIL FAILURES IN MAIN TRACKS

Sheet 5

Bessemer Process

March-1913

Broken Rails

Reference Number	Wt of Rail Lbs. Yd	Rail Section	Manufacturer	Year of Rolling	Position in Ingot	Years in Service	[illegible] or Tangent	Ballast	Carbon Head	Carbon Web	Carbon Base	Manganese Head	Manganese Web	Manganese Base	Phosphorus Head	Phosphorus Web	Phosphorus Base	Silicon Head	Silicon Web	Silicon Base	Sulphur Head	Sulphur Web	Sulphur Base	Tensile Strength Lbs per Sq In	Elastic Limit Lbs per Sq In	Elongation Percent in 2 inches	Reduction of Area Per cent of Original	Character of Fracture	Test Piece at D Blows at 5 Ft	Test Piece at D Blows at 10 Ft	Test Piece at D Blows at 15 Ft	Test Piece at D Total Deflec	Test Piece at D Accum Foot Lbs	Test Piece at E Blows at 3 Ft	Test Piece at E Blows at 6 Ft	Test Piece at E Blows at 10 Ft	Test Piece at E Total Deflec	Test Piece at E Accum Foot Lbs	Brinell Hardness	In Ingot	Segregated Badly	Segregated Somewhat	Very Brittle	Somewhat Brittle in Head	Somewhat Brittle in Web	Hard	Rolling Seam	Slag Present	Foreign Steel Present	Frozen Road Bed	Miscellaneous	Material Fair	Reference Number
124	85	ASCE	Carnegie	1907	–	4 Yr 5 Mo	T	G	57	52	36	1.38	1.39	1.38	.109	.110	.111	.089	.094	.089	.035	.029	.035	125700	63490	17.0	28.15	Fg&S	5	5	50	9/32	47250	5	5	59	1 9/32	31750	232								●	Ties poor		●	Line & surface poor	●	124
125					–	4 4	L		59	58	60	1.17	1.15	1.18	.117	.103		.101	.101	.099	.036	.033	.035	32050	83520	10.5	15.7	G	5	5	33		33000	5	5	37	23/32	20750	257	●						●				●		●	125
126					–	4 4	H		56	55	56	1.09	1.06	1.09	.094	.085	.097	.075	.07	.075	.032	.040	.047	20700	63900	6.5	26.61	Fg&S	5	5	72		57750	5	5	31	1 1/16	750	234											●	Split base	●	126
127					–	4 3	T		54	50	52	1.06	1.05	1.08	.120	.112		.064	.066	.069	.050	.044	.049	6795	80570	5.25	29.0	G	5	5	2	9/32	5250	5	5	4	1 1/16	22750	24					●		●				●	Broken base		127
128					–	4 3	H		57	53	55	1.01	.99	1.00	.098	.087	.097	.066	.06	.07	.037	.03	.05	15750	62230	6.0	30.8	G&S	5	5	49	7/32	40500	5	5	51	7/8	27750	230											●		●	128
129					–	4 3			58	60	58	1.00	1.01	1.00	.098	.10	.092	.06	.06	.06	.05	.066	.050	2980	60970	2.0	5.5	Fg&S	5	2	–	9/16	2250	5	5	8	1 3/16	6250	255					●	●	●				●			129
130					–	4 2	T		55	52	53	1.03	1.05	1.05	.107	.093	.103	.066	.07	.066	.029	.030	.035	6800	57985	20.5	28.47		5	5	65	5/8	52500	5	5	35		9750	222											●	Broken base	●	130
131	100	PS		1909	CC	2 Yr 10 Mo			50	50	51	1.03	1.08	1.10	.086	.090	.098	.141	.146	.146	.035	.035	.035	5.50	6070	19.25	30.73		5	5	86	9/16	68250	5	5	20	1/4	12250	210				Broken in Heel				●			●	Split base		131
132					BB	2 9			57	59	55	.90	.93	.90	.12	.133	.121	.122	.14	.122	.028	.035	.043	19250	57865	3.25	7.57	G	5	5		9/32	4500	5	5	47	1 5/32	25750	228	●		●		●							Hard in neck		132
133					B	2 1		S	49	47	49	1.05	1.06	.03	.093	.093	.093	.13	.38	.13	.029	.03	.035	1350	57855	20.5	31.88	Fg&S	5	5	70	5/8	56250	5	5	34	7/8	9250	2 3	●										●	Line & surface fair	●	133
134					C	2 1	H		47	46	48	.99	1.00	.99	.101	.098	.103	.14	.146	.146	.045	.042	.047	58300	59240	21.5	33.96		5	5	82	9/32	65250	5	5	27	7/8	5750	26											●		●	134
135					C	2 0			53	49	52	1.12	1.13	1.13	.1	.098	.102	.122	.127	.122	.042	.045	.043	8900	64055	17.25	29.77		5	5	66	9/16	51250	5	5	24	1 5/32	4250	229											●		●	135
136					C	2 0	T		61	72	63	1.08	1.13	1.10	.101	.145	.12	.13	.13	.13	.042	.07	.045	18700	63360	18.0	29.89		5	5	81	15/32	64500	5	5	72	1/8	38250	235	●	●									●	Hard in web		136
137					C	1 10	H		53	.5	.51	1.18	1.23	1.19	.123	.091	.098	.135	.146	.150	.045	.039	.044	120500	64600	17.0	30.1		5	5	68	15/32	54750	5	5	55	1/16	29750	231								Split base			●	Hard in head	●	137
138					C-C	1 9			51	5.	50	.9	.94	.93	.093	.09	.092	.15	.121	.15	.028	.029	.019	12875	55540	6.0	28.0	G&S	5	5	28	1/2	24750	5	5	25	1 3/16	4750	222	●												●	138
139					B	1 0	T		53	61	54	1.03	1.25	1.25	.098	.109	.093	.12	.127	.12	.041	.056	.037	124900	67650	4.0	14.97	G	4	–	–	9/16	.000	5	5	3	1/8	3750	255	●		●		●	●	●				little			139
140			Cambria	1910	–	1 0	H	G	63	58	61	1.32	1.31	1.32	.105	.098	.100	.065	.07	.07	.075	.070	.072	28850	53890	4.75	23.35	S&G	5	5				–	–	–	–	—	250							●			●		Mn & S high		140
141					B	1 0	L	S	57	64	59	1.26	1.32	1.27	.085	.127	.102	.052	.052	.052	.07	.07	.083	135950	75335	9.5	3.43	G	5	5	5	3/16	7500	5	5		1/8	7750	273	●	●			●	●	●					S high		141
142			Carnegie	1911	CC	1 11	T		50	45	49	1.11	1.14	1.13	.106	.094	.106	.03	.103	.103	.037	.038	.036	11700	55.30	20.5	34.23	Fg	5	5	58	5/8	47250	5	5	27	7/8	15750	219	●											Line & surface fair	●	142
143			Ill S W	1911	C	1 0	L		56	53	54	.98	.97	1.01	.103	.086	.097	.18	.127	.127	.047	.041	.050	116550	599 5	17.75	31.8	Fg&S	5	5	61	9/16	49500	–	–	—	–	–	224													●	143
144					A	1 0	H		52	66	52	1.03	1.06	1.01	.092	.138	.082	.18	.122	.122	.032	.035	.036	12400	56980	15.75	21.55	Fg	5	3	–	9/16	2750	5	5	29	1 5/32	6750	23	●	●			●							Hard in neck		144
145					C	0 11	T		55	51	55	.93	.90	.91	.12	.096	.099	.172	.12	.122	.048	.038	.04	4650	54645	18.5	30.82	Fg&S	5	5	45	13/32	37500	5	5	26	1 3/16	15250	225								●				Line & surface fair	●	145
146					C	0 11			56	52	55	1.04	1.02	1.01	.13	.096	.102	.18	.18	.118	.038	.020	.04	18700	55970	17.0	28.06		5	5	59	9/16	48000	5	5	—	7/32	2250	23						●						Split base		146
147					C	0 9	L		54	53	54	.97	.98	.98	.099	.099	.098	.41	.46	.41	.035	.033	.035	8200	6 305	17.75	30.73		5	5	55	15/32	45000	5	5	45	1 3/32	24750	227												Split base	●	147
148					A	0 8	L		55	57	55	.98	.99	.97	.093	.099	.097	.197	.193	.197	.037	.032	.032	120800	648.5	17.0	27.54		5	5	53	5/8	43500	5	5	34	1 1/16	9250	237	●										●	Somewhat hard		148
149					C	0 7			55	51	54	.99	.94	.96	.093	.08	.093	.160	.160	.160	.032	.048	.05	117350	62 40	17.5	27.48		5	5	54	1/2	44250	5	5	30	1 1/4	17250	232								Split base			●	Line & surface fair		149
150					B	0 7			58	57	58	.92	.90	.93	.100	.094	.10	.146	.141	.146	.039	.060	.039	115600	57100	6.5	27.9		5	5	69	9/16	55500	5	5	31	1 1/16	7750	231											●	S somewhat high		150
151					C	0 7			56	52	55	1.04	.01	1.03	.093	.088	.099	.141	.141	.132	.079	.022	.022	8150	61220	17.25	28.95		5	6	68	9/16	54750	5	2	—	1 1/16	350	217								Split base			●	Line & surface fair	●	151
152					C	0 7	H		55	53	54	.99	.96	.97	.095	.088	.092	.8	.18	.113	.030	.030	.03	3600	60065	9.0	31.12		5	5	74	17/32	59250	5	5	37	1 1/16	20750	227											●	Broken wheel	●	152
153					A	0 6	T		54	63	54	.97	1.00	.98	.086	.1	.086	.132	.14	.136	.026	.042	.024	118700	63320	14.25	18.36	Fg	5	5	—	9/16	3750	5	5	32	1 1/16	18250	242	●	●			●		●				●	Surface poor		153
154					A	0 6	H		59	66	60	.99	1.03	.99	.093	.123	.093	.144	.14	.146	.036	.051	.035	20450	62845	12.5	27.4	G	5	5	6	17/32	8250	5	5	20	15/16	14250	255		●					●					Hardness irreg.		154
155			Carnegie		B	0 4	T		59	60	60	1.13	1.13	1.13	.107	.113	.110	.144	.141	.125	.024	.023	.027	127850	73560	6.25	5.75		2	—	—	7/16	500	5	5	27	1"	15750	257					●		●							155
156					C	0 2			48	44	44	1.07	1.04	1.07	.090	.082	.081	.230	.235	.230	.033	.026	.029	107200	57300	22.5	37.74	S	5	5	82	15/32	65250	5	5	58	1 1/4	31250	211								●			●		●	156
157	85		Cambria	1907	–	3 Yr 9 Mo	L		48	56	48	.93	1.01	.92	.098	.11	.095	.058	.050	.054	.075	.08	.077	108650	55585	16.75	29.08	G	5	5	30	15/32	26250	–	–	—	—	—	220	●		●						●			Flaw S high		157
158			Maryland		–	2 0			41	55	45	.87	.94	.88	.081	.107	.07	.058	.052	.052	.037	.083	.08	60550	58630	22.25	37.75	S	5	5	24	5/8	29250	5	5	49	1 7/16	26750	206	●	●										Mn & S high in web		158
159			Ill S W	1909	A	3 3	T	G	51	56	51	.9	.95	.91	.098	.110	.096	.3	.157	.146	.05	.068	.05	112900	59955	17.25	30.41	Fg&S	5	5	9	15/32	10500	–	–	—	—	—	223			●											159
160					B	3 0			54	48	52	.76	.75	.75	.0	.098	.097	.22	.32	.26	.03	.029	.02	109400	54015	20.25	32.6		5	5	67	5/32	54000	5	5	24	1 3/16	14250	209												Line & surface fair	●	160
161			Carnegie		D	2 10	L		56	57	56	1.03	1.04	1.03	.098	.097	.103	.094	.089	.089	.039	.035	.04	22050	66075	6.0	25.12		5	5	6	7/32	8250	5	5	17	1 5/32	10750	239							Broken wheel				●	Somewhat hard		161
162			Ill S W.		C	2 10	T		49	47	50	.94	.92	.93	.103	.100	.112	.127	.136	.127	.025	.035	.036	109230	54950	18.0	34.2		5	5	52	11/16	42750	5	5	23	1 5/16	13750	2 4					Broken base Ties fair						●	Line & surface fair	●	162
163					A	2 10			51	63	5.	1.06	1.15	1.06	.098	.166	.092	.169	.174	.169	.022	.043	.022	113150	65650	5.25	4.59	G	3	—	—	9/16	750	5	5	63	1 1/8	33750	237	●	●			●						●	Very hard in neck		163
164			Carnegie		D	2 9	L		58	60	59	1.07	1.08	1.07	.098	.09	.098	.071	.073	.075	.042	.040	.042	124935	65280	4.25	22.45		4	—	—	1/2	1000	5	5	30	5/32	17250	259					●		●				little			164

URGH

Sheet 6

Broken Rails

/. s.	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed												Material Fair	Reference Numbers
			Segregated Badly	Segregated Somewhat	Very Brittle	Somewhat Brittle in Head	Somewhat Brittle in Web	Hard	Rolling Seam	Slag Present	Foreign Steel Pres.	Frozen Roadbed	Broken Wheel	Miscellaneous		
	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
0	273	●										●			●	165
	255	●	●			●		●				●		Possible flaw in base		166
0	234	●				●	Somewhat hard				●	●		Line & surface fair		167
0	218	●	●									●		Hard in neck		168
0	255	●	●			●		●				●				169
	237	●										●		Hardness little high	●	170
	219											●			●	171
0	233	●										●		Flaw		172
0	237	●					●					●		Little hard in web		173
	236											●		Little hard in web	●	174
0	246	●					●	●		●		●				175
0	222	●										●		Flaw	●	176
0	225	●										●			●	177
0	261	●						●						Possible flaw		178
	261	●						●						Possible flaw		179
0	223	●		●		●								Line & surface fair		180
	243	●		●		●		●				●				181
	215	●	●							●				Hardness irreg.		182
	244	●						●								183
0	229	●									●					184
0	237											●		Broken base	●	185
0	233											●		P. a little high		186
0	224						●					●		Split base		187
	260	●	●			●		●				●				188
0	249	●						●				●		Possible flaw		189
0	233			●		●						●		Hard in web		190
0	248							●		●		●		Split base		191
0	219											●			●	192
0	232											●			●	193
0	245							●				●				194
0	254		●		●			●		●		●		Piped		195
0	220											●			●	196
0	227														●	197
0	239	●	●			●				●				Hard in web		198
0	244	●					●	●						Mn. & S. high		199
	—	●	●		●											200
0	239		●			●		●		●				Flaw		201
0	247	●		●				●		●						202
0	241			●				●				●		Coarse grain		203
	228	●	●									●		Hard in web, Pipe		204
	278	●	●		●			●		●		little				205

Sheet 6

PENNSYLVANIA LINES WEST OF PITTSBURGH
STUDY OF RAIL FAILURES IN MAIN TRACKS

Bessemer Process

March-1913

Broken Rails

Reference Number	Wt of Rail Lbs/Yd	Rail Section	Manufacturer	Year of Rolling	Position in Ingot	Years in Service	Alignment or Tangent	Ballast	Chemical Analysis of Rail: Carbon Head	Carbon Web	Carbon Base	Manganese Head	Manganese Web	Manganese Base	Phosphorus Head	Phosphorus Web	Phosphorus Base	Silicon Head	Silicon Web	Silicon Base	Sulphur Head	Sulphur Web	Sulphur Base	Tensile Strength Lbs per Sq In	Elastic Limit Lbs per Sq In	Elongation Percent in 2 Inches	Reduction of Area Percent of Orig Sec	Character of Fracture	Drop Test, Supports 12" apart, 50 Lb Tup: Test Piece at O, Blows at 5 Ft	10 Ft	15 Ft	Int of Deflec	Accumul Foot Lbs	Test Piece at E, Blows at 3 Ft	6 Ft	10 Ft	Initial Deflec	Accumul Foot Lbs	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed: Segregated Badly	Segregated Somewhat	Very Brittle	Somewhat Brittle in Head	Somewhat Brittle in Web	Hard	Rolling Seam	Slag Present	Foreign Substances	Frozen Roadbed	Broken Wheel	Miscellaneous	Material Fair	Reference Numbers
165	85	PS	Ill SW	1909	A	2 Yr 9 Mo	L	G	50	49	49	95	96	95	083	084	074	[illegible]	141	32	28	02	34	[illegible]	56415	[illegible]	256	Fg&S	5	5	52	[illegible]	42750	5	5	35	[illegible]	[illegible]	[illegible]	●										●			●	165
166						2 9	T		59	73	6	106	3	07	091	41	097	69	53	65	23	05	026	124550	68110	[illegible]	[illegible]	Fg	5	2	—	1/3	2250	—	—		—	—	255	●	●			●		●				●		Possible flaw inside		166
167					B	2 9	H		51	53	52	93	95	91	105	097	097	122	13	118	035	026	047	113620	[illegible]	170	320	G&S	5	5		3/8	4500	5	5	23	1 5/8	3750	234	●				●		Somewhat hard			●	●		Lines surface fair		167
168					A	2 8	—		52	60	50	91	96	90	093	106	092	32	23	132	035	048	031	[illegible]	57030	170	232	G&S	5	5	43	1/2	36000	5	5	49	1 7/32	20750	[illegible]	●	●									●		Hard in neck		168
169					A	2 8	T		54	66	55	102	109	101	096	122	089	125	120	6	022	021	022	108570	64290	45	408	G	5	3	—	9/16	2750	5	5	52	1 3/16	28250	255	●	●			●		●				●				169
170					C	2 8			54	52	56	[illegible]	97	97	095	[illegible]	097	[illegible]	74	41	085	033	039	[illegible]	[illegible]	525	277	G&S	5	5	57	13/32	46500	—	—	—	—	—	237	●										●		Hardness little high	●	170
171					C	2 8	H		50	48	50	89	88	89	092	092	100	141	44	148	040	039	044	108950	[illegible]	925	3520		5	5	74	3/8	59250	—	—	—	—	—	[illegible]											●			●	171
172					B	2 7	T		50	55	51	91	94	94	093	107	093	144	141	143	022	042	033	[illegible]	[illegible]	85	3215		5	5	56	3/16	45750	5	3	27	[illegible]	15750	233	●										●		Flaw		172
173					D	2 7			53	53	54	93	94	95	087	087	086	119	119	14	024	025	023	[illegible]	61395	165	3095		5	5	54	13/32	44250	5	3	7	5/8	5750	237	●					●					●		Little hard in web		173
174					D	2 7			55	51	55	90	91	91	087	0.79	085	164	165	172	028	024	025	118640	61505	165	2945		5	5	47		39000	—	—			—	236											●		Little hard in web	●	174
175					C	2 7			50	55	55	94	93	94	089	083	090	163	160	160	027	025	027	123030	63475	140	255	G	5	5	32	17/32	27750	5	1		1"	10050	246	●					●	●		●		●				175
176					A	2 7			47	46	47	87	89	89	078	078	081	134	136	137	029	028	030	107750	52860	1425	206		5	5	41	3/32	34500	5	5	33	[illegible]	18750	222	●										●		Flaw	●	176
177					B	2 7			50	46	50	93	90	92	084	085	080	136	130	132	040	040	043	111875	56400	775	[illegible]		5	5	68		54750	5	5	7	1 1/4	10750	225	●										●			●	177
178					C	2 5			57	55	57	[illegible]	110	12	086	086	087	170	177	170	033	033	035	131150	68575	1525	2835		5	5	52	1/2	42750	5	5	49	5/16	26750	[illegible]	●						●						Possible flaw		178
179					C	2 5			58	56	58	103	102	04	087	087	092	174	174	174	020	019	019	135400	65720	150	2675	G&S	5	5	40	1/8	33750	—	—	—	—	—	[illegible]	●						●						Possible flaw		179
180					A	2 0			53	59	48	82	85	79	113	[illegible]	092	094	094	092	019	051	030	11950	57080	175	2493		5	3	—	9/16	2750	5	5	44	1 3/16	24250	223	●		●		●								Lines surface fair		180
181					A	2 0			50	59	50	100	107	99	074	108	072	[illegible]	50	151	029	053	021	117550	74160	1275	91	G	2	—	—	1/2	500	—		—		—	243	●		●		●		●				●				181
182					A	2 0			47	59	49	86	92	87	074	114	075	169	72	160	023	045	024	111800	63390	180	260	G&S	5	5	12	9/16	12750	—	—		—	—	215	●	●							●				Hardness irreg		182
183					F	2 0			57	55	57	106	105	106	096	082	092	155	55	160	026	027	038	129200	70875	65	266		5	5	50	1/2	41250	—	—	—	—	—	244	●						●								183
184					B	2 0			53	56	54	97	98	97	090	00	095	136	146	141	022	02	051	120600	69530	1675	284		5	5	32	1/2	27750	5	5	42	1 1/16	23250	229	●									●					184
185			Carnegie		DD	2 0	L	G	58	78	55	112	131	114	107	[illegible]	109	127	174	127	038	064	037	118040	58670	105	109	Fg	5	5	41	5/8	34500	5	5	33	1 1/16	18750	237											●		Broken base	●	185
186				1910	C	1 9	T		51	52	53	103	102	101	114	113	135	099	099	108	024	028	025	117690	57180	170	360		5	5	52	9/16	42750	5	5	14	1 1/2	9250	233											●		P a little high		186
187				1909	DD	1 9	—		52	49	51	108	107	109	105	103	103	103	099	099	055	051	056	114550	54850	185	307		5	5	46	9/16	38250	5	5	—		2250	224						●					●		Split base		187
188					D	1 9			56	74	56	115	136	115	108	128	107	132	143	127	[illegible]	065	044	121050	63280	175	2586	Fg	5	5	1	9/16	4500	—		—	—	—	260	●	●			●		●				●				188
189					CC	1 8			57	60	59	112	113	113	093	088	098	120	122	122	043	044	043	126200	61585	145	291	G&S	5	5	38	9/16	32250	5	5	42	1	23250	249	●						●				●		Possible flaw		189
190					B	1 8	H		51	58	53	99	101	101	116	137	114	061	056	066	036	050	038	104110	52980	80	91	Fg	5	4	—	5/8	3250	5	5	28	1 1/16	16250	233			●		●						●		Hard in web		190
191					B	1 8			58	56	58	117	117	114	106	093	106	122	127	126	033	032	029	[illegible]	63085	175	2831	Fg&S	5	5	46	5/8	38250	5	5	23	1 1/8	13750	248							●		●		●		Split base		191
192					D	1 6	L		51	51	53	98	100	100	114	132	124	090	089	094	022	022	021	113150	54945	180	3125		5	5	49	5/8	40500	5	5	4	1 1/2	4250	219											●			●	192
193					CC	1 6			52	5	53	109	108	105	106	097	109	108	122	108	053	045	049	116530	58670	170	2933		5	5	58	21/32	47250	5	5	23	1 1/4	13750	232											●			●	193
194				1910	CC	1 6			55	54	54	106	105	106	113	103	109	108	227	118	022	021	019	121600	65800	55	2423	Fg	5	5	57	19/32	46500	5	5	29	1 1/16	16750	245							●				●				194
195				1909	—	1 4	T		53	109	60	111	113	112	102	099	105	146	148	141	042	050	044	126350	67220	25	135	G	1	—	—	—	250	1	—	—	—	150	254		●		●			●		●		●		Piped		195
196			Ill SW		C	1 0	H		51	48	52	86	84	87	100	087	101	136	139	139	026	025	025	117000	72600	180	2916	G&S	5	5	40	9/16	33750	5	5	20	1	12250	220											●			●	196
197					D	1 0	L		49	50	57	84	83	84	088	076	089	134	132	132	026	021	028	115650	71030	1975	350	S	5	5	59	9/16	48000	5	5	28	1 1/4	16250	227														●	197
198			Carnegie		D	1 0	T		50	76	58	92	110	94	082	59	105	125	257	116	031	067	046	119600	69980	825	1597	G	4	—	—	9/16	1000	5	5	17	1 1/16	10750	239	●	●			●				●				Hard in web		198
199					B	1 0			52	53	54	123	123	123	102	085	099	099	108	099	062	060	064	126200	73915	1375	210		5	5	32	9/16	27750	5	5	3	5/8	3750	244	●					●	●						Mn & S high		199
200					A	1 0			46	54	48	91	95	93	094	127	111	096	064	093	—	—	—	106780	73760	55	55	—	—	—	—	—	—	—	—	—	—	—	—	●	●		●											200
201					C	1 0			50	59	52	119	126	119	082	118	090	127	134	118	032	045	034	126300	61700	80	812	-	5	5	1	1/2	4500	5	5	34	7/8	19250	239		●			●		●		●				Flaw		201
202					D	1 0	—		52	57	54	103	115	105	105	107	108	118	203	118	041	039	045	123400	73500	1525	2198		5	5	23	1/2	21000	5	5	40	1"	22250	247	●		●				●		●						202
203					B	1 0			52	59	55	100	100	101	099	105	098	103	097	101	036	045	038	112200	64850	1125	105		5	5	30		26250	5	5	43	1 7/16	23750	24			●				●				●		Coarse grain		203
204					—	1 0			43	77	48	97	100	98	092	123	104	113	205	118	036	058	040	114050	63965	1375	1865	G&S	5	5	4	5/8	6750	1	—	—	—	150	228	●	●									●		Hard in web, Pipe		204
205					D	1 0	L		55	99	63	111	135	111	099	43	113	136	383	130	044	077	055	—	—	—	—	—	2	—	—	11/16	500	5	1	—	7/8"	1050	278	●	●		●			●		●		little				205

BURGH

Broken Rails

up x1" cumul. ot Lbs.	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed											Material - Fair	Reference Numbers
			Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Steel Pres.	Frozen Road bed	Miscellaneous		
			Badly	Somewhat		in Head	in Web								
39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
—	233	●	●		●					●		●	Piped		206
1050	239	●					●	●							207
0750	250	●						●		●			C.& Mn little high		208
—	248							●				little	C&Mn high. Flaw		209
—	276	●	●		●			●				●			210
—	—	●			●								Piped		211
—	265	●	●		●			●		●			Flaw		212
1650	239		●				●			●			Flaw		213
—	257	●	●		●			●		●		little	Flaw		214
150	288		●		●			●					Flaw		215
—	260		●		●			●			●		Flaw. C very high		216
—	219	●	●			●					●		Very irreg.		217
7750	227												Somewhat abnorm.		218
—	249	●	●			●		●		●		●			219
—	237		●							●			Flaw. Elong. low		220
—	275	●	●		●			●		●			Flaw.		221
—	238	●	●			●							Pipe.		222
—	250			●	●			●			●				223
6250	232								●			●	Split base		224
5750	231											●		●	225
9750	245							●				●		●	226
21750	247					●		●				●			227
22250	238								●			●	Split base		228
7750	243	●		●		●		●							229
2750	222						●					●			230
7250	205								●			●		●	231
—	—	●			●										232
2250	249					●		●							233
2250	224											●		●	234
3750	241							●				●	Broken base		235
2250	219								●	●		●	Flaw. Split base		236
3750	227				●							●	Flaw		237
7750	229						●					little	C. & P. high		238
—	250	●						●				●		●	239
7250	207									●		little	Metal unsatisfa		240
6250	229											●	Split base	●	241
4250	241	●	●			●		●				●			242
0750	225											●		●	243
9750	217											●		●	244
8250	249							●				●		●	245
5250	236	●										●		●	246

Sheet 7

PENNSYLVANIA LINES WEST OF PITTSBURGH
STUDY OF RAIL FAILURES IN MAIN TRACKS

Bessemer Process

March-1913

Broken Rails

Reference Number	Weight of Rail Lbs per Yd	Rail Section	Manufacturer	Year Rolled	Position in Ingot	Years in Service	[illegible]	Ballast	Carbon Head	Carbon Web	Carbon Base	Manganese Head	Manganese Web	Manganese Base	Phosphorus Head	Phosphorus Web	Phosphorus Base	Silicon Head	Silicon Web	Silicon Base	Sulphur Head	Sulphur Web	Sulphur Base	Tensile Strength Lbs per Sq In	Elastic Limit Lbs per Sq In	Elongation Per cent in 2 inches	Reduction of Area	Character of Fracture	Test Piece at D Blows at 5 Ft	Test Piece at D Blows at 10 Ft	Test Piece at D Blows at 15 Ft	Test Piece at D Total Deflect	Test Piece at D Accum Foot Lbs	Test Piece at E Blows at 5 Ft	Test Piece at E Blows at 10 Ft	Test Piece at E Blows at 15 Ft	Test Piece at E Total Deflect	Test Piece at E Accum Foot Lbs	Brinell Hardness	In Joint	Segregated Bad	Segregated Somewhat	Very Brittle	Somewhat Brittle In Head	Somewhat Brittle In Web	Hard	Rolling Seam	Slag Present	Foreign Substances	Faulty Road bed	Miscellaneous	Material Fair	Reference Numbers
206	85	PS	Carnegie	1909	A	1 Yr-0 Mo	—	G	.57	.68	.65	1.06	.22	1.08	.093	.127	.115	.122	.108	.122	.036	.053	.040	6200	72270	4.5	5.6	G	2	—	—	7/32	500	—	—	—	—	—	233	●	●		●					●		●	Piped		206
207					C	1 0	T		.54	.55	.54	1.06	.05	1.06	.098	.092	.095	.075	.071	.075	.019	.029	.019	24000	73600	15.25	23.9	G&S	5	5	45	1/2	37500	5		—	1/2	350	239	●					●	●							207
208					C	1 0			.56	.56	.58	.9	1.23	1.22	.095	.09	.092	.169	.101	.196	.032	.033	.034	28800	73190	4.25	20.4	G	5	5	39	7/16	33000	5	5	37	5/16	20250	250	●						●		●			C & Mg little high		208
209					D	1 0			.59	.57	.59	1.24	1.28	1.26	.102	.092	.097	.18	.18	.16	.017	.032	.014	28250	72180	5.25	29.6	G&S	5	5	43	7/16	36000	—	—	—	—	—	248							●				little	C & Mn high Flaw		209
210					—	0 11			.57	.77	.60	1.30	1.44	1.33	.109	.113	.120	.165	.174	.155	.032	.042	.036	126650	70415	5.5	45.9	G	3	—	—	1/2	2750	—	—	—	—	—	276	●	●		●			●				●			210
211					C	0 5			.51	.76	.52	.85	1.25	.95	.111	.144	.109	.135	.142	.130	—	—	—	108790	63850	4.5	55.7		—	—	—	—	—	—	—	—	—	—	—	●			●								Piped		211
212					D	0 5			.55	.86	.60	1.07	1.20	1.09	.093	.129	.102	.182	.237	.122	.027	.055	.024	116400	72900	5.5	40.8		5	3	—	9/16	750	—	—	—	—	—	265	●	●		●			●		●			Flaw		212
213					—	0 5			.51	.67	.56	1.22	1.24	1.21	.096	.18	.107	.182	.152	.132	.045	.025	.051	118550	68450	10.0	10.78		5	5	6	1/2	8250	5	3	—	1"	650	[illegible]		●				●			●			Flaw		213
214					C	0 4			.57	.74	.58	1.26	1.38	1.27	.088	.16	.093	.148	.228	.121	.034	.045	.038	117900	73650	4.75	49.5		1	—	—	—	250	—	—	—	—	—	257	●	●		●			●		●		little	Flaw		214
215					A	0 3			.53	.75	.61	1.03	1.45	1.07	.082	.138	.09	.18	.297	.118	.025	.064	.030	114650	69650	4.5	3.9		4	—	—	7/16	1000	1	—	—	—	50	288		●		●			●					Flaw		215
216					—	0 3			.57	.137	.6	1.05	1.10	1.07	.091	.103	.128	.172	.312	.153	.038	.052	.029	20250	79425	7.5	7.72		1	—	—	—	250	—	—	—	—	—	260		●		●			●			●		Flaw C very high		216
217					C	0 3	L		.45	.74	.48	.98	.99	.99	.087	.133	.099	.103	.22	.101	.030	.045	.038	104800	57345	.825	2.97	G&S	3	—	—	5/8	750	—	—	—	—	—	[illegible]	●	●			●					●		Very irreg.		217
218					C	0 3	T		.49	.47	.49	1.09	1.07	1.09	.088	.09	.098	.080	.075	.069	.048	.044	.048	107200	68700	1.0	16.23		5	5	60	5/8	48750	5	5	3	1 5/16	17750	227												Somewhat abnorm		218
219					—	0 2			.50	.74	.53	1.12	1.32	1.13	.095	.120	.125	.14	.198	.132	.045	.052	.050	22750	67440	2.13	10.71	G	5	5	1	5/16	4500	—	—	—	—	—	249	●	●			●		●		●		●			219
220					—	0 1	″		.48	.50	.50	1.23	1.29	1.25	.090	.124	.088	.15	.228	.123	.048	.037	.053	122900	78160	9.5	9.25		4	—	—	9/16	1000	—	—	—	—	—	237		●							●			Flaw & Elong low		220
221					D	2 weeks			.51	.67	.57	1.19	1.59	1.18	.082	.128	.105	.097	.319	.122	.053	.084	.066	17700	75265	4.0	5.6		2	—	—	7/16	500	—	—	—	—	—	275	●	●		●			●		●			Flaw		221
222					D	Not used	—	—	.49	.79	.54	1.05	1.12	1.06	.080	.097	.086	.13	.169	.116	.037	.045	.046	125745	80410	.20	3.4		2	—	—	1/2	500	—	—	—	—	—	238	●	●			●							Pipe		222
223					A		—	—	.53	.95	.54	1.4	1.8	1.5	.098	.13	.096	.15	.216	.122	.035	.065	.035	94590	71150	2.0	1.99		1	—	—	—	250	—	—	—	—	—	250			●	●			●			●				223
224				1910	C	2 Yr-0 Mo	H	G	.56	.55	.54	1.1	1.14	1.13	.114	.107	.108	.150	.155	.150	.036	.032	.034	120700	60250	6.25	27.67	Fg & S	5	5	57	9/32	46500	5	5	48	1 1/8	26250	232								●			●	Split base		224
225					D	1 11	T		.53	.53	.55	1.05	1.23	1.05	.112	.107	.118	.089	.089	.089	.025	.025	.025	119300	62585	8.0	26.91		5	5	57	7/8	46500	5	5	29		15750	231											●		●	225
226					GG	1 10	H		.56	.54	.55	1.11	1.13	1.14	.103	.098	.103	.123	.125	.125	.033	.048	.050	109900	63690	4.75	23.58	G	5	5	47	1/2	39000	5	5	35	1 1/16	9750	245							●				●		●	226
227					BB	1 10			.55	.57	.56	1.09	1.1	1.10	.102	.102	.106	.127	.132	.127	.029	.040	.026	122300	66800	5.0	24.99		5	5	1	9/32	4500	5	5	39	1 3/32	21750	237					●		●				●			227
228					CC	1 9	″		.56	.54	.56	1.18	1.9	1.17	.06	.096	.05	.150	.160	.150	.028	.021	.035	124700	63775	16.5	28.18	Fg & S	5	5	61	9/16	49500	5	5	40	1 3/32	22250	238								●			●	Split base		228
229					B	1 8	T		.54	.56	.53	.96	.96	.97	.117	.131	.116	.073	.070	.069	.039	.048	.040	115829	60760	11.5	17.71	G	5	3	—	21/32	2750	5	5	31	1 3/16	17250	243	●		●		●		●							229
230					DD	1 8		″	.52	.50	.53	1.10	1.12	1.10	.113	.099	.107	.127	.136	.122	.034	.030	.031	117100	60700	18.0	29.59	Fg & S	5	5	61	5/8	49500	5	5	1	1 3/32	2750	222						●					●			230
231					DD	1 5	L		.48	.46	.46	.87	.85	.85	.12	.130	.127	.083	.088	.085	.026	.022	.019	107850	58530	2.0	34.39	″	5	5	69	9/16	55500	5	5	30	1 5/8	17250	205								●			●		●	231
232					B	1 0	T	″	.67	.66	.54	.92	.94	1.00	.113	.118	.109	.123	.121	.130	—	—	—	125530	69840	17.53	25.77	G	—	—	—	—	—	—	—	—	—	—	—	●			●										232
233					D	1 0		″	.57	.54	.57	1.23	1.25	1.21	.107	.098	.102	.133	.136	.125	.036	.034	.034	127500	70780	24.75	4.48	G&S	5	3	—	1/2	2750	5	5	40	1"	22250	249					●		●							233
234					C	1 0		″	.49	.49	.50	.94	.93	.95	.110	.116	.117	.085	.085	.089	.031	.036	.036	118550	64780	19.0	31.65		5	5	52	5/8	42750	5	5	40	1 1/4	22250	224											●		●	234
235			Ill Stl	1911	—	1 7			.58	.58	.58	1.26	1.29	1.36	.105	.107	.101	.136	.136	.136	.035	.036	.036	126350	65500	4.0	22.63	Fg	5	5	11	1/2	12000	5	5	43	1 1/8	23750	241							●				●	Broken base		235
236					D	1 0			.57	.53	.57	1.27	1.35	1.09	.102	.094	.071	.165	.152	.165	.023	.018	.022	125050	65240	.60	28.1	Fg & S	5	5	51	3/8	42000	5	5	20	1 1/8	12250	[illegible]								●	●		●	Flaw Split base		236
237					D	0 [illegible]			.54	.52	.55	1.02	1.21	1.23	.098	.092	.098	.146	.146	.146	.025	.026	.026	119750	66680	3.75	2.06	Fg	2	—	—	17/32	500	5	5	63	1 1/16	33750	227				●							●	Flaw		237
238					B	0 9			.60	.60	.58	.95	.93	.92	.109	.112	.110	.146	.146	.146	.037	.022	.027	124600	63870	16.0	22.36		5	5	33	5/8	28500	5	5	3	1 3/32	3750	229						●					little	C & P high		238
239					C	0 9	″		.55	.54	.56	1.9	1.9	1.21	.109	.098	.106	.186	.193	.222	.023	.027	.023	127700	65310	4.0	24.10		5	5	29	9/16	25500	—	—	—	—	—	250	●						●				●		●	239
240					B	0 9	L	″	.51	.51	.51	.92	.90	.94	.099	.098	.097	.127	.127	.127	.031	.035	.031	108050	57055	19.0	31.61	Fg & S	5	5	77	17/32	61500	5	5	30	1 3/16	17250	207									●			Metal unsatisfac		240
241					D	0 8	T		.52	.48	.54	.90	.90	.90	.091	.085	.083	.141	.139	.134	.026	.027	.024	110650	59850	21.0	36.25	G&S	5	5	66	5/8	53250	5	5	28	1 3/16	16250	229											●	Split base	●	241
242					A	0 8		″	.58	.67	.49	.97	1.04	.92	.106	.165	.088	.152	.163	.151	.021	.028	.023	116610	75085	12.0	18.4	G	2	—	—	9/16	500	5	5	4	1 3/32	4250	241	●	●			●		●				●			242
243					C	0 8	L		.5	.48	.52	.96	.94	.97	.099	.089	.101	.153	.146	.155	.044	.037	.042	114200	61110	8.75	31.84	G&S	5	5	61	5/8	49500	5	5	37	1 3/32	20750	225											●		●	243
244					D	0 8			.50	.47	.51	.89	.89	.88	.100	.084	.092	.179	.184	.181	.032	.028	.034	113750	64050	16.5	24.16		5	5	70	9/16	56250	5	5	35		19750	217											●		●	244
245					—	0 8	T	″	.56	.54	.56	1.03	1.02	1.03	.096	.094	.096	.169	.174	.172	.033	.04	.043	123000	67220	4.5	24.52	G	5	5	52	15/32	42750	5	5	32	1 1/16	18250	249							●				●		●	245
246					A	0 8	L		.51	.55	.51	.97	.99	.99	.089	.092	.084	.141	.141	.146	.033	.035	.031	117600	66500	17.25	29.73	G&S	5	5	46	17/32	38250	5	5	46	1 1/8	25250	236	●										●		●	246

Broken Rails

/"	Brinell Hardness 40	In Joint 41	Defects in Quality of Material and Road Bed											Material Fair 53	Reference Numbers 54
umul. t Lbs.			Segregated		Very Brittle 44	Somewhat Brittle		Hard 47	Rolling Seam 48	Slag Present 49	Foreign Steel Pres. 50	Frozen Road bed 51	Miscellaneous 52		
			Badly 42	Somewhat 43		in Head 45	in Web 46								
50	253						●	●				●	Flaw		247
2250	219						●					●			248
250	254					●		●				●			249
250	219											●	S. a little high	●	250
—	234	●						●				●			251
050	222						●					●	Split base		252
250	242	●	●		●			●				●	Flaw		253
750	221								●			●	C. a little high		254
1250	210								●			●	Split base	●	255
250	225											●		●	256
750	221												Split base	●	257
250	232	●									●	●	C&S. a little high		258
750	188								●			●	Little soft	●	259
750	251							●				●	Split base		260
250	216											●		●	261
550	249	●	●			●		●				●			262
2250	246					●		●				●			263
250	226											●		●	264
750	257	●					●	●				●			265
—	250							●				●			266
750	228											●	Split base		267
250	247							●				●			268
—	231											●		●	269
2750	243	●	●			●		●				●			270
7750	231											●		●	271
5750	219	●										●		●	272
5250	249	●	●			●		●							273
250	246	●	●			●		●							274
250	250	●		●			●	●							275
—	241	●						●				●	Flaw		276
750	247	●				●		●				●	Flaw. C. high		277
150	239	●	●		●										278
250	247	●	●		●			●							279
250	249	●	●		●			●							280

Sheet 8

PENNSYLVANIA LINES WEST OF PITTSBURGH
STUDY OF RAIL FAILURES IN MAIN TRACKS

Bessemer Process March - 1913 **Broken Rails**

Reference Number	Wt of Rail lbs/yd	Rail Section	Manufacturer	Year of Rolling	Position in Ingot	Years in Service	[illegible] or Tangent	Ballast	Carbon Head	Carbon Web	Carbon Base	Manganese Head	Manganese Web	Manganese Base	Phosphorus Head	Phosphorus Web	Phosphorus Base	Silicon Head	Silicon Web	Silicon Base	Sulphur Head	Sulphur Web	Sulphur Base	Tensile Strength Lbs per Sq In	Elastic Limit Lbs per Sq In	Elongation Per cent in 2 inches	Reduction Area Per ct of Orig Sect	Character of Fracture	Drop Test - Supports 12 apart - 50 Lb Tup: Test Piece at D, Blows at 5 Ft	10 Ft	15 Ft	Initial Deflec	Accumul Foot Lbs	Test Piece at E ½" x 1", Blows at 3 Ft	6 Ft	10 Ft	Initial Deflec	Accumul Foot Lbs	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed: Segregated Badly	Segregated Somewhat	Very Brittle	Somewhat Brittle in Head	Somewhat Brittle in Web	Hard	Rolling Seam	Slag Present	Foreign Steel Pres	Frozen Road bed	Miscellaneous	Material Fair	Reference Numbers
247	85	PS	Ill S W	1911	C	0 Yr 8 Mo	T	G	.57	.56	.57	1.03	1.02	1.04	[illegible]	[illegible]	[illegible]	.13	.108	.13	.033	.032	.033	23750	61890	16.3	24.4	Fg & S	5	5	46	9/16	38250	5	5	—		2250	253						●	●				●	Flaw		247
248					D	0 8			.58	.51	.54	.92	.91	.92	.092	.083	.091	.136	.136	.136	.036	.031	.036	115200	57050	19.0	30.48		5	5	56	5/8	45750	5	5	2	1 1/4	3250	2 9						●					●			248
249					B	0 8	H		.57	.56	.56	1.02	1.00	1.03	.07	.107	.105	.153	.160	.157	.024	.022	.023	26550	61710	16.0	21.17	S	5	2	—	3/16	2250	5	5	22		13250	254					●		●				●			249
250					D	0 8	L		.51	.49	.54	.88	.89	.87	.095	.088	.105	.146	.146	.146	.051	.042	.050	113550	58885	20.0	32.23	Fg & S	5	5	39	5/8	33000	5	5	22		13250	219											●	S a little high	●	250
251					A	0 8	T		.56	.58	.56	1.03	1.20	1.02	.102	.106	.123	.150	.155	.155	.033	.028	.033	120450	60850	16.5	26.37		5	5	45	13/32	37500	—	—	—	—	—	234	●						●				●			251
252					D	0 8			.54	.50	.55	1.09	1.07	1.08	.104	.088	.095	.127	.136	.127	.027	.024	.026	113750	62400	19.5	30.99		5	5	7	13/32	9000	5	1	—	1 7/32	1050	222						●					●	Split base		252
253					A	0 8			.54	.71	.54	.98	1.01	.95	.107	.186	.108	.094	.094	.088	.031	.038	.033	121950	62550	8.0	7.77	G	2	—	—	9/32	500	5	5	26	1 3/16	15250	242	●	●		●			●				●	Flaw		253
254					C	0 7			.58	.56	.56	.93	.92	.94	.107	.105	.110	.127	.132	.132	.029	.028	.028	122050	60790	17.5	26.53	Fg & S	5	5	63	17/32	51000	5	5	25	1 1/8	14750	221								●			●	C a little high		254
255					C	0 7	H		.53	.50	.53	.92	.90	.91	.100	.091	.100	.150	.150	.155	.021	.019	.024	112500	58910	19.25	32.73		5	5	77	9/16	61500	5	5	58	1 1/4	31250	210								●			●	Split base	●	255
256					AD	0 7	T		.56	.58	.56	.95	.91	.91	.103	.092	.102	.132	.132	.132	.028	.021	.025	115900	61050	19.0	30.76	〃	5	5	60	9/16	48750	5	5	68	1 5/16	36250	225											●		●	256
257					D	0 7	H		.52	.48	.51	.96	.96	.97	.097	.083	.088	.160	.163	.160	.026	.024	.025	115250	60180	20.5	33.25	〃						5	5	31	1 13/32	17750	221												Split base	●	257
258					A	0 7	T		.58	.58	.58	.87	.88	.89	.097	.101	.101	.141	.132	.141	.055	.061	.058	119900	61200	17.0	21.81	〃	5	5	46	19/32	38250	5	5	28	1 1/8	16250	232	●									●	●	C&S a little high		258
259					D	0 7			.46	.42	.44	.66	.68	.69	.085	.083	.085	.085	.094	.085	.027	.026	.029	95995	53030	25.5	38.77	S	5	5	65	5/8	52500	5	5	33	1 5/16	18750	188								●			●	Little soft	●	259
260					B	0 7	H		.55	.56	.55	.99	.96	.99	.105	.104	.104	.150	.155	.155	.033	.029	.030	121830	60980	17.0	28.8	Fg & S	5	5	44	9/32	36750	5	5	5	1 1/4	4750	251							●				●	Split base		260
261					D	0 7			.54	.47	.51	.85	.83	.83	.101	.090	.104	.118	.108	.118	.030	.025	.031	106400	54320	19.0	32.1	S	5	5	56	[illegible]	45750	5	5	26	1 1/8	15250	2 6											●		●	261
262					A	0 6	T		.54	.75	.58	.89	.99	.91	.088	.65	.102	.130	.130	.134	.032	.032	.035	116930	72090	11.5	17.75	G	2	—	—	5/8	500	5	3	—	1 3/32	1650	249	●	●			●		●				●			262
263					C	0 6	L		.55	.51	.55	.93	.93	.94	.104	.093	.099	.148	.153	.148	.034	.030	.032	121350	64350	15.75	25.75	G & S	5	5	6	17/32	8250	5	5	36	1 5/32	20250	246					●		●				●			263
264					D	0 6			.45	.43	.50	.93	.93	.93	.089	.079	.102	.141	.146	.150	.025	.027	.032	105750	52190	21.0	38.4	S	5	5	49	9/32	40500	5	5	20	1 3/16	12250	226											●		●	264
265					—	0 6	T		.56	.54	.57	1.03	1.03	1.03	.096	.096	.092	.118	.127	.123	.021	.023	.025	24850	64190	16.0	25.7	Fg & S	5	5	43	9/16	36000	5	5	9	1 1/8	6750	257	●					●	●				●			265
266					D	0 6			.56	.52	.57	1.20	1.17	1.23	.105	.107	.105	.136	.132	.145	.276	.022	.027	123300	63345	.80	29.09		5	5	57	9/16	46500	—	—	—	—	—	250							●				●			266
267					B	0 6	L		.57	.57	.59	.94	.95	.96	.101	.098	.103	.169	.165	.169	.043	.042	.048	120950	62420	17.0	25.75	〃	5	5	50	17/32	41250	5	5	19	1 5/32	11750	228											●	Split base		267
268					D	0 6	T		.56	.54	.58	1.21	1.20	1.23	.104	.096	.101	.182	.188	.187	.027	.026	.028	129000	66425	15.0	25.67	〃	5	5	56	1/2	45750	5	5	28	1 3/32	16250	247							●				●			268
269					D	0 6	L		.53	.52	.55	.89	.92	.91	.097	.090	.093	.165	.165	.169	.025	.025	.029	118750	61990	17.75	30.35	〃	5	5	57	9/16	46500	—	—	—	—	—	231											●		●	269
270					A	0 5	T		.51	.60	.49	.93	1.21	.93	.082	.123	.080	.108	.099	.108	.024	.040	.023	117110	59980	15.75	23.9	G	5	3	—	1/2	2750	5	5	41	1 5/16	22750	243	●	●			●		●				●			270
271					D	0 5	L		.54	.50	.53	.96	.95	.96	.097	.087	.097	.163	.163	.158	.034	.034	.034	117295	71090	15.5	29.05	G & S	5	5	50	9/16	41250	5	5	51	1 1/8	27750	231											●		●	271
272					B	0 4	T		.57	.49	.50	1.01	.97	.99	.100	.091	.089	.165	.165	.169	.035	.030	.033	118300	65115	16.25	28.58	Fg	5	5	67	9/16	54000	5	5	47	1 5/32	25750	219	●										●		●	272
273					A	0 4			.51	.64	.50	1.01	1.01	1.01	.083	.141	.083	.120	.127	.127	.036	.036	.041	6900	61105	13.5	18.65	G	5	1	—	9/16	1750	5	5	46	1 3/32	25250	249	●	●			●		●							273
274					AA	0 4			.45	.65	.47	.86	.95	.87	.074	.149	.075	.132	.134	.122	.022	.050	.021	119550	64265	14.75	19.8		5	5	—	5/8	3750	5	5	12	1"	8250	246	●	●			●		●							274
275					A	0 3			.55	.57	.65	.92	.94	.92	.097	.113	.097	.118	.118	.118	.032	.043	.032	128600	62595	15.25	26.55	G & S	5	5	18	9/16	17250	5	5	4	1 5/32	4250	250	●		●			●	●							275
276					—	0 3	L		.55	.52	.54	1.06	1.04	1.06	.109	.108	.109	.107	.108	.118	.031	.029	.029	120250	60870	16.5	27.55	Fg & S	5	5	50		41250	—	—	—	—	—	241	●						●				●	Flaw		276
277					B	0 2	H		.60	.63	.61	1.12	1.11	1.13	.105	.111	.107	.183	.183	.183	.034	.035	.031	128925	68290	14.5	20.8	Fg	5	5	8	1/2	9750	5	5	33	1"	18750	247	●				●		●				●	Flaw C high		277
278					A	0 2	T		.51	.67	.53	1.04	1.14	1.05	.084	.148	.084	.130	.132	.127	.039	.084	.341	121150	62265	9.75	11.88	G	5	2	—	5/8	2250	1	—	—	—	150	239	●	●		●										278
279					A	0 2		G	.52	.68	.50	.95	1.02	.94	.079	.163	.093	.088	.089	.089	.032	.057	.031	112550	65225	7.5	20.4	〃	5	5	—	5/8	3750	5	1	—	1 3/16	1050	247	●	●		●			●							279
280					A	0 1			.51	.69	.51	1.01	1.10	1.02	.080	.134	.078	.165	.160	.163	.020	.041	.019	136350	70630	11.5	13.1		5	5	—	9/16	3750	5	1	—	1"	1050	249	●	●		●			●							280

BURGH

Sheet 9

Crushed Head Failures

p x/" cumul. of Lbs.	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed											Material Fair	Reference Numbers
			Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Steel Pres	Frozen Road bed	Miscellaneous		
			Badly	Some-what		in Head	in Web								
39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
—	207			●		●						●			281
5750	225		●			●									282
2250	172											●	Soft Material poor		283
—	227												Sulphur high		284
2250	247							●						●	285
—	215			●									Sulphur high		286
—	210			●									Soft Struc Unsatis		287
3250	218													●	288
—	225										●			●	289
1250	254							●			●				290
950	205		●			●						●	Split head		291
7750	253		●		●			●				●	Split head		292
260	277		●					●				●	Split head		293
750	251		●		●			●							294
7750	216										●				295

BURGH

Sheet 10

Flow-of-Metal Failures

x/" cumul. of Lbs.	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed											Material Fair	Reference Numbers.
			Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Steel Pres	Frozen Road bed	Miscellaneous		
			Badly	Some-what		in Head	in Web								
39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
2250	218			●						●			Rather soft		296
—	214					●					●				297
—	239		●			●		●					S.high		298
—	199												Soft. Struc. unsatis		299
1250	206											●	S.high		300
7750	216											●	S high		301
0750	200											●	S.high. Soft		302
2250	220												S.high		303
1250	199					●							Somewhat soft		304
3750	207												Soft. C.low		305
250	221													●	306
—	220													●	307
2250	234											●		●	308
4750	243		●		●			●				●	Split head		309

Sheet 9

PENNSYLVANIA LINES WEST OF PITTSBURGH
STUDY OF RAIL FAILURES IN MAIN TRACKS

Bessemer Process March-1913 **Crushed Head Failures**

Reference Number	Wt of Rail Lbs Yd	Rail Section	Manufacturer	Year of Rolling	Position in Ingot	Years in Service	Curve or Tangent	Ballast	Carbon Head	Carbon Web	Carbon Base	Manganese Head	Manganese Web	Manganese Base	Phosphorus Head	Phosphorus Web	Phosphorus Base	Silicon Head	Silicon Web	Silicon Base	Sulphur Head	Sulphur Web	Sulphur Base
281	85	PAR	Carnegie	1895	–	6Yr 9Mo	H	G	.48	.52	.49	.77	.79	[illegible]	.129	.148	.128	.032	.032	.032	.046	.035	.044
282				1898	–	13 4	T		.50	.60	.47	.80	.84	.79	.086	.056	.084	3			.020	.022	0.3
283		ASCE	"	1901	–	10 10	"		.44	.44	.44	.65	.64	.65	.098	.096	.093	.022	.032	.032	.04	.039	.038
284			I.I.S.W	1904	–	7 4	"	"	.52	.5	.52	.94	.94	.95	.102	.091	.094	.078	.078	.075	.071	.073	.071
285			Carnegie	1905	–	6 5		"	.55	.51	.51	1.09	.108	.107	.103	.096	.098	.13	.13	.113	.056	.051	.052
286	100	PS	Maryl'd	1907	2	3Yr 8Mo	L	S	.53	.61	.53	.82	.84	.82	.099	.107	.095	.113	.075	.066	.075	.107	.072
287	100	PS	Cambria	"	A	3 5	"	"	.39	.46	.43	.95	.97	.96	.077	.086	.077	.08	.123	.08	.056	.074	.064
288			Carnegie	1911	C	0 6	T	"	.50	.47	.50	.94	.95	.95	.09	.086	.091	.167	.188	.172	.046	.046	.046
289	85		I.S.W	1909	–	2 8		G	.49	.47	.48	.89	.88	.89	.102	.06	.103	.163	.167	.167	.022	.022	.021
290					D	2 5			.59	.56	.45	.58	.61	.61	.085	.039	.063	.087	.087	.065	.044	.043	.045
291			Carnegie		AA	2 0		"	.5	.69	.55	.05	.27	.08	.091	.156	.103	.03	.233	.103	.036	.055	.041
292	"			"	D	1 8		"	.53	.82	.52	10	8	110	.095	.157	.093	.13	.113	.113	.047	.037	.042
293					CC	1 6			.78	.98	.76	[illegible]	.10	.13	.16	.13	.15	.061	[illegible]	.061	.045	.050	.056
294				1910	B	1 8	"	"	.52	.61	.49	.85	.85	.85	.120	.146	.106	.063	.066	.069	.026	.027	.021
295			I.S.W	1911	O	0 6			.48	.46	.50	.96	.95	.97	.093	.084	.093	.085	.092	.085	.037	.034	.039

Reference Number	Tensile Strength Lbs per Sq In	Elastic Limit Lbs per Sq In	Elongation Percent in 2 Inches	Reduction of Area Pct of Orig Sec	Character of Fracture	Test Piece at 'D' Blows at 5 Ft	10 Ft	15 Ft	Initial Deflec	Accumul Foot Lbs	Test Piece at 'E' Blows at 3 Ft	6 Ft	10 Ft	Initial Deflec	Accumul Foot Lbs	Brinell Hardness	In Joint	Segregated Badly	Segregated Somewhat	Very Brittle	Somewhat Brittle in Head	Somewhat Brittle in Web	Hard	Rolling Seams	Slag Present	Foreign Substances	Frozen Roadbed	Miscellaneous	Material Fair	Reference Numbers
281	[illegible]	56840	13.5	21.8	G	5	3	–	9/16	2750	–	–	–	–	–	207			●		●						●			281
282	99725	59825	13.5	19.25	"	5	1	–	9/16	1750	5	5	29	1 1/16	16750	225		●			●									282
283	88725	43875	14.0	17.03	G&S	5	4	–	21/32	3250	5	5	60	1 3/16	32250	172											●	Soft Material pax		283
284	114800	60430	19.5	30.72		5	5	36	17/32	30750	–	–	–	–	–	227												Sulphur high		284
285	121650	64110	7.5	26.41	G	5	5	48	[illegible]	39750	5	5	40	1 1/8	22250	247							●						●	285
286	110000	52815	18.5	41.2	Fg&S	5	5	35	5/8	30000	–	–	–	–	–	215			●									Sulphur high		286
287	[illegible]	58980	8.0	31.12		5	5	71	7/16	57000	–	–	–	–	–	210			●									Soft Struc Unsatis		287
288	[illegible]	59500	18.5	32.6	G	5	5	57	19/32	46500	5	5	32	1 1/8	18250	218													●	288
289	[illegible]	58290	20.75	36.44	"	5	5	49	5/8	40500	–	–	–	–	–	225										●			●	289
290	[illegible]	61145	16.5	26.4	G&S	5	5	25	5/8	22500	5	5	18	1 1/16	11250	254							●			●				290
291	110200	55200	10.75	12.13	G	1	–	–	19/32	250	5	4	–	1 5/32	1950	205		●			●						●	Split head		291
292	[illegible]	62690	6.0	4.55	Fg	2	–	–	9/16	500	5	5	23	1	13750	253		●		●			●				●	Split head		292
293	[illegible]	61995	–	1.01	G	1	–	–	–	250	5	5	14	1 1/8	9260	277		●					●				●	Split head		293
294	97205	60030	3.75	4.30		5	1	–	9/16	1750	5	5	3	1 1/16	3750	251		●		●			●							294
295	109000	62435	20.75	27.05	–	5	5	86	5/8	68250	5	5	31	1 1/16	17750	216										●				295

Drop Test - Supports 12' apart - 50 Lb Tup. Test Piece at 'D' [illegible]; Test Piece at 'E' ½"

Sheet 10

PENNSYLVANIA LINES WEST OF PITTSBURGH
STUDY OF RAIL FAILURES IN MAIN TRACKS

Bessemer Process March-1913 **Flow of Metal Failures**

Reference Number	Wt of Rail Lbs Yd	Rail Section	Manufacturer	Year of Rolling	Position in Ingot	Years in Service	Curve or Tangent	Ballast	Carbon Head	Carbon Web	Carbon Base	Manganese Head	Manganese Web	Manganese Base	Phosphorus Head	Phosphorus Web	Phosphorus Base	Silicon Head	Silicon Web	Silicon Base	Sulphur Head	Sulphur Web	Sulphur Base
296	85	ASCE	Ill SW	1904	–	7Yr 4Mo	+	G	.44	.46	.44	.97	.97	.97	.075	.081	[illegible]	.071	.071	.071	.053	.063	.056
297	"		"		–	7 4	"	"	.48	.43	.43	.89	.86	.87	.088	.075	.078	.089	.089	.089	.063	.053	.052
298	"		"	"	–	6 10	"		.52	.68	.50	.87	.94	.87	.085	.55	.088	.07	.07	.07	.056	.09	.052
299	100	PS	Cambria	1907	A	3Yr 8Mo	L	S	.40	.43	.43	.93	.95	.95	.064	.077	.077	.075	.071	.075	.047	.06	.068
300	"	"		"	D	3Yr 7			.47	.46	.47	.95	.96	.95	.104	.100	.105	.113	.113	.113	.080	.081	.077
301			"		C	3 7	"	"	.47	.46	.47	.93	.95	.98	.097	.085	.097	.103	.103	.103	.064	.067	.082
302		"	"	"	D	3 7	"	"	.46	.43	.45	.95	1.00	.97	.096	.088	.094	.141	.141	.136	.078	.068	.083
303	"		"	"	"	3 0	"	"	.51	.48	.50	.104	.102	1.03	.093	.093	.100	.120	.123	.118	.085	.079	.089
304	"		"	"	E	3 0	"	"	.45	.46	.46	.79	.78	.79	.101	.103	.103	.08	.102	.108	.035	.047	.043
305	"		"	"	A	3 0	"	"	.41	.41	.41	.91	.89	.90	.081	.077	.060	.113	.096	.09	.032	.031	.028
306	85	PS	Ill SW	1909	–	2Yr 8Mo	T	G	.50	.48	.50	.91	.92	.92	.085	.080	.080	.167	.169	.157	.039	.037	.040
307	"	"			–	2 8	"	"	.50	.49	.50	.92	.92	.92	.089	.081	.088	.157	.165	.160	.047	.040	.044
308	"	"	"	"	C	2 7	"	"	.52	.52	.52	.94	.94	.95	.098	.088	.088	.148	.150	.153	.079	.038	.039
309	"	"	Carnegie	1910	D	1 9	"	"	.56	.71	.53	.96	1.02	.97	.098	.151	.098	.118	.118	.118	.03	.057	.030

Reference Number	Tensile Strength Lbs per Sq In	Elastic Limit Lbs per Sq In	Elongation Percent in 2 Inches	Reduction of Area Pct of Orig Sec	Character of Fracture	Test Piece at 'D' Blows at 5 Ft	10 Ft	15 Ft	Initial Deflec	Accumul Foot Lbs	Test Piece at 'E' Blows at 3 Ft	6 Ft	10 Ft	Initial Deflec	Accumul Foot Lbs	Brinell Hardness	In Joint	Segregated Badly	Segregated Somewhat	Very Brittle	Somewhat Brittle in Head	Somewhat Brittle in Web	Hard	Rolling Seams	Slag Present	Foreign Substances	Frozen Roadbed	Miscellaneous	Material Fair	Reference Numbers
296	[illegible]	58020	15.0	17.47	G	5	5	73	9/16	13500	5	5	40	1 3/16	22250	218			●						●			Rather soft		296
297	[illegible]	61485	17.0	21.75		5	1	–	5/8	1750	–	–	–	–	–	214					●					●				297
298	[illegible]	58010	19.5	20.31	G&S	3	–	–	5/8	750	–	–	–	–	–	239		●			●		●					S high		298
299	[illegible]	56860	19.25	31.63	Fg&S	5	5	72	1/2	57750	–	–	–	–	–	199												Soft Struc unsat's		299
300	[illegible]	68405	17.0	31.09	"	5	5	45	9/16	37500	5	5	38	1 3/16	21250	206											●	S high		300
301	111650	58490	19.25	29.34	"	5	5	77	9/16	61500	5	5	51	1 3/16	27750	216											●	S high		301
302	108000	62550	20.75	34.94	S	5	5	10	19/32	11250	5	5	57	1 3/8	30750	200											●	S high, Soft		302
303	113500	57750	18.0	31.28	S&G	5	5	52	5/8	42750	5	5	40	1 1/4	22250	220												S high		303
304	107000	50780	19.5	34.44	"	1	–	–	–	250	5	5	38	1 1/16	21250	199					●							Somewhat soft		304
305	108100	63655	20.0	36.35	"	5	5	43	9/16	36300	5	5	43	1 3/8	23750	207												Soft C low		305
306	[illegible]	51980	21.0	36.3	"	5	5	46	9/16	38250	5	5	30	1 1/4	17250	221													●	306
307	[illegible]	63725	18.5	34.7	G	5	5	56	9/16	45750	–	–	–	–	–	220													●	307
308	117035	78550	15.75	29.45	S&G	5	5	66	5/8	53250	5	5	40	1 1/16	22250	234											●		●	308
309	[illegible]	60895	6.5	5.10	Fg	5	5	1	9/16	4500	5	5	25	1 1/16	14750	243		●		●			●				●	Split head		309

Drop Test - Supports 12' apart - 50 Lb Tup. Test Piece at 'D' [illegible]; Test Piece at 'E' ½" x 1"

BURGH

Sheet 11

Split Head Failures

1" Cumul. Foot Lbs. 39	Brinell Hardness 40	In Joint 41	Defects in Quality of Material and Road Bed											Material Fair 53	Reference Numbers 54
			Segregated		Very Brittle 44	Somewhat Brittle		Hard 47	Rolling Seam 48	Slag Present 49	Foreign Steel Pres. 50	Frozen Road bed 51	Miscellaneous 52		
			Badly 42	Somewhat 43		in Head 45	in Web 46								
—	235		●			●		●							310
—	215		●			●							Very irreq.		311
—	218									●					312
150	193		●				●								313
5750	201		●			●							P very high Irreq.		314
0250	198		●			●						●	Very irreq.		315
4750	194		●				●					●	Very irreq.		316
23750	212		●									●	Hardness irreq		317
—	202		●									●	Hardness irreq.		318
7250	199		●			●						●	Hardness irreq.		319
2250	215		●			●	●					●			320
9250	224													●	321
1050	195	●	●			●	●					●	Hardness irreq		322
2250	224		●		●							●	Very hard in web		323
—	203		●							●			C. low in head		324
1650	211												Little soft	●	325
1650	233		●			●	●	●					Hardness irreq		326
7250	235		●		●			●					Very hard in web		327
5250	253		●		●			●							328
—	222		●							●					329
2750	230		●			●	●			●		●	Very hard in web		330
70750	226		●			●									331
—	213												Metal abnormal		332
—	206		●			●							S high		333
2250	195			●		●							Soft		334
—	182												Soft		335
5250	169											●	Soft Split not found		336
0750	214			●								●	Much worn		337
0250	213		●			●							Hard in web		338
7250	188		●			●						●			339
650	234		●		●			●				●	Very hard in web		340
7250	244		●		●			●							341
8250	230		●							●		●	Hard in web		342
300	225		●			●	●						Hard in web		343
2750	201										●				344
1750	257		●					●							345
7250	254			●		●		●				●	Very hard in neck		346
4750	202			●							●		S high Hard low		347
—	—		●		●										348
2750	222		●										Hard in web		349
6750	218												Possibly foreign mat	●	350

PENNSYLVANIA LINES WEST OF PITTSBURGH
STUDY OF RAIL FAILURES IN MAIN TRACKS

Sheet 11

Bessemer Process

March-1913

Split Head Failures

Record No.	Wt. of Rail Lbs per Yd	Rail Section	Manufacturer	Year of Rolling	Position in Ingot	Years in Service	High or Low Side	Ballast	Chemical Analysis of Rail: Carbon			Manganese			Phosphorus			Silicon			Sulphur			Tensile Strength Lbs per Sq In	Elastic Limit Lbs per Sq In	Elongation % in 2 in	Reduction of Area
310	85	PRR	Carnegie	1895	–	5 Yr. 0 Mo.	T	G	40	58	48	85	92	85	[illegible]	78	[illegible]	075	07	07	029	034	068	[illegible]345	68570	83	30
311					–				40	68	43	70	89	77	082	204	093	095	045	052	028	02	021	[illegible]	67790	195	2704
312			I. S. W.	1897	–	13 Yr. 0 Mo.			49	47	48	93	92	93	07	065	070	83	74	79	045	036	022	13000	69280	165	2308
313			Carnegie	1898	–	4 0			44	5	43	67	76	88	097	16	102	089	45	089	[illegible]	039	09	00050	5025	2.25	3265
314					–	13 0			53	78	50	80	99	89	46	259	1	095	3	089	015	059	015	07900	54575	775	255
315					–	13 9	–		38	60	43	64	72	67	065	132	089	07	080	07	02	028	017	99120	50250	180	263
316					–		T		42	65	48	76	87	78	083	85	103	06	050	056	[illegible]	038	020	[illegible]	67430	140	222
317					–				39	55	43	[illegible]	67	67	074	27	087	07	066	066	05	026	015	09870	62730	100	119
318					–				44	67	48	72	8	72	08	87	5	14	40	50	027	059	029	85880	48590	230	371
319					–				44	59	44	57	62	57	105	87	11	07	08	060	04	030	018	86130	48730	50	51
320					–	13 8			46	60	45	82	85	84	086	14	14	089	089	089	09	020	07	96020	53190	40	212
321					–	3 5			5	47	49	9	91	91	03	092	6	00	13	8	022	09	021	3575	59490	90	291
322			″		–	13 5			40	60	40	82	87	81	086	83	083	07	035	083	018	044	06	05400	53550	80	338
323					–	13 0			40	58	44	75	8	74	077	5	088	24	097	089	024	054	042	88500	62950	35	362
324					–	12 0			39	56	40	72	78	74	077	159	079	094	105	8	02	056	022	96595	62940	213	3454
325					–	12 0			47	43	43	81	75	80	099	086	097	3	150	12	02	018	010	109650	[illegible]	2025	287
326					–	12 0			51	64	49	100	107	99	093	151	087	093	099	094	017	035	06	117750	75260	90	07
327					–	12 0			44	71	55	83	96	85	077	84	10	085	08	086	03	042	022	93200	79250	225	29
328		ASCE		1899	–	14 Yr. 0 Mo.			53	7	58	103	109	108	071	36	086	075	086	108	022	049	03	138000	63570	50	81
329					–	11 0			46	60	57	88	86	97	079	154	34	08	372	113	024	066	035	6350	64765	475	684
330					–	11 0			46	60	48	94	101	93	084	31	079	085	57	083	07	034	08	104970	72 73	90	130
331					–	11 0			45	56	48	93	107	94	024	22	077	8	193	122	025	038	022	104500	64500	50	236
332				1900	–	10 0			50	47	49	81	80	81	02	097	10	056	047	054	037	035	036	4950	65180	1525	236
333				190[illegible]	–	[illegible] 2 Mo.			44	55	48	64	68	65	096	50	1.6	047	047	057	047	078	055	95430	50260	180	295
334					–	11 0			46	51	41	64	63	64	098	27	112	042	038	042	043	056	040	92330	48880	195	258
335		″			–	11 0			40	39	41	64	63	65	099	099	106	047	052	052	053	036	036	89320	47440	200	348
336					–	10 5			39	37	38	67	65	68	099	092	096	061	066	066	032	072	031	92265	50540	2375	4005
337					–	10 3			43	57	49	78	84	82	078	9	03	094	094	094	035	059	041	108690	59970	95	262
338					–	9 0			43	55	49	78	85	82	082	46	103	093	094	075	043	090	065	107450	70110	50	2276
339				1903	–	9 0			44	63	60	57	63	62	099	[illegible]	182	019	021	028	032	060	049	100130	47960	100	112
340					–	9 0			52	64	48	83	89	82	16	167	096	075	080	075	026	048	022	95130	60060	30	29
341					–	8 0			49	63	57	96	99	98	088	138	110	066	071	071	026	050	037	14700	68180	60	334
342			Ill. S. W.	1904	–	7 0			49	74	46	83	9	83	076	150	088	136	136	134	032	120	033	120400	66575	1175	335
343			Carnegie	1907	–	3 0			42	62	46	84	94	86	065	40	082	065	080	080	034	083	042	99130	60420	178	259
344	100	PS	Cambria	1907	E	4 0	H	S	43	44	46	83	89	92	086	085	089	098	113	115	041	040	044	98870	51925	230	3505
345	″		″	″	B	3 0	L		55	63	53	[illegible]	114	111	093	8	088	18	113	113	038	050	035	127050	66500	150	272
346					A	3 0			52	59	52	110	114	[illegible]	099	122	099	108	106	098	086	081	038	119900	7345	1775	297
347	″		Maryland		–	3 0	H		48	57	54	71	75	73	083	066	017	033	038	033	068	114	096	108590	49080	170	2638
348			Cambria	″	A	2 0	L		53	63	56	110	114	114	055	130	078	093	105	112	–	–	–	14780	65290	195	2986
349	″	″	″	″	A	2 0			40	63	45	93	102	94	071	[illegible]	088	092	101	103	036	105	034	111750	68800	200	2796
350				″	O	1 Yr. 0 Mo.	H		51	48	50	94	92	93	093	088	095	108	082	086	033	031	016	114450	69810	200	185

Record No.	Character of Fracture	Drop Test – Supports 12" apart – 50# Tup: Test Piece at D: Blows at			In. of Deflect	Actual Foot Lbs	Test Piece at E: Blows at			In. of Deflect	Actual Foot Lbs	Brinell Hardness	Lr	Defects in Quality of Material and Road Bed: Soft	Somewhat Coarse	Very Brittle	Somewhat Brittle In Head	Somewhat Brittle In Web	Hard	Rolled Seam	Slag Present	Foreign Segregation	Frozen Roadbed	Miscellaneous	Material OK	Reference Number
310	S & G	3	–	–	9/16	750	–	–	–	–	–	[illegible]		●			●		●							310
311		5	5	2	9/16	5250	–	–	–	–	–	[illegible]		●			●							Very irreg		311
312	G	5	5	50	5/8	4250	–	–	–	–	–	[illegible]									●					312
313	Fg & S	5	5	44	23/32	6750	1	–	–	–	50	93		●				●								313
314		1	–	–	–	250	5	5	67	[illegible]	15750	20		●			●							[illegible] irreg		314
315	Fg	5	3	–	5/8	2750	5	5	6	[illegible]	10250	98		●			●						●	Very irreg		315
316		5	5	43	2	36000	5	5	5	[illegible]	4750	94		●				●					●	Very irreg		316
317	G	5	5	28	21/32	24750	5	5	43	5/16	23750	[illegible]		●									●	Hardness irreg		317
318	S	5	5	16	3/4	5760	–	–	–	–	–	202		●									●	Hardness irreg		318
319	G	1	–	–	–	250	5	5	30	[illegible]	7250	99		●			●						●	Hardness irreg		319
320	G & S	5	2	–	5/8	2250	5	5	–	1 3/8	3250	[illegible]		●			●	●					●			320
321	G	5	5	51	9/16	42000	5	5	34	[illegible]	9250	224													●	321
322	Fg & S	3	–	–	3/16	750	5	[illegible]	–	[illegible]	1050	95	●	●			●	●					●	Hardness irreg		322
323	G	5	1	–	[illegible]	750	5	5	20	[illegible]	2250	[illegible]		●		●							●	Very hard in web		323
324	S	5	5	41	1/2	34500	–	–	–	–	–	203		●							●			C low in head		324
325	–	5	5	44	2	36750	5	3	–	[illegible]	1650	2												Little soft	●	325
326	G	5	1	–	[illegible]	1750	5	3	–	15/16	650	233		●			●	●	●					Hardness irreg		326
327	″	–	–	–	–	–	5	5	30	5/16	17250	235		●		●			●					Very hard in web		327
328		1	–	–	–	250	5	5	6	3/4	5250	253		●		●			●							328
329	S & G	5	2	–	9/16	2250	–	–	–	–	–	222		●							●					329
330	G	5	1	–	1/2	1750	5	5	1	7/8	2750	230		●			●	●			●		●	Very hard in web		330
331		5	1	–	1/2	1750	5	5	57	13/16	30750	226		●			●									331
332	S	5	5	7	1/2	9000	–	–	–	–	–	213												Metal [illegible]		332
333	Fg & S	5	3	–	7/16	2750	–	–	–	–	–	206		●			●							S high		333
334	″	3	–	–	[illegible]	750	5	5	40	[illegible]	22250	195			●		●							Soft		334
335	S	5	5	–	[illegible]	3750	–	–	–	–	–	182												Soft		335
336		5	5	41	7/8	34500	5	5	28	[illegible]	16250	169											●	Soft Split not hard		336
337	G	5	5	56	[illegible]	45750	5	5	37	1 5/32	20750	214			●								●	Much worn		337
338	S & G	5	5	8	[illegible]	9750	5	5	56	1	30250	213		●			●							Hard in web		338
339	G	5	5	–	[illegible]	3750	5	5	10	[illegible]	7250	188		●			●						●			339
340		5	3	–	17/32	2750	5	5	48	1 1/8	2650	234		●		●			●				●	Very hard in web		340
341		5	3	–	1/2	2750	5	5	30	[illegible]	17250	244		●		●			●							341
342		5	5	25	[illegible]	22500	5	5	12	1	8250	230		●							●		●	Hard in web		342
343	S	3	–	–	[illegible]	750	2	–	–	[illegible]	300	225		●			●	●						Hard in web		343
344	S	5	5	82	5/8	66750	5	5	61	[illegible]	32750	201										●				344
345	S & G	5	5	11	1/2	12000	5	5	39	[illegible]	21750	257		●					●							345
346		5	3	–	9/16	2750	5	5	30	[illegible]	17250	254			●		●		●				●	Very hard in neck		346
347		5	5	36	1 1/16	30750	5	5	25	1 7/8	14750	202			●							●		S high Hard low		347
348	G	–	–	–	–	–	–	–	–	–	–	–		●		●										348
349	S & G	–	–	–	–	–	5	5	41	7/8	22750	222		●										Hard in web		349
350	″	5	5	9	7/16	10500	5	5	9	[illegible]	6750	218												Possibly foreign mtl	●	350

SBURGH
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Sheet 12

Split Head Failures

Tup	Tup	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed											Material Fair	Reference Numbers
"	1/2" x 1"			Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Steel Pres.	Frozen Road bed	Miscellaneous		
al ec	Accumul. Foot Lbs.			Badly	Somewhat		in Head	in Web								
	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
6"	1050	235						●	●							351
8	26750	206		●			●									352
3"	12750	213										●				353
	—	242		●		●			●				●			354
3"	1050	211		●			●	●					●			355
"	1650	242		●		●			●				●	Very hard in web		356
"	1650	265		●		●			●				●	Very hard in web		357
	—	210		●												358
5"	3750	237		●			●	●	●					Hard in neck		359
"	30750	226												Compos. irreq.		360
"	25250	224	●									●			●	361
'	23250	202			●								●			362
'	11250	230			●		●									363
"	14750	235										●				364
5"	12750	256			●		●		●	●						365
5"	6750	234		●			●		●							366
"	11250	259		●			●		●							367
6"	19750	196										●				368
6"	28250	237		●					●					Hard in web		369
3"	26750	235		●			●		●					Very hard in neck		370
	—	229		●		●										371
2"	21250	241		●			●		●				little	Very hard in neck		372
6"	13750	244		●			●		●					Very hard in neck		373
3"	2750	221		●		●								Hard in web		374
2"	14250	209											●	Identity doubtful		375
5"	18250	208		●			●							Hardness irreq & low		376
9"	5250	249		●		●			●							377
6"	9250	247			●				●							378
2"	15250	205		●			●						●	Hardness irreq & low		379
3"	10250	229		●			●				●			Hardness irreq.		380
	—	197									●			Soft & poor		381
3"	19250	224	●	●									●			382
"	13750	231		●			●						●	Hardness irreq.		383
-	—	228		●		●					●			Pipe. Hard in web		384
9"	17750	199			●		●							Hardness low		385
8"	8750	216		●			●							Hard in web & irreq.		386
6"	4250	243		●			●	●	●					Hard in web & irreq.		387
	—	252		●		●			●		●					388
6"	17750	219											●	Not split. Worn		389
9"	14750	238											●		●	390
9"	17250	224		●			●							Hard in web		391

PENNSYLVANIA LINES WEST OF PITTSBURGH

STUDY OF RAIL FAILURES IN MAIN TRACKS

Bessemer Process

March-1913

Split Head Failures

Reference Number	Wt. of Rail	Section	Manufacturer	Year of Rolling	Position in Ingot	Years in Service	[illegible]	Ballast	Carbon Head	Carbon Web	Carbon Base	Manganese Head	Manganese Web	Manganese Base	Phosphorus Head	Phosphorus Web	Phosphorus Base	Silicon Head	Silicon Web	Silicon Base	Sulphur Head	Sulphur Web	Sulphur Base
351	100	[illegible]	Carnegie	909	B	2Yr 5Mo	L	S	.59	.54	.57	[illegible]	[illegible]	.9	.02	.07	.6	[illegible]	[illegible]	[illegible]	.028	.033	[illegible]
352					B	2 5	T		.47	.60	.49	[illegible]	.83	.78	.099	.130	.098	.061	.06	.06	.032	.079	.037
353						2 0	H	G	.49	.47	.47	.85	.82	.84	[illegible]	.09	.09	.16	.18	.13	.035	.034	[illegible]
354						2 0	L	S	.53	.64	.5	.87	.97	.87	[illegible]	.4	.096	.058	.073	.073	.022	.089	.054
355						2 0	H		.5	.56	.50	.59	.73	.70	.090	.14	.093	.07	.07	.07	.14	.068	.046
356						2 0			.47	.75	.59	.74	.79	.76	.072	.14	.096	.068	.069	.066	.022	.044	.030
357						2 0	L		.56	.80	.64	1.02	1.07	.04	.088	.134	.093	.075	.075	.07	.033	.060	.027
358						0 1		G	.43	.56	.53	.73	.76	.74	.066	.120	.093	.068	.07	.059	.028	.060	.044
359			Cambria	910	A	2Yr 4Mo		S	.43	.73	.54	1.03	1.13	.8	[illegible]	[illegible]	[illegible]	.061	.056	[illegible]	.052	.120	.069
360					E	1 0	T		.55	.48	.49	.94	.94	.97	.094	.08	.087	.075	.066	.066	.047	.036	.035
361					C	1 0			.50	.47	.5	.92	.99	1.00	[illegible]	.092	.099	.27	.283	.275	.026	.032	.038
362			Carnegie	91	BB	1 7	L	G	.43	.51	.43	.95	.97	.93	.088	.113	.083	.183	.183	.183	.241	.253	.4
363			Ill S'n		A	1 1	H	S	.55	.5	.55	.04	.04	.03	.09	.10	.02	.18	.18	.18	.052	.062	.050
364			Carnegie		C	1 0	T		.55	.5	.54	1.06	1.02	1.04	.097	.088	.094	.120	.122	.120	.027	.024	.026
365					BB	0 10			.56	.59	.56	[illegible]	[illegible]	1.10	.101	.13	.103	.16	.16	.120	.029	.033	.035
366					B	0 9	H		.42	.5	.48	.89	.91	.90	.075	.11	.101	.06	.06	.06	.023	.033	.036
367					BB	0 9	T	S	.56	.6	.59	[illegible]	.98	[illegible]	.101	.133	.12	.135	.04	.101	.024	.033	.027
368	85		Maryland	907	C	2Yr 0Mo	L	S	.42	.43	.47	.91	.85	.87	.076	.073	.081	.06	.06	.06	.035	.032	.035
369			Cambria	908	-	2Yr 0Mo	T	"	.36	.61	.43	.98	1.06	.98	.086	.166	.093	.087	.077	.07	.023	.059	.016
370					E	2 0		G	.42	.63	.49	1.03	1.4	1.04	.09	.161	.098	.122	.123	.122	.039	.18	.059
371			Carnegie	909	C	3 0	H		.47	.69	.58	.79	.86	.82	.069	.137	.108	.069	.07	.069	.029	.070	.049
372			I. S'n	"	-	2 9	L		.5	.63	.51	.88	.92	.88	.096	.14	.084	.12	.130	.121	.027	.060	.034
373					A	2 7	T		.46	.64	.48	.94	.96	.83	.09	.1	.092	.099	.099	.099	.028	.05	.020
374			Carnegie		CC	2 6	H	S	.42	.68	.48	.76	.82	.76	.065	.148	.078	.07	.066	.066	.027	.069	.035
375					D	2 1	L	G	.49	.49	.48	.86	.87	.81	.097	.098	.095	.188	.188	.188	.041	.041	.039
376					C	2 0			.43	.56	.45	.82	.86	.83	.090	[illegible]	.092	[illegible]	.092	.09	.028	.054	.029
377					"	2 0			.50	[illegible]	.6	.66	.73	.69	.07	.6	.096	[illegible]	[illegible]	.271	.024	.064	.073
378					D	2 0	"		.52	.58	.53	1.00	1.01	.99	.09	.113	.09	.09	.103	.109	.030	.035	.030
379			Il. S'n		A	2 0			.43	.57	.46	.72	.75	.71	[illegible]	.40	.089	.122	.120	.122	.16	.02	.05
380						2 0	T		.49	.62	.49	.86	.92	.86	.096	.159	.09	.132	.14	.136	.025	.065	.03
381					A	2 0			.43	.47	.44	.77	.79	.78	.074	.090	.080	.122	.122	.122	.072	.03	.027
382						2 0		"	.44	.58	.47	.84	.91	.85	.072	.145	.09	.132	.136	.133	.02	.026	.033
383						2 0	L		.51	.61	.52	.97	.91	.97	.085	.126	.098	.46	.06	.43	.036	.050	.037
384			Carnegie	"	-	2 0	T	"	.44	.76	.48	1.05	1.14	1.06	.098	.14	.096	.18	.34	.128	.044	.062	.052
385			Il S'n		-	1 0	L		.50	.54	.50	.86	.88	.85	.096	.12	.093	.122	.125	.122	.031	.028	.032
386	"	"	Carnegie	"	D	1 0		"	.42	.62	.47	.85	.91	.86	.08	.154	.094	.087	.075	.075	.079	.087	.04
387	"					1 0	"	"	.50	.72	.53	1.1	1.18	1.1	.088	.147	.090	.12	.132	.127	.02	.069	.042
388	"	"	-			Not Laid	-	-	.54	.83	.56	1.16	1.24	1.16	.095	.128	.085	.122	.344	.113	.028	.048	.044
389				1910	B	2Yr 1Mo	L	G	.49	.47	.49	.80	.77	.80	.14	1.0	.41	.08	.108	.12	.03	.031	.035
390					C	2 1		"	.55	.56	.54	.99	.96	.99	.18	.10	.122	.36	.36	.136	[illegible]	[illegible]	.037
391				"	B	2 0	H		.52	.5	.55	.61	.64	.62	.08	.136	.13	.06	.06	.06	.027	.013	.028

Reference Number	Tensile Strength Lbs per Sq In	Elastic Limit Lbs per Sq In	Elongation Percent	Reduction of Area Percent	Character of Fracture	Test Piece at D Blows at 5 Ft	Test Piece at D Blows at 10 Ft	Test Piece at D Blows at 15 Ft	Test Piece at D Initial Deflection	Test Piece at D Accumulated Foot Lbs	Test Piece at E Blows at 5 Ft	Test Piece at E Blows at 10 Ft	Test Piece at E Blows at 15 Ft	Test Piece at E Initial Deflection	Test Piece at E Accumulated Foot Lbs	Brinell Hardness
351	24200	63350	.50	24.26	[illegible]	5	5	"	9/16	3500	5	[illegible]		[illegible]	1050	235
352	[illegible]	53400	6.5	70	G	5	5	49	[illegible]	40500	5	5	49	[illegible]	26750	206
353	[illegible]	67335	2.75	35.23	S&G	5	5	66	5/8	53250	5	5	2	[illegible]	2750	213
354	[illegible]	72800	3.75	3.4	G	4	-	-	9/16	1000	-	-	-	-	-	247
355	[illegible]	62250	1.0	13.4		4	-	-	[illegible]	1000	5	[illegible]	-	[illegible]	[illegible]	[illegible]
356	94320	[illegible]	3.76	2.55		4	-	-	5/8	1000	5	3	-	[illegible]	550	[illegible]
357	85080	68835	1.25	2.02		2	-	-	2	500	5	3	-	[illegible]	650	265
358	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	210
359	[illegible]	56855	5.25	24.08	[illegible]	5	5	3	[illegible]	6000	5	5	3	[illegible]	3750	237
360	[illegible]	63845	7.0	24.7	S	5	5	23	[illegible]	2,000	5	5	57	[illegible]	30750	226
361	[illegible]	[illegible]	2.75	26.3		5	5	52	[illegible]	42250	5	5	46	[illegible]	25250	224
362	105000	[illegible]	20.0	32.27	[illegible]	5	5	39	[illegible]	33000	5	5	42	1	23250	202
363	[illegible]	62570	5.0	4.82		5	-	-	[illegible]	1250	5	5	8		1250	230
364	[illegible]	62820	17.0	31.9	G	5	5	40	9/16	33750	5	5	25	[illegible]	4750	[illegible]
365	[illegible]	[illegible]	9.25	3.75	G&S	4	-	-	[illegible]	1000	5	5	21	[illegible]	2750	256
366	89360	55.85	2.75	21.8	G	5	5	-	[illegible]	3750	5	5	9	[illegible]	6750	234
367	[illegible]	70390	6.0	4.48	"	5	1	-	[illegible]	750	5	5	8	[illegible]	250	259
368	100750	66450	21.75	40.7	S	5	5	40	[illegible]	33750	5	5	35	[illegible]	9750	196
369	[illegible]	68270	[illegible]	[illegible]	G	5	5	33	[illegible]	28500	5	5	52	15/16	28250	237
370	117350	70700	6.25	24.25	S&C	4	-	-	[illegible]	[illegible]	5	5	49	[illegible]	26750	235
371	92930	68965	1.5	18	G	5	1	-	[illegible]	1750	-	-	-	-	-	229
372	[illegible]	[illegible]	.80	33.5	Fg&S	1	-	-	-	250	5	5	38	[illegible]	2 250	[illegible]
373	[illegible]	61365	.425	22.3	G	1	-	-	-	250	5	5	23	[illegible]	[illegible]	244
374	[illegible]	60930	2.5	3.6		5	5	-	[illegible]	3750	5	5	1	[illegible]	[illegible]	221
375	10950	57250	.85	34.01	Fg&S	5	5	63	3/4	51000	5	5	24	[illegible]	4250	209
376	[illegible]	53765	2.0	[illegible]	S&G	2	-	-	[illegible]	500	5	5	22	[illegible]	[illegible]	208
377	88350	77360	2.25	3.0	G	2	-		[illegible]	750	5	5	6	7/8	6250	249
378	[illegible]	69450	[illegible]	[illegible]	S&G	5	5	13	[illegible]	[illegible]	5	5	14	[illegible]	9250	247
379	[illegible]	62200	22.25	31.4	S.	5	2	-	9/16	[illegible]	5	5	26	[illegible]	[illegible]	205
380	[illegible]	[illegible]	20.5	37.7	S&G	5	1	-	[illegible]	[illegible]	5	5	6	[illegible]	[illegible]	229
381	[illegible]	[illegible]	3.75	16.03	G	5	5	40	[illegible]	33750	-	-	-	-	-	197
382	[illegible]	66200	.70	21.25	S&G	5	5	8	5/8	[illegible]	5	3	34	[illegible]	19250	224
383	116800	70440	16.75	27.5	G	5	1	-	[illegible]	[illegible]	5	5	23	[illegible]	13750	[illegible]
384	103700	68350	9.0	3.97	"	1	-	-	-	250	-	-	-	-	-	228
385	[illegible]	67800	[illegible]	36.8	S&G	5	5	5	[illegible]	[illegible]	5	5	31	[illegible]	17750	199
386	107340	66325	9.25	9.73	G	2	-	-	[illegible]	500	5	5	13	[illegible]	8750	216
387	[illegible]	[illegible]	[illegible]	.69		5	5	-	[illegible]	3750	5	5	4	[illegible]	4250	243
388	[illegible]	74775	3.25	7.8	"	3	-	-	[illegible]	750	-	-	-	-	-	252
389	109380	57440	17.0	31.1	Fg&S	5	5	27	[illegible]	24000	5	5	31	[illegible]	17750	219
390	[illegible]	[illegible]	15.0	25.4		5	5	24	13/32	21750	5	5	25	[illegible]	[illegible]	238
391	105300	[illegible]	6	6.17	G	5	1	-	[illegible]	1750	5	5	30	[illegible]	7250	224

Reference Number	[illegible]	Segregates Much	Segregates Somewhat	Very Brittle	Somewhat [illegible] in Head	Somewhat [illegible] in Web	Hard	Rolling Seam	Slag Present	Foreign Matter	Frozen Roadbed	Miscellaneous	Material Fair	Reference Numbers
351						●	●							351
352		●			●									352
353										●				353
354		●		●			●				●			354
355		●			●	●					●			355
356		●		●			●				●	Very hard in web		356
357		●		●			●				●	Very hard in web		357
358		●												358
359		●			●	●	●					Hard in neck		359
360												Compos irreg		360
361	●									●			●	361
362			●								●			362
363			●		●									363
364										●				364
365			●		●		●	●						365
366		●			●		●							366
367		●			●		●							367
368										●				368
369		●					●					Hard in web		369
370		●			●		●					Very hard in neck		370
371		●		●										371
372		●			●		●				Little	Very hard in neck		372
373		●			●		●					Very hard in neck		373
374		●		●								Hard in web		374
375											●	Identity doubtful		375
376		●			●							Hardness irreg & low		376
377		●		●			●							377
378			●				●							378
379		●			●						●	Hardness irreg & low		379
380		●			●				●			Hardness irreg.		380
381									●			Soft & poor		381
382	●	●									●			382
383		●			●						●	Hardness irreg		383
384		●		●					●			Pipe Hard in web		384
385			●		●							Hardness low		385
386		●			●							Hard in web & irreg		386
387		●			●	●	●					Hard in web & irreg		387
388		●		●			●		●					388
389											●	Not split Worn		389
390											●		●	390
391		●			●							Hard in web		391

URGH

Sheet 13

Split Head Failures

x1" umul. t Lbs.	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed											Material Fair	Reference Numbers
			Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Steel Pres.	Frozen Road bed	Miscellaneous		
			Badly	Somewhat		in Head	in Web								
39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
750	251		●			●		●					Very hard in web		392
—	224		●			●							Hard in web		393
250	230		●			●		●					Very hard in web		394
750	197		●		●								Hardness irreg.		395
750	229												Possible flaw	●	396
—	245		●		●			●					Very hard in web		397
—	252					●		●					Very hard in web		398
50	231				●			●				●	P high. Irreg.		399
50	217			●		●				●		●			400
750	210												Defect in head	●	401
2250	220		●			●						●			402
—	230		●			●		●				●	Hard in web		403
550	259		●		●			●							404
2250	238		●					●			●				405
250	243			●		●		●							406
750	224		●			●									407
—	227			●									C high		408
750	230			●		●							C high		409
250	245		●		●			●					Hard in web		410
250	251		●		●			●					Very hard in web		411
250.	230		●			●									412
—	228		●			●							Hard in web		413
750	236		●			●		●					Hard in web		414
750	237		●			●		●					Hard in web		415
250	212		●			●									416
—	231		●			●							Hard in web		417
—	227		●			●							Hardness irreg.		418
750	228		●			●			●						419
750	246		●			●		●					Hard in web		420
—	208		●			●							Hardness irreg.		421
—	234		●			●									422
250	228		●		●										423
750	206		●			●							Hard in web		424
250	232		●			●						●			425
—	239		●			●		●				●			426
250	214		●			●	●					●			427
350	226		●			●						●	Hard in web		428
250	235		●			●	●	●				●	Hard in web		429
—	227		●			●						●			430
250	240		●			●		●	●			●			431
250	231		●			●						●	Hard in web		432
250	248		●					●	●			●	Hard in web		433

PENNSYLVANIA LINES WEST OF PITTSBURGH

Sheet 13

STUDY OF RAIL FAILURES IN MAIN TRACKS

Bessemer Process

March-1913

Split Head Failures

Reference Number	Wt of Rail Lbs/Yd	Rail Section	Manufacturer	Year Rolled	Position in Ingot	Years in Service	[illegible]	Ballast	Chemical Analysis of Rail: Carbon			Manganese			Phosphorus			Silicon			Sulphur			Tensile Strength	Elastic Limit	Elongation Percent	Reduction of Area Percent	Character of Fracture	Drop Test - Supports 42 apart - 50 Lb Tup: Test Piece at D: Blows at			Initial Deflec	Accumul Foot Lbs	Test Piece at E: Blows at			Initial Deflec	Accumul Foot Lbs	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed: Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign [illegible]	Frozen Road Bed	Miscellaneous	Material [illegible]	Reference Numbers
									Head	Web	Base	Head	Web	Base	Head	Web	Base	Head	Web	Base	Head	Web	Base	Lbs per Sq In					5 Ft	10 Ft	15 Ft			3 Ft	6 Ft	10 Ft					Badly	Somewhat	Very Brittle	in Head	in Web								
392	85	PS	Carnegie	90	C	1 Yr 9 Mo	+	S	49	68	59	87	91	89	.088	.144	[illegible]	.07	.066	.056	.038	.066	.054	124325	60370	3.25	3.34	G	2	–	–	9/16	500	5	5	3	1 5/32	20750	251		●			●		●					Very hard in web		392
393					"	1 0		.	50	62	52	74	78	76	.098	.11	.098	.080	.078	.080	.022	.051	.039	113300	58035	9.3	12.1	.	–	–	–	–	–	–	–	–	–	–	224		●			●							Hard in web		393
394	"	"	"		"	1 0	.	G	47	70	60	85	1.00	.93	.080	.133	.08	.080	.088	.075	.036	.035	.057	115900	72600	8.25	8.44	S & G	3	–	–	9/16	750	5	5	30	[illegible]	7250	230		●			●		●					Very hard in web		394
395	"	"	"		A	1 0			44	68	69	77	80	80	.080	.158	.45	.080	.090	.080	.033	.075	.068	84200	65860	5.5	6.78	G	1	–	–	–	250	5	5	1	1 3/16	2750	37		●		●								Hardness irreg		395
396		"		"	D	1 0			50	49	50	1.08	1.10	1.08	.105	.098	.102	.101	.125	.116	.020	.028	.025	118050	63460	17.0	29.13		5	5	33	9/16	28500	5	5	23	1 5/16	13750	229												Possible flaw	●	396
397	.	.	"	"	C	1 0	L	S	48	63	53	95	1.02	98	.087	.10	.102	.122	.167	.122	.031	.040	.038	98000	68900	3.0	3.5	.	3	–	–	1/2	750	–	–	–	–	–	245		●		●			●					Very hard in web		397
398		.	"	.	B	1 0	–		56	54	58	99	99	1.00	.100	.098	.104	.150	.155	.150	.039	.037	.040	131100	62680	4.0	7.46	"	1	–	–	–	250	–	–	–	–	–	252					●		●					Very hard in web		398
399	.	"	"	"	"	1 0	T	G	57	55	51	74	76	.75	.112	.122	.107	.080	.080	.080	.036	.045	.036	110500	57910	5.5	3.58	"	–	–	–	–	–	5	5	2	1 1/8	3250	231				●			●				●	P high Irreg		399
400	.	"	.	"	C	1 0			45	55	47	88	95	89	.086	.07	.10	.07	.058	.085	.031	.047	.032	111350	63650	9.0	20.25	S	3	–	–	3/4	750	5	5	2	1 1/2	3250	217			●		●				●		●			400
401	"	.	"		D	0 3	"	"	48	43	46	85	85	85	.110	.094	.103	.098	.103	.127	.030	.027	.030	[illegible]200	65750	20.25	33.8	S & G	5	5	59	5/8	48000	5	5	47	1 3/32	25750	2[illegible]0												Defect in head	●	401
402	"	.	I.S.W.	1911	A	0 8	L		51	63	.50	91	91	90	.091	.137	.097	.141	.136	.136	.021	.032	.021	99540	58800	1.70	30.9	G	5	4	–	9/16	3250	5	5	40	1 5/16	22250	220		●			●						●			402
403		"	.			0 7	-	.	59	69	55	85	93	90	.120	.166	.110	.108	.113	.113	.021	.073	.018	115000	56480	1.60	2.32	S & S	[illegible]	–	–	1/16	1000	–	–	–	–	–	230		●			●		●				●	Hard in web		403
404		"				0 4			51	66	51	97	1.05	97	.087	.144	.079	.050	.050	.050	.019	.037	.019	108250	63565	5.25	6.65	G	2	–	–	9/32	500	5	3	–	1 1/8	650	259		●		●			●							404
405		.	"		"	0 2	.	"	47	62	49	93	97	93	.081	.125	.086	.125	.127	.125	.016	.028	.028	111450	59140	11.75	18.34		5	5	43	9/16	36000	5	5	32	1 3/8	8250	238		●					●			●				405
406					.	0 2	.	.	50	57	49	1.00	1.02	.99	.083	.118	.080	.099	.097	.099	.021	.033	.021	103000	60680	4.3	3.8		5	3	–	9/16	2750	5	5	34	1 1/4	19250	243			●		●		●							406
407	100	A A	Carnegie	1909	88	3 Yr 8 Mo	T	S	47	71	45	97	1.02	95	.085	.139	.088	.085	.094	.134	.037	.096	.046	104800	55500	9.5	15.40	.	5	1	–	5/8	1750	5	5	37	7/8	20750	224		●			●									407
408					–	3 [illegible]	.		57	58	55	1.06	1.06	1.06	.109	.120	.104	.089	.089	.089	.056	.067	.056	[illegible]8400	62200	15.5	26.10	Fr	5	5	22	1/2	20250	–	–	–	–	–	227			●									C high		408
409	.	.			88	3 6	L	G	55	62	58	1.04	99	1.03	.104	.117	.107	.089	.089	.089	.059	.068	.057	126650	67225	11.5	16.2		5	1	–	9/16	1750	5	5	31	1 1/8	17750	230			●		●							C high		409
410	.		"		.	3 6	H	.	59	73	53	1.16	1.18	1.17	.085	.118	.087	.036	.071	.066	.063	.080	.057	[illegible]02950	65760	3.0	1.9	G	5	1	–	[illegible]	1750	5	5	8	1	6250	245		●		●			●					Hard in web		410
411					.	3 4	T	.	58	72	56	1.10	1.13	1.10	.098	.127	.096	.06	.06	.061	.052	.072	.051	99000	64540	2.0	2.29		1	–	–	–	250	5	5	–	1	2250	251		●		●			●					Very hard in web		411
412		–				3 4	"		52	63	55	1.01	1.02	1.02	.090	.112	.099	.047	.047	.047	.059	.055	.057	90720	46975	5.5	[illegible]	Fr	5	3	–	9/16	2750	5	5	30	1 1/16	7250	230		●			●									412
413		"		.		3 3	"	S	52	66	50	78	79	79	.096	.129	.083	.056	.066	.06	.040	.054	.035	[illegible]2300	60260	4.25	4.19	.	2	–	–	9/16	500	–	–	–	–	–	228		●			●							Hard in web		413
414				.	.	3 3	.		54	69	53	86	90	86	.087	.137	.086	.058	.066	.075	.048	.069	.045	110250	59850	4.0	3.32	G	5	4	–	1/2	3250	5	5	53	1 3/16	28750	236		●			●		●					Hard in web		414
415			"	.		3 2	"	G	54	73	54	97	1.03	97	.092	.136	.091	.075	.066	.075	.063	.102	.062	93915	63[illegible]	7.75	2.29	.	5	–	–	1/2	1250	5	5	19	1 3/16	11750	237		●			●		●					Hard in web		415
416			.	.	.	3 2	.	S	45	[illegible]	46	83	87	83	.090	.141	.082	.056	.056	.052	.041	.075	.048	[illegible]3900	55[illegible]	[illegible]	[illegible]	[illegible]	5	1	–	9/16	750	5	5	22	1 1/4	13250	212		●			●									416
417			.	.		3 2	.	.	49	74	[illegible]	93	97	92	.079	.123	.078	.056	.056	.06	.020	.05	.036	[illegible]650	54820	13.75	20.98	S & S	2	–	–	9/[illegible]	500	–	–	–	–	–	231		●			●							Hard in web		417
418		"	.			3 2	"		48	66	47	[illegible]	1.02	98	.087	.156	.085	.071	.071	.075	.029	.087	.030	114650	54930	11.5	15.98	Fr	3	–	–	[illegible]	750	–	–	–	–	–	227		●			●							Hardness irreg		418
419			.			3 2	H	G	54	65	50	97	97	96	[illegible]	.127	.093	.066	.060	.066	.052	.072	.047	100450	62840	2.25	2.67	G	3	–	–	1/2	750	5	5	1	1 1/16	2750	228		●			●			●						419
420						3 2	T	S	5[illegible]	7[illegible]	[illegible]	9[illegible]	[illegible]	[illegible]	[illegible]	.148	[illegible]	[illegible]	[illegible]	[illegible]	.03	.032	.036	[illegible]980	59902	1.5	1.78		5	–	–	9/16	1250	5	5	27	1 1/16	15750	246		●			●		●					Hard in web		420
421					.	3 2	.	.	44	62	46	[illegible]	[illegible]	77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	49780	15.0	[illegible]	Fr	5	1	–	[illegible]	1750	–	–	–	–	–	208		●			●							Hardness irreg		421
422			.			3 2	.		47	67	49	89	97	92	[illegible]	.139	[illegible]	.061	[illegible]	.061	.032	[illegible]	.03	111250	539[illegible]	12.5	16.96	.	1	–	–	–	250	–	–	–	–	–	234		●			●									422
423						3 1	H	G	52	[illegible]	50	97	1.02	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	107750	64320	3.0	3.70	.	5	5	1	1/2	4500	5	5	2	1 1/8	3250	228		●		●										423
424					.	3 0	T	S	42	63	45	79	92	.73	[illegible]	.130	[illegible]	[illegible]	.062	.071	[illegible]	.100	[illegible]	107000	50130	15.0	21.31	S & S	2	–	–	[illegible]	500	5	5	49	1 1/4	26750	206		●			●							Hard in web		424
425						2 10	.	[illegible]	50	70	[illegible]	1.01	1.05	1.03	[illegible]	.116	.103	[illegible]	[illegible]	.068	[illegible]	[illegible]	[illegible]	123800	64160	[illegible]	6.24	.	3	–	–	[illegible]	750	5	5	4	1 1/32	9250	232		●			●						●			425
426	.	.	.	.	B	2 9	.	–	53	68	62	97	[illegible]	97	[illegible]	[illegible]	.102	.07	.071	.071	[illegible]	[illegible]	.038	108995	60690	9.5	2.13	Fr	[illegible]	–	–	15/[illegible]	250	–	–	–	–	–	239		●			●		●				●			426
427	.		"	.	88	2 9	"	S	53	69	57	91	96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.08	[illegible]	[illegible]	[illegible]	.03	84610	61850	25	2.29		5	5	9	9/16	10500	5	5	12	1 9/16	8250	214		●			●	●					●			427
428					.	2 9	.	G	55	73	52	1.08	1.13	1.09	[illegible]	[illegible]	.04	.05	.05	.05	.03	[illegible]	.0[illegible]	78210	55640	1.25	1.52	G	1	–	–	–	250	5	5	46	1 [illegible]	26250	226		●			●						●	Hard in web		428
429			"			2 9	H	.	57	69	5[illegible]	1.04	1.09	1.07	.09	.12	[illegible]	[illegible]	.04	[illegible]	[illegible]	[illegible]	[illegible]	125550	63900	11.5	14.59	.	2	–	–	19/[illegible]	500	5	5	–	1 [illegible]	2250	235		●			●	●	●				●	Hard in web		429
430	.		.	.		2 9	T		56	73	51	92	98	90	[illegible]	[illegible]	[illegible]	[illegible]	.073	[illegible]	[illegible]	[illegible]	[illegible]	119300	65640	5.5	5.47	.	5	–	–	9/16	1250	–	–	–	–	–	227		●			●						●			430
431			.	.	.	2 8	H		54	60	57	1.02	1.02	1.02	[illegible]	.122	.110	[illegible]	[illegible]	[illegible]	.04	[illegible]	[illegible]	117950	59520	7.25	6.48	Fr	[illegible]	4	–	15/32	3250	5	5	34	1 5/16	19250	240		●			●		●	●			●			431
432						2 8	T	G	5[illegible]	7[illegible]	58	[illegible]	1.10	1.09	[illegible]	[illegible]	.10	[illegible]	.05	[illegible]	[illegible]	[illegible]	[illegible]	92860	60610	2.5	1.78	G	3	–	–	1/2	750	5	5	56	1 [illegible]	32250	231		●			●						●	Hard in web		432
433	100	[illegible]		1909	B	2 7			[illegible]	76	72	83	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]4320	69970	5.0	4.07	.	5	4	–	[illegible]	3250	5	5	54	[illegible]	29250	248		●					●	●			●	Hard in web		433

BURGH

Sheet 14

Split Head Failures

o r 1" cumul. oot Lbs.	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed											Material Fair	Reference Numbers
			Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Steel Pres	Frozen Road bed	Miscellaneous		
			Badly	Some what		in Head	in Web								
39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
0750	243		●		●			●					Hard in web		434
—	238														434A
6250	232		●										Hard in Web		435
2750	238		●			●		●							436
6250	241		●					●					Hardness Irreg		437
24250	242		●			●		●				●			438
22750	218			●		●						●			439
8750	227		●			●				●		●	Hard in Neck		440
29750	253		●			●		●					Hardness Irreg		441
4750	246		●			●		●					Hard in Neck		442
9750	250		●			●		●					Hard in Web		443
2750	241		●			●		●					Hard in Web		444
—	—		●		●										445
3250	252		●		●			●							446
0750	246		●			●		●							447
4750	258		●			●		●							448
3250	217		●			●							Hard in Web		449
0750	252		●			●		●				●	Hard in Web		450
350	242		●		●			●				Little			451
0750	243		●			●		●				●			452

BURGH

Sheet 15

Split Web Failures

p × 1" cum'ld. ot Lbs.	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed											Material Fair	Reference Numbers
			Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Steel Pres.	Frozen Road bed	Miscellaneous		
			Badly	Some-what		in Head	in Web								
39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
3250	199		●			●									453
25750	221		●										S.high. Split head		454
9250	195												A little soft		455
2250	225			●						●			Hard in neck		456
7750	242		●					●		Split head			Hard in web		457
1650	217	●										●		●	458
—	264		●		●			●				●	Split head		459
—	206										●		Soft. Irreq.		460
600	240			●				●		●			Poor Ductil. Piped		461
750	249		●		●					●			Piped		462
300	255	●	●		●			●		●		●			463
7250	246							●					Possible flaw	●	464
2750	238		●			●				Split head			Hard in base		465
350	276					●	●	●							466

PENNSYLVANIA LINES WEST OF PITTSBURGH
STUDY OF RAIL FAILURES IN MAIN TRACKS

Sheet 14

Bessemer Process

March-1913

Split Head Failures

Reference Number	Wt of Rail Lbs/Yd	Rail Section	Manufacturer	Year of Rolling	Position in Ingot	Years in Service	High Low R or Tangent	Ballast	Chemical Analysis of Rail: Carbon			Manganese			Phosphorus			Silicon			Sulphur		
									Head	Web	Base	Head	Web	Base	Head	Web	Base	Head	Web	Base	Head	Web	Base
434	85	ASCE	Carnegie	1909	B	2 Yr 6 Mo	T	S	54	63	57	86	96	90	.098	.123	.102	[illegible]	[illegible]	[illegible]	.034	.032	.039
434A			"		—	2 5			54	70	83	89	93	92	.088	.121	.117	.075	.075	.071	.033	.067	.044
435					BB	2 5	H		51	60	54	96	98	98	.086	.108	.095	.039	.06	.06	.032	.041	.035
436					"	2 5		G	44	57	54	89	92	9	.086	.127	"	.038	.038	.038	.042	.072	.060
437					B	2 0	T	S	48	65	52	90	94	9	.084	.122	.095	.06	.058	.061	.027	.056	.035
438			"		"	2 0	H	G	52	73	62	85	90	86	.091	.133	.100	.061	.061	.061	.041	.079	.054
439		"	-	-	"	2 0	T		47	55	53	91	94	92	.087	.125	.099	.061	.052	.053	.040	.079	.062
440	"		"		"	2 0		S	48	70	60	91	98	96	.087	.131	.107	[illegible]	[illegible]	[illegible]	.036	.039	.032
441			"			2 0	—	G	52	67	57	98	101	99	.086	.123	.093	.047	.052	.053	.035	.062	.041
442				"		2 0	T		51	62	59	98	103	101	.090	.125	.118	.038	.056	.038	.038	.063	.057
443			"		"	2 0			58	71	58	105	107	106	.092	.118	.088	[illegible]	[illegible]	[illegible]	[illegible]	.038	.040
444						2 0			54	68	54	87	90	87	.093	.128	.087	.039	.036	.057	.039	.068	.045
445						1 0		S	56	72	51	90	96	95	[illegible]	[illegible]	[illegible]	.066	.072	.055	—	—	—
446			"	"		1 0	"	G	52	65	54	95	100	97	.084	.137	.124	.038	.042	.042	.037	.084	.06
447					"	1 0	"	S	52	67	66	90	92	93	.083	.121	[illegible]	[illegible]	[illegible]	[illegible]	.032	.043	.051
448			"			1 0	"	G	54	75	66	86	89	88	.093	.125	[illegible]	[illegible]	.066	.06	.04	.07	.045
449					"	1 0		"	42	60	50	79	84	80	.078	.137	.088	[illegible]	[illegible]	[illegible]	.037	.059	.038
450	"		"	"		1 0	L	S	53	68	57	94	99	95	.094	.125	[illegible]	.075	.085	.075	.040	.061	.042
451				-	"	1 0	T	G	52	68	58	92	97	98	.092	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.035
452		"	"	-	-	1 0		S	52	62	54	95	100	97	.084	.128	[illegible]	.066	.066	.066	.037	.065	.044

Reference Number	Tensile Strength	Elastic Limit	Elongation per cent in 2 inches	Reduction of Area per cent of Orig Sect	Character of Fracture	Drop Test - Supports 12' apart - 50 Lb Tup: Test Piece at D, Blows at			Initial Deflec	Accum Foot Lbs	Test Piece at E, Blows at			Initial Deflec	Accum Foot Lbs	Brinell Hardness
	Lbs per Sq In	Lbs per Sq In				5 Ft	10 Ft	15 Ft			3 Ft	6 Ft	10 Ft			
434	6000	62300	7.25	10.45	G	5	5	9	9/16	8000	5	5	5	1 3/16	30750	243
434A	97800	68290	3.75	5.6		4	—	—	9/16	1000	—	—	—	—		238
435	94900	62000	4.5	2.05		5	5	48	19/32	39750	5	5	48	1/4	20250	232
436	2600	65235	4.0	5.2		2	—	—	5/8	500	5	5	8	1 3/8	32750	238
437	08000	74020	3.5	3.44		5	5	16	3/4	5250	5	5	28	1"	16250	231
438	7500	73300	5.75	6.99		1	—	—	—	250	5	5	44	1"	24250	232
439	[illegible]	63425	4.5	1.2		1	—	—	—	250	5	5	4	1 1/4	22750	218
440	98800	67250	3.25	2.69		5	3	—	3/8	2750	5	5	33	[illegible]	8750	227
441	98450	72180	3.0	2.53		1	—	—	—	250	5	5	55	1	29750	253
442	4200	[illegible]985	5.25	4.28	-	—	—	—	—	—	5	5	5	15/16	4750	246
443	38000	55780	4.5	4.38		1	—	—	—	250	5	5	25	1 1/8	19750	250
444	5250	64040	4.5	5.28		3	—	—	[illegible]	750	5	5	41	1 1/4	22750	241
445	82940	80080	[illegible]	2.08	Crystal	—	—	—	—	—	—	—	—	—	—	—
446	7200	83930	4.0	2.31	G	3	—	—	[illegible]	750	5	5	2	1/4	3250	252
447	4500	83460	5.5	4.4		3	—	—	1/2	750	5	5	37	1	20750	246
448	[illegible]470	68350	2.0	2.04		2	—	—	1/2	500	5	5	25	1 5/16	14750	258
449	20300	64800	12.0	4.3		2	—	—	9/16	500	5	5	22	[illegible]	13250	217
450	2600	74525	8.5	8.1		4	—	—	9/16	300	5	5	57	[illegible]	30750	252
451	24750	67720	5.0	4.92		3	—	—	2	750	5	2	—	[illegible]	350	242
452	9000	66600	8.0	2.86	S&G	5	1	—	9/16	750	5	5	37	[illegible]	20750	243

Reference Number	In Joint	Defects in Quality of Material and Road Bed: Segregated Body	Segregated Somewhat	Very Brittle	Somewhat Brittle in Head	Somewhat Brittle in Web	Hard	Rolling Seam	Slag Present	Foreign Pipe Pres	Frozen Road Bed	Miscellaneous	Material Fair	Reference Number
434		●		●			●					Hard in [illegible]		434
434A														434A
435		●										Hard in Web		435
436		●			●		●							436
437		●					●					Hardness irreg		437
438		●			●		●				●			438
439			●		●						●			439
440		●			●				●		●	Hard in Neck		440
441		●			●		●					Hardness irreg		441
442		●			●		●					Hard in Neck		442
443		●			●		●					Hard in web		443
444		●			●		●					Hard in web		444
445		●		●										445
446		●		●			●							446
447		●			●		●							447
448		●			●		●							448
449		●			●							Hard in web		449
450		●			●		●				●	Hard in web		450
451		●		●			●				[illegible]			451
452		●			●		●				●			452

PENNSYLVANIA LINES WEST OF PITTSBURGH
STUDY OF RAIL FAILURES IN MAIN TRACKS

Sheet 15

Bessemer Process

March-1913

Split Web Failures

Reference Number	Wt of Rail Lbs/Yd	Rail Section	Manufacturer	Year of Rolling	Position in Ingot	Years in Service	High Low R or Tangent	Ballast	Chemical Analysis of Rail: Carbon			Manganese			Phosphorus			Silicon			Sulphur		
									Head	Web	Base	Head	Web	Base	Head	Web	Base	Head	Web	Base	Head	Web	Base
453	85	PRR	Carnegie	1898	—	13 Yr 10 Mo	T	G	44	57	40	75	81	73	.098	.169	.080	.085	.089	.089	.017	.040	.014
454		ASCE	Ill S W	1904	—	7 0			52	66	48	87	92	86	.100	.141	.082	.122	.122	.122	.078	.33	.077
455		"	Carnegie	1907	—	3 0	T	C	50	44	48	63	62	64	.098	.085	.095	.075	.066	.061	.051	.048	.053
456	100	PS	"	1909	B	2 0	L	S	56	60	55	87	89	88	.100	.116	.102	.085	.082	.082	.036	.043	.041
457			Ill S W	1911	A	0 6		"	52	56	54	101	107	1.02	.085	.135	.094	.118	.116	.118	.034	.062	.043
458	85	"	" "	1909	C	2 9	T	G	52	51	53	94	93	.95	.091	.084	.090	.160	.160	.165	.030	.028	.03
459		"	Carnegie	"	AA	2 8	"	"	55	.73	58	1.00	1.12	1.00	.088	.146	.103	.075	.071	.075	.037	.064	.046
460	"	"	Ill S W	"	A	2 0	"	"	47	40	45	96	96	.96	.084	.093	.080	.17	.168	.139	.019	.023	.019
461	"	"	Carnegie	"	C	1 0	"	"	49	65	49	99	1.08	.99	.097	.125	.103	.139	.136	.138	.047	.070	.055
462	"	"	"	"	C	1 0	"	"	56	61	58	1.08	1.17	1.10	.100	.109	.101	.136	.254	.136	.053	.060	.054
463	"	"	"	"	D	Not Laid	"	"	54	70	54	1.10	1.23	1.11	.093	.119	.097	.127	.248	.127	.056	.081	.060
464	"		"	"	D	1 Yr 7 Mo			55	52	54	1.19	1.17	1.16	.105	.101	.106	.113	.108	.118	.061	.057	.059
465	"	"	"	1910	D	1 Yr 5 Mo	L	S	46	65	54	.78	.86	.81	.095	.140	.107	.094	.094	.094	.025	.057	.057
466	"	"	"	"	B	0 8	T	G	61	60	63	1.36	1.34	1.35	.095	.088	.093	.157	.151	.150	.037	.036	.038

Reference Number	Tensile Strength	Elastic Limit	Elongation per cent in 2 inches	Reduction of Area per cent of Orig Sect	Character of Fracture	Drop Test - Supports 12' apart - 50 lb Tup: Test Piece at D, Blows at			Initial Deflec	Accumul Foot Lbs	Test Piece at E, Blows at			Initial Deflec	Accumul Foot Lbs	Brinell Hardness
	Lbs per Sq In	Lbs per Sq In				5 Ft	10 Ft	15 Ft			3 Ft	6 Ft	10 Ft			
453	93090	43395	12.0	16.51	G&S	3	—	—	5/8	750	5	3	62	1 3/8	33250	199
454	108700	58500	18.25	35.5	"	5	5	35	9/16	30000	5	5	47	1 5/16	25750	221
455	105000	67205	9.0	25.93	Silky	5	5	39	9/16	33000	5	5	34	7/8	19250	195
456	116800	74710	7.0	7.27	Gran	5	5	3	9/16	13500	5	5	40	1 1/16	22250	225
457	125200	61700	13.75	17.74	"	5	5	30	9/16	26250	5	5	31	1 1/16	17750	242
458	114900	58315	9.35	30.87	FG&S	5	5	58	9/16	47250	5	3	—	1 9/32	1650	2 7
459	96500	67360	1.75	2.0	G	4	—	—	1/2	1000	—	—	—	—	—	264
460	120550	62145	15.5	24.56	S&G	5	5	51	11/16	42000	—	—	—	—	—	206
461	116750	74200	12.5	21.18	G	1	—	—	—	250	4	—	—	1"	800	240
462	127550	67950	10.0	12.68	"	5	5	3	1/2"	6000	5	5	9	15/16"	8750	249
463	105900	70985	2.5	3.33	"	3	—	—	1/2	750	2	—	—	1 1/16	300	255
464	123400	78070	15.8	22.54	S&G	5	5	51	1/2	42000	5	5	30	7/8	17250	246
465	112200	55590	10.75	11.47	G	2	—	—	19/32	500	5	5	41	1 1/4	22750	238
466	142450	72220	11.0	.91	"	5	5	1	1/2	4500	5	2	—	7/16	1350	278

Reference Number	In Joint	Defects in Quality of Material and Road Bed: Segregated Body	Segregated Somewhat	Very Brittle	Somewhat Brittle in Head	Somewhat Brittle in Web	Hard	Rolling Seam	Slag Present	Foreign Pipe Pres	Frozen Road Bed	Miscellaneous	Material Fair	Reference Numbers
453		●			●									453
454		●										Slight Split head		454
455												A little soft		455
456			●						●			Hard in neck		456
457		●					●		Split head			Hard in neck		457
458	●										●		●	458
459		●		●			●				●	Split head		459
460										●		Soft Irreg		460
461			●				●		●			Poor Ductil Piped		461
462		●		●					●			Piped		462
463	●	●		●			●		●		●			463
464							●					Possible flaw	●	464
465		●			●				Split head			Hard in base		465
466					●	●	●							466

BURGH

Sheet 16

Broken Base Failures

Top " x 1" ccumul. ot Lbs.	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed											Material Fair	Reference Numbers
			Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Steel Pres.	Frozen Road bed	Miscellaneous		
			Badly	Somewhat		in Head	in Web								
19250	211											●		●	468
17250	225											●	Line & surface fair	●	469
1250	239							●	●			●	C.& Mn. high		470
5760	246							●		Ties fair		●	Line & surface fair		471
3750	239							●	●				Rolling seam in head		472
21750	207								●			●	Rolling seam in web	●	473
18250	239							●						●	474
14250	226											●	Line & surface fair	●	475
9750	204									Ties fair			Line & surface poor	●	476
24750	256					●		●				●	Line & surface fair		477
2250	243		●		●			●				●	Line & surface fair		478
25250	223											●	Line & surface fair	●	479
20750	236								●			●	Line & surface fair	●	480
19750	231	Ties fair. Flaw in head. Mn. & S. high.										●	Line & surface fair		481
600	230						●					●			482
26750	232											●	S. high	●	483
16250	204									Ties fair		●	Line & surface fair	●	484
12250	223		3 pieces broken out							Ties fair		●	Line & surface fair	●	485
17250	222									Ties fair		●	Line & surface fair	●	486
17250	253					Mn high		●		Ties fair			Line & surface fair	●	487
15250	213													●	488
5250	229												Slight defect in base	●	489
16250	207											●		●	490
18250	198											●	Little soft	●	491
14250	219					●						●			492
16250	220											●			493
24750	212											●	Possible rolling seam	●	494
—	225			●								●	C. high		495
20750	213		●										Hard in web		496
13250	222		●									●	Hard in neck		497
11250	257							●				●			498
16750	213	●												●	499
28250	246							●				●	C. high		500
23750	230											●		●	501
25250	235											●	Little hard	●	502
14750	251		●			●		●				●	Line & surface fair		503
5250	215						●		●			●	Line & surface fair		504
29750	212											●		●	505
—	232											●	Little hard	●	506
30750	225												Possible rolling seam	●	507
—	231								●	●		●			508
2750	241						●	●				●			509

PENNSYLVANIA LINES WEST OF PITTSBURGH
STUDY OF RAIL FAILURES IN MAIN TRACKS

Bessemer Process

March -1913

Broken Base Failures

Reference Number	Weight of Rail Lbs per Yd	Rail Section	Manufacturer	Year of Rolling	Rail in Ingot	Years in Service	Position in Track	Ballast	Carbon Head	Carbon Web	Carbon Base	Manganese Head	Manganese Web	Manganese Base	Phosphorus Head	Phosphorus Web	Phosphorus Base	Silicon Head	Silicon Web	Silicon Base	Sulphur Head	Sulphur Web	Sulphur Base	Tensile Strength Lbs per Sq In	Elastic Limit Lbs per Sq In	Elongation Percent in 2 inches	Reduction of Area	Character of Fracture	Drop Test 'D' Blows at 5 Ft	'D' Blows at 10 Ft	'D' Blows at 15 Ft	'D' Total Deflec.	'D' Energy Ft Lbs	Drop Test 'E' Blows at 3 Ft	'E' Blows at 6 Ft	'E' Blows at 10 Ft	'E' Total Deflec.	'E' Accum. Foot Lbs	Brinell Hardness	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] Head	[illegible] Web	Hard	Rolling Seam	Slag Present	Foreign Substances	Frozen Roadbed	Misc[illegible]	[illegible]	Reference Number
468	85	PAR	Ill S W	1897	–	14Yr 0Mo		G	47	45	46	.5	.6	.115	.081	.077	.081	.65	.55	.55	.018	.062	.056	98700	55650	210	379	S	5	5	35	1 1/32	30500	5	5	34	5/32	19250	211											●		●	468
469			Carnegie	1898	–	13 8			51	47	50	81	85	82	.103	.087	.103	.22	.22	.27	.027	.022	.028	[illegible]	53580	90	239	Fg & S	5	5	28	5/8	24750	5	5	30	[illegible]	7250	224											●	Line & surface fair	●	469
470		ASCE		1906	–	5 10	L		63	61	64	.23	.22	.25	.092	.084	.090	.18	.22	.18	.040	.042	.041	130450	64370	140	2046	G	5	5	49	2	40500	5	5	58	1 1/16	12250	239							●	●			●	C & Mn high		470
471			"	1905	–	6 9	H		59	57	59	.08	.07	.108	.102	.093	.092	.13	.132	.132	.050	.042	.043	122450	63120	150	347	Fg & S	5	5	41	9/16	34500	5	5	7	1 5/32	5750	246							●		Ties fair		●	Line & surface fair		471
472			"	"	–	6 5	T		57	54	57	.14	.114	.115	.094	.089	.093	.075	.085	.075	.032	.027	.031	122300	61895	165	2705	"	5	5	43	7/8	36000	5	5	3	1 1/16	3750	239							●	●				[illegible]		472
473				"	–	6 5			52	50	57	96	93	95	.095	.089	.096	.090	.085	.085	.074	.032	.033	[illegible]	54830	2025	327		5	5	64	1/2	51750	5	5	39	1 9/32	[illegible]	[illegible]								●			●	[illegible] in web	●	473
474					–	5 0	H		58	52	53	.14	.113	.14	.098	.089	.095	.084	.094	.078	.031	.027	.030	121650	77920	160	2404	S & G	5	5	35	1/2	30000	5	5	32	3/4	18250	[illegible]							●						●	474
475			"	1906	–	5 8	"	"	53	49	.52	99	99	100	.097	.075	.087	.094	.085	.089	.037	.035	.038	112440	51240	170	323	Fg & S	5	5	33	5/8	28500	5	5	24	3/16	14250	226											●	Line & surface fair	●	475
476			"		–	5 5	T	"	51	47	.51	76	.76	78	.095	.088	.095	.103	.103	.108	.024	.022	.022	106200	52255	205	395		5	5	43	9/32	36000	5	5	35	[illegible]	19750	204									Ties fair			Line & surface poor	●	476
477			"	1907	–	4 10	H	G	58	55	57	.134	.135	.124	.096	.093	.095	.06	.107	.106	.050	.045	.049	128450	70480	125	2239	G	5	5	4	1/8	6750	5	5	45	9/32	24750	236					●		●				●	Line & surface fair		477
478					–	4 9	"	"	58	69	.59	.135	.142	.135	.100	.129	.101	.089	.089	.089	.074	.097	.079	110950	63860	50	37	Fg	5	1	–	9/16	1750	5	5	–	1 1/16	2250	242		●		●			●				●	Line & surface fair		478
479			"		–	4 8	"	"	50	47	.49	13	.113	.113	.094	.093	.093	.085	.094	.087	.054	.049	.052	113430	66250	65	3512	G & S	5	5	45	9/16	37500	5	5	46	3/16	25250	223											●	Line & surface fair	●	479
480	"		"		–	4 8	T		56	56	58	.111	.111	.113	.101	.097	.110	.108	.103	.113	.048	.048	.046	121830	62830	65	2657	Fg & S	5	5	59	5/8	48000	5	5	37	3/32	20750	236								●			●	Line & surface fair	●	480
481	"		"	"	–	4 8		"	53	53	52	.137	.136	.135	.084	.076	.087	.103	.108	.109	.063	.067	.065	119550	63625	1825	3137	"	5	5	56	1 1/16	45750	5	5	35	1 9/32	19750	231	Ties fair		Flaw in head				Mn & S high				●	Line & surface fair		481
482			"		–	4 8	"	"	54	52	53	.116	.118	.111	.096	.088	.092	.099	.099	.099	.025	.050	.053	118300	63920	80	3482	"	5	5	44	21/32	36750	4	–	–	7/8	600	230						●					●			482
483			"	"	–	4 4	L		51	53	51	.114	.116	.116	.113	.132	.129	.080	.085	.080	.061	.058	.060	114915	71320	175	336	G & S	5	5	49	9/16	40500	5	5	49	1 1/8	26250	23[illegible]											●	S high	●	483
484	"		"	"	–	4 4	T		54	52	54	86	85	86	.106	.096	.112	.056	.056	.052	.034	.032	.034	113550	61450	170	292	Fg & S	5	5	39	7/16	33000	5	5	28	1 5/32	16250	204									Ties fair		●	Line & surface fair	●	484
485			"		–	4 3	"		53	49	.5	100	99	101	.099	.082	.097	.26	.07	.27	.032	.027	.028	116670	63730	180	345		5	5	35	9/16	30000	5	5	20	1/4	12250	223		3 pieces broken out							Ties fair		●	Line & surface fair	●	485
486					–	4 3			52	50	51	94	92	94	.106	.098	.098	.089	.085	.089	.048	.041	.046	113560	55445	80	300		5	5	6	9/16	8250	5	5	30	3/16	17250	222									Ties fair		●	Line & surface fair	●	486
487					–	4 0	L	S	58	55	57	.132	.131	.132	.094	.094	.092	.122	.22	.22	.048	.046	.044	130650	72000	155	261	G & S	5	5	40	7/8	33750	5	5	30	1"	17250	253					Mn high		●		Ties fair			Line & surface fair	●	487
488		PS		1909	AA	3Yr 7Mo	"	G	52	48	53	91	91	92	.107	.088	.098	.061	.066	.071	.049	.043	.051	110100	54510	190	3163	Fg & S	5	5	47	5/8	39000	5	5	26	1/2	15250	213													●	488
489			Ill S W		A	3 1		"	51	49	50	.89	88	90	.107	.106	.107	.179	.179	.179	.021	.020	.019	113200	60865	190	3584		5	5	63	9/16	51000	5	5	6	3/32	5250	229												Slight defect in base	●	489
490				"	C	2 11	T	"	50	46	50	89	93	90	.092	.087	.092	.132	.65	.32	.028	.025	.025	116450	53140	2025	3720	S	5	5	66	7/32	53250	5	5	28	1/4	16250	207											●		●	490
491					–	2 8	H		48	46	.50	94	94	94	.087	.077	.090	.136	.46	.136	.041	.033	.041	105250	53855	225	3776	–	5	5	82	21/32	65250	5	5	32	1/4	18250	198											●	Little soft	●	491
492					C	2 8		"	51	47	51	100	98	100	.099	.088	.102	.41	.36	.141	.032	.030	.032	115050	60915	205	3202	Fg & S	5	–	–	1/2	1250	5	5	24	5/16	14250	219					●						●			492
493					B	2 8	T	G	47	44	49	91	94	95	.091	.084	.093	.41	.46	.146	.038	.036	.038	100350	55525	210	3625	–	5	5	67	21/32	54000	5	5	28	1 5/32	16250	220											●			493
494					C	2 7		"	48	47	.48	92	95	97	.093	.090	.093	.176	.146	.141	.025	.028	.025	110225	59515	2225	3699	S	5	5	92	5/16	72750	5	5	45	1 5/16	24750	212											●	Possible rolling seam	●	494
495				"	B	2 7		–	59	61	58	107	108	.107	.094	.103	.093	.150	.150	.150	.035	.037	.033	125275	64770	175	2717	Fg & S	5	5	54	21/32	44250	–	–	–	–	–	225			●								●	C high		495
496			Carnegie		C	2 7	T	Cind	43	60	46	76	7?	77	.079	.147	.095	.097	.274	.08	.030	.046	.035	112850	57525	1975	2864	G	5	5	39	7/32	33000	5	5	37	5/8	20750	213		●										Hard in web		496
497					DD	2 0	H	G	55	51	55	106	109	106	.108	.104	.106	.56	.160	.150	.037	.034	.033	117700	60585	180	3023	Fg	5	5	43	9/16	36000	5	5	22	1 1/2	13250	222		●									●	Hard in neck		497
498					CC	2 0	H		57	57	58	.105	.105	.104	.114	.109	.110	.65	.60	.155	.033	.029	.032	126700	66510	150	2071		5	5	50	9/16	41250	5	5	8	5/32	11250	257							●				●			498
499			Ill S W		A	2 0	T		52	50	.51	76	.76	76	.099	.097	.099	.113	.113	.109	.047	.048	.045	111100	61955	2056	2816	G & S	5	5	39	5/8	33000	5	5	29	1"	6750	213	●												●	499
500			Carnegie	1910	D	2 0	H	"	60	57	59	.18	.119	.18	.132	.095	.105	.22	.22	.22	.043	.039	.044	126960	63825	150	2 88	G	5	5	55	15/32	45000	5	5	52	1 5/16	28250	246							●				●	C high		500
501					DD	1 10		"	54	51	53	.106	.109	.109	.08	.095	.102	.107	.113	.113	.034	.031	.031	118550	61855	165	2820	Fg & S	5	5	62	9/32	50250	5	5	43	1 9/32	23750	230											●		●	501
502						1 9	L	"	54	57	55	105	.124	.105	.118	.095	.109	.122	.113	.113	.023	.020	.023	119300	62170	190	2857	"	5	5	56	9/16	45750	5	5	46	1 1/8	25250	235											●	Little hard	●	502
503	"		Ill S W	1911	A	1 0	T	"	54	61	56	106	107	.105	.090	.132	.101	.155	.155	.165	.020	.029	.021	126720	65270	150	236	"	5	5	2	5/8	5250	5	5	25	1 5/32	4750	251		●			●		●				●	Line & surface fair		503
504			"	"	C	0 9			50	49	51	110	110	111	.094	.091	.093	.174	.174	.174	.033	.032	.034	116800	59850	1925	3023	"	5	5	80	9/16	63750	5	5	6	5/32	5250	215						●		●			●	Line & surface fair		504
505	"		"	"	D	0 7	H		51	47	51	95	94	94	.105	.094	.095	.32	.32	.127	.036	.035	.035	107500	58010	200	3622	"	5	5	60	17/32	48750	5	5	55	1 1/8	23750	212											●		●	505
506	"		"		B	0 7	"	"	57	56	56	91	90	89	.105	.098	.100	.88	.188	.188	.029	.026	.026	119600	59365	170	2685	"	5	5	53	5/8	43500	–	–	–	–	–	232											●	Little hard	●	506
507					D	0 7	L		54	50	54	97	96	97	.096	.088	.096	.141	.141	.136	.041	.044	.044	115700	60480	1825	3277		5	5	64	1 1/32	51750	5	5	57	21/32	30750	225												Possible rolling seam	●	507
508					D	0 6	H	"	54	51	54	103	98	.102	.107	.090	.096	.79	.165	.165	.023	.021	.021	116350	60700	180	3130		5	5	52	9/16	42750	–	–	–	–	–	231								●	●		●			508
509					C	0 6	L		53	52	54	98	94	.99	.09	.096	[illegible]	.45	.41	.150	.030	.031	.028	120000	63600	160	298	Fg	5	5	46	5/8	38250	5	5	1	1 5/16	2750	241						●	●				●			509

GH

Sheet 17

ll Types of Failures

1"			Defects in Quality of Material and Road Bed													
cumul. ot Lbs.	Brinell Hardness	In Joint	Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Slet Pres	Frozen Road bed	Misceilaneous	Material Fair	Reference Numbers
			Badly	Somewhat		in Head	in Web								
5250	264	●					●			●			P&S high		510
—	305														511
050	307														512
7750	308														513
—	331														514
—	330														515
250	255										●		Tie plates on stool	●	516
750	247										●		Tie plates on stool		517
—	294		●		●			●							518
—	256										●		Tie plates on stool		519
5250	213												Defect in head Soft	●	520
750	226						●				●				521
—	206										●		Tie plates on stool		522
750	250		●								●				523
250	223										●				524
250	224												Defect in head	●	525
250	237			●							●				526
750	244			●							●	●	Low Ductility		527
—	—							●					C high		528
5750	209			●							●				529
—	226	●									●	●	S high		530
—	233											●	P a little high		531
—	267	●		●		●		●				●			532
—	258	●		●											533

PENNSYLVANIA LINES WEST OF PITTSBURGH

STUDY OF RAIL FAILURES IN MAIN TRACKS

Open Hearth Processes

March-1913

All Types of Failures

Reference Number	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Chemical Analysis of Rail															[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Drop Test [illegible] Tup										[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Reference Number
											Carbon			Manganese			Phosphorus			Silicon			Sulphur								Test Piece "D"					Test Piece "E"																			
																															Blows of			[illegible]	[illegible]	Blows of			[illegible]	[illegible]															
	Bronot [illegible]			[illegible]	[illegible]	[illegible]	C	6 Mo	L	S	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2850	[illegible]	[illegible]	[illegible]	5	5	5	[illegible]	8250	5	5	6	[illegible]	5250	224	●					●			●			[illegible]		
[illegible]		85		[illegible] 70		[illegible]	A	0			81	83	82	83	82	82	.024	[illegible]	.024	63	[illegible]	[illegible]	[illegible]	.024	[illegible]	[illegible]	[illegible]	6.5	9.3	G	3	—	—	[illegible]	750	—	—	—	—	—	[illegible]														[illegible]
512							[illegible]	0			84	82	82	80	83	80	.024	.024	.023	81	81	85	.023	.026	.027	52350	85000	60	12.8		5	2	—	[illegible]	2250	5	1	—	[illegible]	250	[illegible]														512
513					1901	[illegible]	H	1 6	4	0	83	84	84	87	90	89	.025	.024	.026	[illegible]	[illegible]	[illegible]	.022	.023	.023	[illegible]525	84 80	4.0	6.7		—	—	—	—	—	5	5	[illegible]	9/16	750	[illegible]														513
514								1 6			88	84	86	87	87	90	.029	.024	.025	.065	[illegible]	[illegible]	.022	.028	.035	36850	86575	[illegible]	4.57		5	[illegible]	—	5/16	1750	—	—	—	—	—	[illegible]														514
515								1 6			87	85	87	88	86	89	.025	.024	.026	[illegible]	7	67	.035	.035	.032	24750	93150	[illegible]	1.02		5	3	—	[illegible]	2750	—	—	—	—	—	[illegible]														515
516	Fen [illegible]			Gary	1909	O.H.	B	0	T	G	[illegible]	72	76	72	[illegible]	71	.023	.024	.022	.44	.46	.130	[illegible]	.023	.02	[illegible]9300	73530	13.0	6.58	G & S	5	5	2	[illegible]	12750	5	5	20	3/4	12250	[illegible]										●		[illegible]	●	516
517	C[illegible] 48					O.H.	A	2 5			40	65	7[illegible]	58	74	78	.026	.047	.024	.038	.32	.3[illegible]	.036	.028	.025	[illegible]800	693[illegible]5	3.0	.855		5	5	30	[illegible]	26250	5	5	.9	1"	[illegible]1750	[illegible]										●		[illegible]		517
518						O.H.	A	2 2			86	9	73	[illegible]	[illegible]	70	.029	.028	.024	.17	.27	.27	.022	.029	.03	38200	69870	5.5	8.3		1	—	—	—	250	—	—	—	—	—	[illegible]		●		●			●							518
519							—	2 0	L		78	77	78	79	79	79	.044	.044	.047	.60	.60	.55	.039	.052	.05	[illegible]5200	72950	5	7.75	G	5	5	6	1/2	8250	—	—	—	—	—	236										●		[illegible]		519
520	C[illegible]	100		Cambria	1910	O.H.	E	2 2	T	S	66	63	65	60	59	60	.027	.02	.02	.0[illegible]	.052	.045	.036	.032	.035	[illegible]8[illegible]	50530	5.75	25.07	G & S	5	5	32	1/2	27750	5	5	26	3/8	15250	2[illegible]3												[illegible]	●	520
521	Sp [illegible]						E	1 0	H		75	88	72	58	57	59	.033	.034	.05	.07	.069	.079	.05	.044	.046	2550	54235	4.3	22.5		5	5	23	5/8	2.000	5	5	1	[illegible]	2750	226						●				●				521
522				Gary			D	1 0	L		67	66	69	60	60	60	.029	.024	.025	.27	.18	.122	.030	.024	.03	90000	42475	4.0	[illegible]		5	5	34	5/8	29250	—	—	—	—	—	206										●		T plate [illegible] shot		522
523				Carnegie	1912		D	0 5	H		76	81	75	64	64	62	.065	.072	.075	.36	.136	.06	.028	.027	.026	31850	64850	10.5	13.77	G	5	5	3	9/16	6000	5	5	21	7/8	12750	230		●								●				523
524		85		Gary	1909		C	2 Yr 7 Mo	T	G	70	69	68	61	61	61	.022	.030	.020	.06	.08	.08	.033	.031	.03	.8800	58735	15.25	25.83	G & S	5	5	32	5/8	27750	5	5	6	1 1/8	5250	223										●				524
525						O.H.	B	2 5			69	71	66	63	64	62	.026	.017	.028	.092	.085	.087	.049	.059	.049	05050	50690	6.0	26.7		5	5	28	5/8	24750	5	5	28	1 1/16	16250	224												[illegible] head	●	525
526						O.H.	D	2 1			64	67	68	66	69	66	.020	.028	.02	.27	.27	.27	.025	.04	.027	.25350	63480	13.25	8.15	-	5	5	12	9/16	12750	5	5	18	[illegible]	11250	2[illegible]			●							●				526
527						O.H.	—	2 0			86	67	83	72	65	70	.032	.032	.025	.282	.09	.18	.053	.035	.272	127950	72500	8.00	8.39	G	—	—	—	—	—	5	5	11	7/8	2750	244			●							●	●	[illegible] Ductility		527
528						O.H.	C	1 0	L		92	90	93	78	78	79	.026	.028	.026	.23	.12	.133	—	—	—	39880	91970	9.50	10.94		—	—	—	—	—	—	—	—	—	—	—							●					C high		528
529					1912	O.H.	G	0 4	T		71	5	70	83	67	79	.022	.027	.026	.46	.46	.46	.022	.044	.022	12450	53920	4.0	23.02	5	5	5	29	5/16	25500	5	5	47	1"	25750	219			●							●				529
530	Gr [illegible]	100		Cambria	1907	B	D	3 4	L	S	50	48	5	91	1.00	1.01	.092	.085	.097	.108	.06	.098	.07	.073	.076	3525	60255	8.5	3.85	G	5	5	60	9/16	48750	—	—	—	—	—	226	●									●	●	C high		530
531				Carnegie	1909	O.H.	C	2 9			72	7[illegible]	72	75	74	74	.044	.045	.45	.105	.03	.103	.025	.023	.021	29200	68340	12.25	21.43	G & S	5	5	29	1/32	25500	—	—	—	—	—	233											●	P [illegible] high		531
532				Cambria	1910		—	1 0	T	G	[illegible]	82	83	73	74	77	.283	.064	.087	.07	.112	.136	.020	.046	.050	14600	79940	9.5	11.2	G	5	2	—	1/2	2250	—	—	—	—	—	267	●		●		●		●				●			532
533				Carnegie	1912		GG	0 3		S	76	82	76	76	77	76	.026	.035	.02	.74	.4	.179	.032	.045	.034	127200	60125	2.75	16.88	G & S	5	5	21	3/8	19500	—	—	—	—	—	258	●		●											533

Worn-out Rails

Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed: Segregated, Badly	Segregated, Somewhat	Very Brittle	Somewhat Brittle, in Head	Somewhat Brittle, in Web	Hard	Rolling Seam	Slag Present	Foreign Steel Pres	Frozen Road bed	Miscellaneous	Material Fair	Reference Numbers
	43	44	45	46	47	48	49	50	51	52	53	54	55	56
184												Rather soft	●	601
216			●									S.a little high		602
190												Rather soft	●	603
203													●	604
172										C.low		Rather soft		605
183												Somewhat soft	●	606
179									Much worn			Rather soft		607
179									Much worn			Rather soft	●	608
199			●									Low ductility		609
216													●	610
201			●		●									611
193												C&Mn.low in web		612
175												Rather soft		613
195			●									S.little high		614
199													●	615
218													●	616
208												S little high		617
207													●	618
199												Little irreg.		619
205													●	620
190													●	621
230													●	622
189												Rather soft		623
179												Rather soft		624
208													●	625
211													●	626
192													●	627
202													●	628
217													●	629
211													●	630
200													●	631
203													●	632
187			●					Hardness low				S high in web		633
199									●			S.high Hardness low		634
144												S.high Hardness low		635
186												Rather soft		636
197			●											637
187												Somewhat soft		638
196												Hardness low	●	639
198												S.little high		640
202			●											641
192			●											642

PENNSYLVANIA LINES WEST OF PITTSBURGH
STUDY OF RAIL FAILURES IN MAIN TRACKS

Bessemer Process

March-1913

Worn-out Rails

Reference Number	Location	Wt of Rail Lbs per Yd	Rail Section	Manufacturer	Year of Rolling	Position in Ingot	Years in Service	Degree of Curve	High Low Rail or Tangent	Ballast	Carbon Head	Carbon Web	Carbon Base	Manganese Head	Manganese Web	Manganese Base	Phosphorus Head	Phosphorus Web	Phosphorus Base	Silicon Head	Silicon Web	Silicon Base	Sulphur Head	Sulphur Web	Sulphur Base	Tensile Strength Lbs per Sq In	Elastic Limit Lbs per Sq In	Elongation Per cent in 2 inches	Reduction of Area Per cent	Character of Fracture	Drop Test – Supports 12" apart – 50 Lb Tup: Test Piece at D, Blows at 5 Ft	Blows at 10 Ft	Blows at 15 Ft	Initial Deflec	Accumul Foot Lbs	Test Piece at E, Blows at 3 Ft	Blows at 6 Ft	Blows at 10 Ft	Initial Deflec	Accumul Foot Lbs	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed: Segregation Both	Segregation Somewhat	Very Brittle	Somewhat Brittle In Head	Somewhat Brittle In Web	Hard	Rolling Seam	Slag Present	Foreign Substances	Frozen Roadbed	Miscellaneous	Material Fair	Reference Numbers
601	East of [illegible]	80	PS	Carnegie	1909	C	3Yr 2 Mo	5°24'	-	S	48	44	47	71	72	74	.05	.088	.105	.06	.061	.06	.054	.051	.047	99850	45550	23.5	33.5	Fg B S	5	5	64	7/8	57750	"	"	"	"	"	84	"	"	"	"	"	"	"	"	"	"	"	Rather soft	●	601
602		·				B	3 · 2			-	.54	56	53	88	90	87	.106	.14	.088	.085	.085	.085	.054	.059	.049	9150	56000	19.5	29.63	·	5	5	40	9/16	73750	—	—	—	—	—	26			●									S little high		602
603						B	3 · 2 ·	·		·	46	45	44	74	79	71	.129	.105	.08	.06	.058	.056	.057	.053	.044	100600	49160	9.75	26.39	G B S	5	5	46	19/32	38250	5	5	43	1 3/32	23750	190												Rather soft	●	603
604						C	3 - 2	·	-		.57	49	51	92	90	89	.095	.082	.096	.084	.084	.084	.046	.039	.042	107100	52400	21.75	33.67	Fg B S	5	5	42	21/32	36250	5	5	55	1 1/4	29750	203													●	604
605				·		C	3 · 2	· -			42	38	39	75	76	73	.096	.088	.096	.066	.065	.059	.044	.044	.043	115600	56070	7.5	5.20	G	5	5	38	7/32	32250	5	5	40	3/32	22250	172										Clow		Rather soft		605
606						C	3 · 2				47	43	46	76	80	80	.098	.087	.092	.06	.066	.066	.042	.037	.038	98430	51125	22.75	36.05	S	5	5	83	1/16	67500	5	5	47	1 5/16	25750	83												Somewhat soft	●	606
607						B	3 2	-	L		44	39	45	71	70	71	.105	.102	.105	.06	.064	.064	.047	.047	.044	100300	57285	8.25	36.04	Fg B S	5	5	9	3/32	10500	5	5	42	1 9/32	23250	179									Much worn			Rather soft		607
608			·			—	3 2				46	44	48	77	79	77	.090	.087	.101	.066	.063	.056	.04	.036	.045	99070	59420	9.0	36.08	S	—	—	—	—	—	—	—	—	—	—	179									Much worn			Rather soft	●	608
609						—	3 · 2				50	54	46	72	78	69	.122	.12	.097	.047	.047	.047	.048	.056	.050	96830	56650	4.75	3.65	G	5	5	29	5/32	25500	—	—	—	—	—	199			●									Low ductility		609
610						C	3 2 ·	·			.52	49	53	91	90	91	.101	.092	.101	.085	.089	.085	.045	.042	.046	103450	57760	7.0	30.62	G B S	5	5	68	7/16	54750	5	5	35	1 3/32	19750	216													●	610
611						B	3 2		-	-	43	56	48	74	74	74	.104	.10	.098	.056	.056	.056	.045	.059	.042	108300	53720	8.25	23.27							—	—	—	—	—	201			●		●									611
612	·		-			-	3 2				47	39	47	73	68	73	.07	.088	.07	.056	.058	.058	.043	.038	.044	123000	50095	17.0	31.59		5	5	31	1/32	27000	5	5	31	1 1/2	17750	193												Lo Mn, low in web		612
613	East of [illegible] Sta					B	3Yr 3 Mo	4°55'			40	37	44	65	64	66	.034	.087	.094	.066	.071	.07	.031	.029	.032	89740	47735	23.5	40.59	S	5	5	63	17/32	51000	5	5	51	1 3/16	27750	175												Rather soft		613
614		·	-		·	B	3 3 -	-	-	·	48	51	47	69	69	69	.111	.111	.104	.066	.066	.066	.066	.069	.065	111450	62440	19.26	26.66	G B S	5	5	4	3/32	6750	5	5	27	1 3/32	15750	195			●									S little high		614
615						C	3 3 ·			·	49	45	47	89	85	91	.097	.088	.095	.083	.099	.092	.028	.033	.039	103400	49950	20.0	36.21	·	—	—	—	—	—	5	5	37	1 3/32	20750	99													●	615
616		·	-			B	3 · 3	·	-		51	.51	53	79	79	80	.099	.098	.105	.092	.080	.088	.044	.042	.042	112000	54580	16.5	29.13	Fg B S	5	5	32	19/32	27750	5	5	54	1 3/32	29250	218													●	616
617			-			B	3 · 3 -	· ·	-	·	50	45	48	87	86	88	.097	.087	.094	.071	.071	.075	.060	.056	.053	112050	56875	16.5	29.61	-	5	5	60	5/8	48750	5	5	40	1 3/16	22250	208												S little high		617
618						B	3 3	·			50	47	48	71	.73	73	.06	.096	.101	.085	.085	.085	.03	.036	.040	108400	44960	18.5	30.79	'	5	5	24	5/8	21750	5	5	36	1 3/16	30250	207													●	618
619	East of [illegible]					BB	3Yr 6 Mo	2°30'	H	S	50	45	48	82	.8	.83	.04	.089	.099	.085	.089	.089	.050	.040	.046	120200	48340	22.25	36.35		5	5	58	1/16	43250	5	5	36	1 3/16	20250	199												Little irreg		619
620						CC	3Yr 6				52	48	51	88	88	88	.096	.094	.094	.089	.03	.089	.044	.051	.053	104000	50680	21.00	35.04	"	5	5	8	2/32	9750	5	5	31	1 3/8	17750	205													●	620
621						BB	3 6 -	-	-		46	46	45	81	80	81	.03	.098	.03	.06	.06	.06	.04	.048	.05	101750	48270	20.5	35.31		5	4	—	2/32	3250	5	5	40	1 3/32	22250	190													●	621
622						BB	3 · 6 ·	·			56	58	56	.99	97	.99	.084	.081	.083	.108	.108	.108	.044	.038	.045	61250	58740	5.5	26.80	G B S	5	5	29	9/16	25500	5	5	29	1 1/16	16750	430													●	622
623			-		·	CC	3 · 6	·	·		49	.45	.48	76	77	76	.099	.088	.098	.076	.075	.080	.044	.039	.042	98730	45875	23.0	36.02	Fg B S						5	5	36	1 9/32	20250	189												Rather soft		623
624	·	·				CC	3 · 6 -	·	·	·	45	.41	46	77	78	77	.084	.083	.098	.080	.071	.075	.04	.040	.046	93360	43555	25.0	41.82	S	5	5	81	11/16	64500	5	5	29	1 5/16	16750	179												Rather soft		624
625						BB	3 · 6	·			54	50	54	78	75	78	.101	.088	.101	.094	.094	.094	.046	.045	.045	105250	49130	20.0	31.37	Fg B S	5	5	65	9/16	52500	5	5	43	1 3/32	23750	208													●	625
626			-		·	CC	3 · 6 ·	·	L		52	51	52	87	86	.86	.03	.03	.03	.089	.089	.089	.051	.034	.053	110200	54350	20.0	32.64		5	5	60	19/32	48750	5	5	36	1 5/16	20250	211													●	626
627						CC	3 6	·	·		48	45	48	75	74	73	.083	.085	.096	.07	.089	.088	.04	.039	.043	[illegible]	49865	12.0	36.37	"	5	5	61	9/16	49500	5	5	37	1 1/32	20750	192													●	627
628						BB	3 6	·	-	-	48	49	49	.83	83	84	.14	.14	.113	.103	.099	.03	.046	.046	.046	109950	55285	19.75	31.88	"	5	5	36	5/8	30750	5	2	—	1 9/32	1350	202													●	628
629		"			-	CC	3 - 6	·		·	54	50	51	97	.97	.96	.094	.088	.096	.085	.085	.085	.053	.047	.049	112650	60330	18.5	30.24	·	5	5	53	19/32	43500	5	5	41	1 5/32	22750	217													●	629
630						BB	3 - 6 ~	·			52	.50	50	91	90	91	.102	.098	.097	.089	.083	.089	.058	.058	.058	[illegible]	56135	19.0	30.45	·	5	5	62	19/32	50250	5	5	51	1 3/16	27750	211													●	630
631			-	·		CC	3 · 6 ·	·		·	.50	47	50	77	.79	.78	.098	.097	.100	.066	.066	.066	.059	.051	.061	106600	57800	20.0	33.17	"	5	5	61	13/32	49500	5	5	22	1 3/16	13250	200													●	631
632				"		BB	3 - 6	·		·	51	46	50	.89	94	91	.07	.099	.078	.080	.118	.085	.051	.049	.048	107350	52920	20.0	35.35	"	5	5	69	19/32	55500	5	5	37	1 11/32	20750	203													●	632
633	[illegible]	85		Maryland	1907	4	4 5 ·	2°48'	H	-	44	54	44	.70	74	70	.060	.19	.078	.061	.061	.061	.037	.072	.045	98850	50125	23.5	35.15	"	5	5	46	3/4	38250	5	5	47	1"	25750	187			●					Hardness low				S high in web		633
634						4	4 5 ·				51	48	55	.82	83	84	.086	.078	.103	.066	.066	.066	.073	.065	.078	104000	53730	21.0	36.73	"	5	5	49	5/32	40500	5	5	27	1 1/4	15750	199									●			S high Hardness low		634
635						4	4 5 "	·	L	-	47	47	47	1.02	99	1.01	.076	.075	.077	.052	.052	.052	.087	.077	.084	108660	55495	21.0	36.3	·	5	5	57	9/16	46500	5	5	37	1 1/8	20750	44												S high Hardness low		635
636						5	4 " 5 ·		·		48	43	47	88	92	90	.075	.067	.073	.066	.066	.061	.03	.047	.052	98270	51530	22.0	35.62		5	5	45	5/8	37500	5	5	19	1 5/16	11750	186												Rather soft		636
637		-	·			1	4 · 5	8°27'	H	-	50	46	50	90	89	88	.077	.072	.083	.061	.061	.061	.029	.035	.039	104250	54390	22.75	38.38	Fg	5	5	48	3/4	39750	5	5	14	1 1/4	9250	197			●											637
638						4	4 - 5 ·	·			47	46	48	92	90	91	.092	.089	.091	.066	.061	.066	.046	.050	.046	102750	51885	22.5	34.76	Fg B S	5	5	68	11/16	54750	5	5	25	1 1/8	14750	187												Somewhat soft		638
639	·	·	·		-	3	4 5 ·	·		·	47	45	48	.88	86	88	.077	.076	.076	.056	.061	.056	.031	.035	.038	104200	52790	21.75	38.10	Fg	5	5	38	3/4	32250	5	5	28	1 1/2	18250	196												Hardness low	●	639
640						2	4 · 5 "	·	L	·	49	46	50	86	83	86	.089	.087	.088	.07	.066	.066	.068	.063	.070	104650	54030	21.0	36.38	Fg B S	5	5	36	11/16	30750	5	5	11	1 1/4	7750	198												S little high		640
641	"	-		·		2	4 · 5				47	55	49	86	88	87	.078	.097	.081	.080	.080	.080	.041	.058	.042	110000	53670	19.0	31.12		5	5	31	9/16	27000	5	5	45	1 1/8	24750	202			●											641
642		·	·			2	4 · 5 ·	· -	·		45	.5	49	.81	82	82	.084	.04	.089	.038	.038	.038	.061	.088	.065	103650	53900	19.5	32.3		5	5	49	5/8	40500	5	5	28	1 3/8	16250	192			●											642

H

Sheet 19

Worn-out Rails

lbs.	Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed											Miscellaneous	Material Fair	Reference Numbers
			Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign Steel Pres.	Frozen Roadbed			
			Badly	Somewhat		in Head	in Web								
	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
50	253													●	643
	230													●	644
	266			●				●					Ductility low		645
50	244												C. well up	●	646
50	259								●				C. well up	●	647
50	230												C. low in web	●	648
50	260			●			●	●							649
50	253													●	650
50	240													●	651
50	215												Little soft		652
50	261			●				●					C. high		653
50	300						●	●					C. high		654
50	229					●							Hard in web		655
	196					●						●	Hardness low		656

PENNSYLVANIA LINES WEST OF PITTSBURGH
STUDY OF RAIL FAILURES IN MAIN TRACKS

Open Hearth - Class "A" - Process

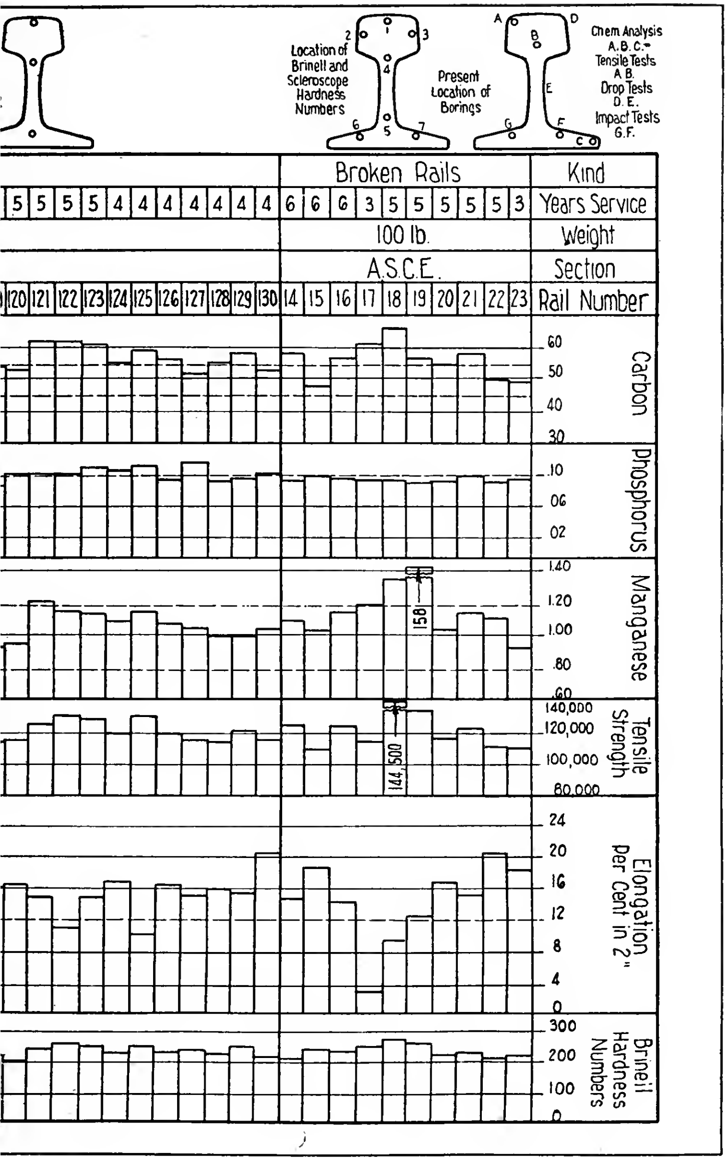
March - 1913

Worn-out Rails

Reference Number	Location	Wt of Rail Lbs/Yd	Rail Section	Manufacturer	Year of Rolling	Position in Ingot	Years in Service	Degree of Curve	High, Low R. or Tangent	Ballast	Chemical Analysis of Rail: Carbon			Manganese			Phosphorus			Silicon			Sulphur			Tensile Strength	Elastic Limit	Elongation Percent in 2 inches	Reduction Area Per Cent of Orig Sec	Character of Fracture	Drop Test - Supports 12" apart - 60 Lb Tup: Test Piece at "D": Blows at					Test Piece at "E"					Brinell Hardness	In Joint	Defects in Quality of Material and Road Bed: Segregated		Very Brittle	Somewhat Brittle		Hard	Rolling Seam	Slag Present	Foreign [illegible]	Frozen Roadbed	Miscellaneous	Material Fair	Reference Numbers
											Head	Web	Base	Head	Web	Base	Head	Web	Base	Head	Web	Base	Head	Web	Base	Lbs per Sq In	Lbs per Sq In				5 Ft	10 Ft	15 Ft	Initial Deflec	Accumul. Foot Lbs	3 Ft	6 Ft	10 Ft	Initial Deflec	Accumul. Foot Lbs			Badly	Somewhat		in Head	in Web								
643	North End of O.C. Bridge	85	PS	Carnegie	1909	A	0 Yr. 9 Mo.	8°0'	H	—	.76	75	75	67	68	68	.038	.038	.038	.103	.103	.103	.019	.021	.021	127650	63175	11.25	13.44	Fg	5	5	21	1/2"	19500	5	5	16	7"	10250	253													●	643
644			″		″	″	0 9	″		—	71	72	72	67	67	68	.023	.023	.036	.080	.080	.083	.017	.018	.017	117050	59400	15.75	20.30	Fg & S	5	5	11	7/16"	12000	—	—	—	—	—	230													●	644
645	″		″		″	″	0 9	″ ″	″	—	83	90	85	.62	63	63	.017	.017	.017	.085	.085	.085	.024	.029	.023	139800	68245	9.0	10.55	G	5	5	8	3/8	9750	—	—	—	—	—	266			●				●					Ductility low		645
646							0 9	″	L	—	79	.76	79	58	62	58	.023	.020	.023	.075	.075	.080	.017	.018	.018	123300	60350	12.75	.649	Fg & S	5	5	40	3/8"	33750	5	5	6	15/16"	5250	244												C well up	●	646
647					″		0 9		″	—	78	79	.78	70	70	69	.027	.030	.026	.094	.094	.094	.022	.024	.022	118250	59550	17.0	29.67	″	5	5	—	1/2"	3750	5	5	—	7/8"	2250	259								●				C well up	●	647
648			″		″	″	0 9	″ ″	″	—	73	65	.75	.72	70	70	.028	.022	.024	.118	.118	.118	.019	.018	.019	118800	59200	15.0	16.36	″	5	5	13	1/2"	13500	5	5	1	7/8"	2750	230												C low in web	●	648
649			″	Gary	″		0 9	8°0'	H	—	.80	84	.78	76	76	.76	.032	.036	.032	.141	.146	.141	.032	.032	.032	139150	66315	10.0	14.87	G	5	5	5	7/16"	7500	3	—	—	1/2"	450	260			●			●	●							649
650	″				″		0 9		″	—	.77	72	77	75	76	.77	.034	.027	.034	.122	.122	.127	.032	.029	.036	128950	64710	11.0	16.28	″	5	5	21	1/2	19500	5	5	14	13/16"	9250	253													●	650
651					″	″	0 9	″ ″		—	77	74	78	78	.78	80	.030	.024	.027	.13	.13	.18	.028	.028	.030	127300	63980	12.0	8.37	″	5	5	23	7/16"	21000	5	5	8	7/8"	6250	240													●	651
652	″		″		″		0 9	″	L	—	68	63	69	61	62	62	.021	.019	.021	.086	.086	.086	.030	.028	.037	114950	53800	14.0	19.84	Fg & S	5	5	13	1/2"	13600	5	5	8	1 5/8"	6250	215												Little soft		652
653	″	″			″		0 9	″ ″	″	—	.80	83	.80	74	75	75	.032	.040	.033	.113	.113	.119	.037	.045	.043	133700	66345	11.0	14.23	Fg	5	5	21	1/2"	19500	5	5	6	7/8"	5250	261			●				●					C high		653
654		″	″	″	″	″	0 9	″ ″	″	—	83	81	83	92	93	96	.029	.026	.027	.155	.160	.155	.033	.032	.033	155800	80250	9.75	10.84	″	5	5	5	5/16"	7500	5	1	—	3/8"	1050	300						●	●					C high		654
*655	W. of MP 82 Cin'ti Div	″	ASCE	Carnegie	1904	—	7 3	2°-0'	H	G	56	58	56	32	93	94	.112	.122	.107	.061	.061	.061	.044	.052	.051	117500	58985	16.5	24.97	Fg & S	5	1	—	19/32"	1750	5	5	22	3/16"	13250	229					●							Hard in web		655
*656	W. of MP 17 Cin'ti Div	″	″	Nat Steel Co	1900	—	11 5	1°-30'	L	G	.54	53	55	99	99	99	110	.102	108	.103	113	113	.022	.023	.021	102540	53620	20.0	35.9	S	5	1	—	11/16"	1750	—	—	—	—	—	196					●						●	Hardness low		656

*Nos 655 and 656 were damaged by wheels

PLATE 1.



Location of Brinell and Scleroscope Hardness Numbers
1 2 3 4 5 6 7
Present Location of Borings
A B C D E F G
Chem Analysis A.B.C.
Tensile Tests A.B.
Drop Tests D.E.
Impact Tests G.F.
Broken Rails
Kind
Years Service
5 5 5 5 4 4 4 4 4 4 4 6 6 6 3 5 5 5 5 5 3
Weight
100 lb.
Section
A.S.C.E.
Rail Number
120 121 122 123 124 125 126 127 128 129 130 14 15 16 17 18 19 20 21 22 23
Carbon
60 50 40 30
Phosphorus
.10 06 02
Manganese
1.40 1.20 1.00 .80 .60
158
Tensile Strength
140,000 120,000 100,000 80,000
144,500
Elongation per Cent in 2"
24 20 16 12 8 4 0
Brinell Hardness Numbers
300 200 100 0

PLATE 1

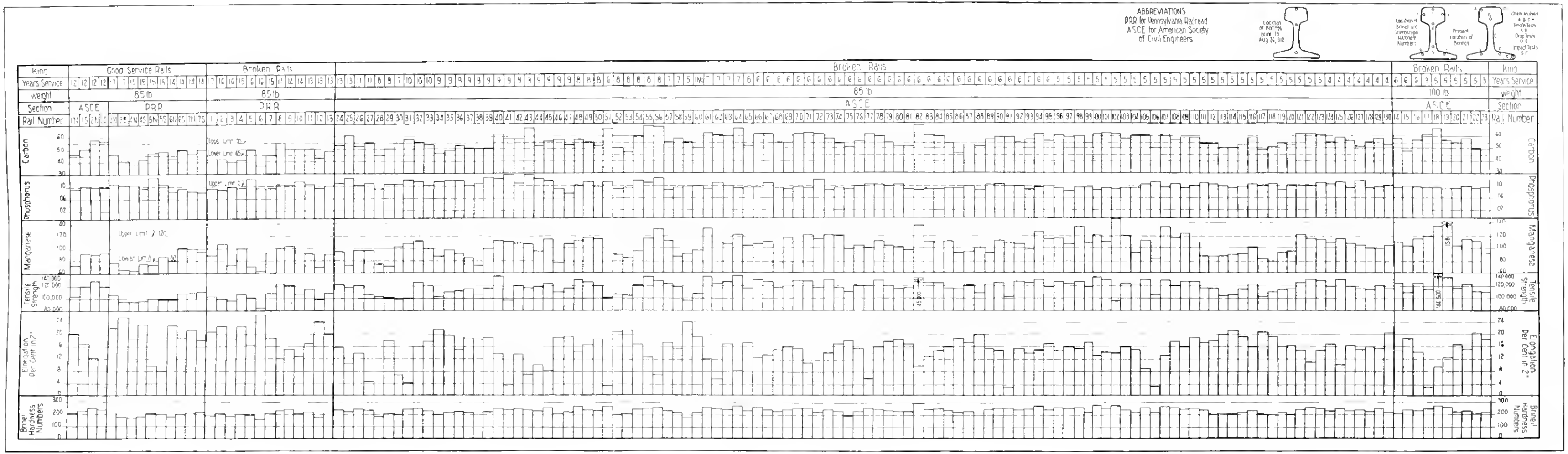

ABBREVIATIONS
PRR for Pennsylvania Railroad
ASCE for American Society of Civil Engineers
Location of Borings prior to Aug 26, 1912
Location of Brinell and Scleroscope Hardness Numbers
Present Location of Borings
Chem Analysis A B C
Tensile Tests A B
Drop Tests D E
Impact Tests G F
Kind
Good Service Rails
Broken Rails
Years Service
Weight
85 lb
100 lb
Section
ASCE
PRR
Rail Number
Carbon
Upper Limit 55
Lower Limit 45
Phosphorus
Upper Limit 0.2
Manganese
Upper Limit 7 120
Lower Limit
Tensile Strength
Elongation Per Cent in 2"
Brinell Hardness Numbers

PLATE 2.

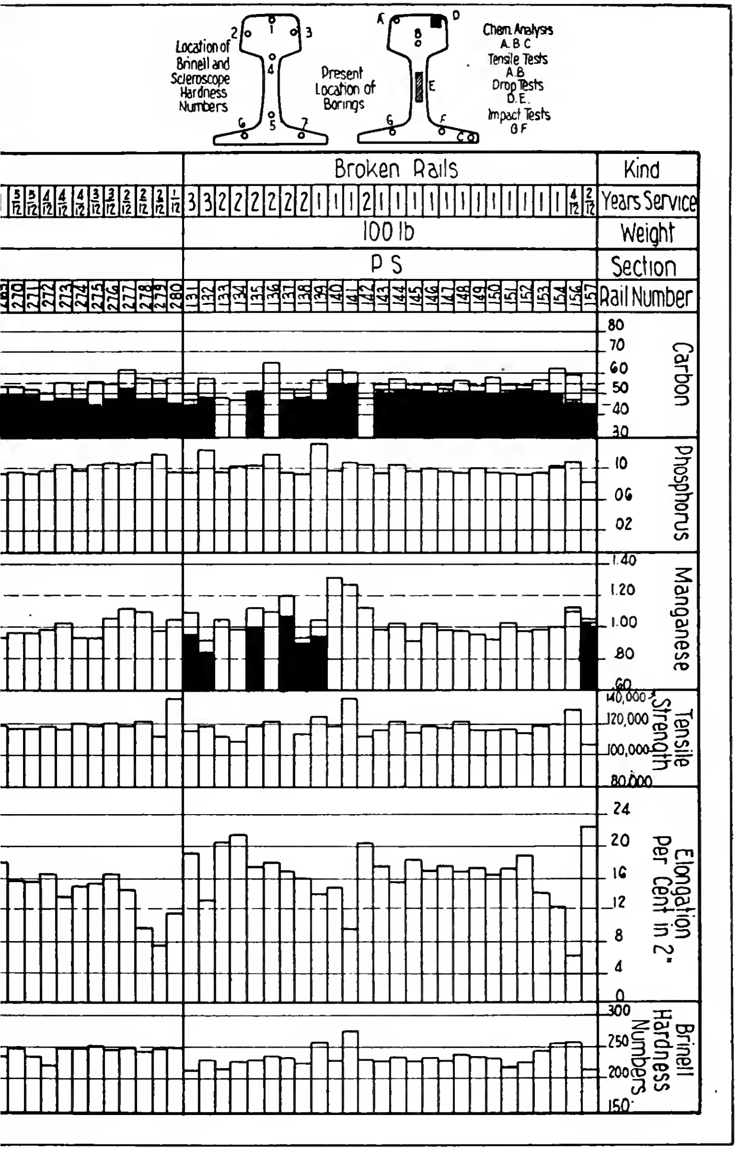
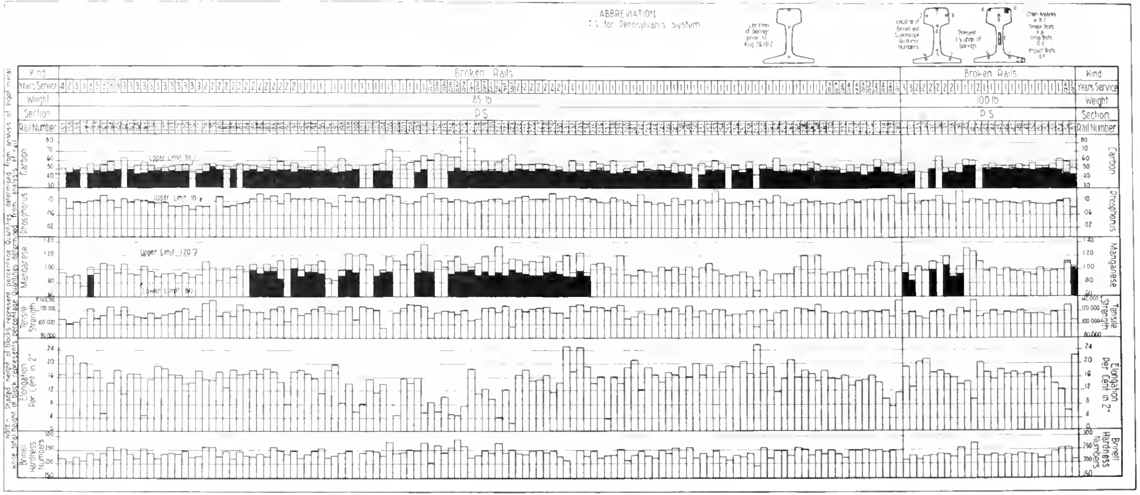

Location of Brinell and Scleroscope Hardness Numbers
1
2
3
4
5
6
7
Present Location of Borings
A
B
C
D
E
F
G
Chem. Analysis A.B.C
Tensile Tests A.B
Drop Tests D.E.
Impact Tests G.F
Broken Rails
Kind
Years Service
3 3 2 2 2 2 2 2 2 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 4/12 2/12
5/12 5/12 4/12 4/12 4/12 4/12 3/12 3/12 2/12 2/12 2/12 1/12
Weight
100 lb
Section
P S
Rail Number
270 271 272 273 274 275 276 277 278 279 280
131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 156 157
Carbon
80
70
60
50
40
30
Phosphorus
10
06
02
Manganese
1.40
1.20
1.00
.80
.60
Tensile Strength
140,000
120,000
100,000
80,000
Elongation Per Cent in 2"
24
20
16
12
8
4
0
Brinell Hardness Numbers
300
250
200
150

PLATE 2.



NOTE – Shaded height of blocks represent percentage Quantities determined from analysis of ingot metal while total height of block represents percentage Quantities determined from analysis of rail

PLATE 3.

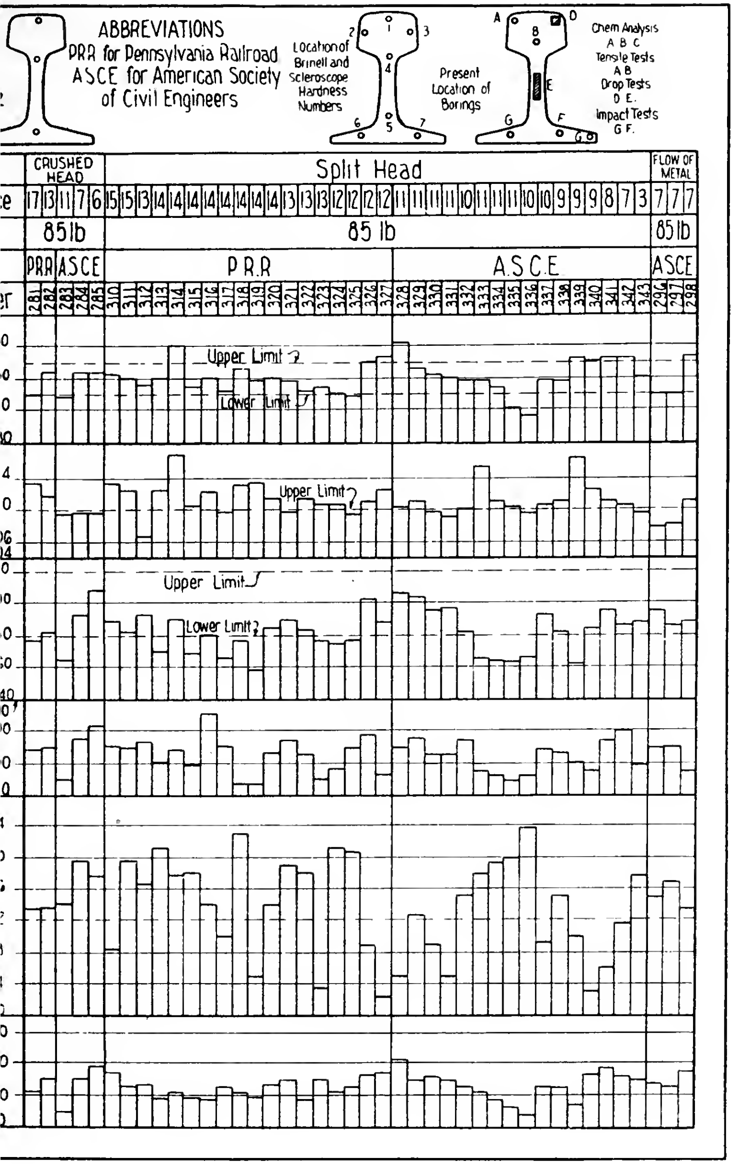

ABBREVIATIONS
PRR for Pennsylvania Railroad
ASCE for American Society of Civil Engineers
Location of Brinell and Scleroscope Hardness Numbers
1
2
3
4
5
6
7
Present Location of Borings
A
B
D
E
F
G
Chem Analysis A B C
Tensile Tests A B
Drop Tests D E.
Impact Tests G F.
CRUSHED HEAD
Split Head
FLOW OF METAL
17 13 11 7 6 15 15 13 14 14 14 14 14 14 14 14 13 13 13 12 12 12 12 11 11 11 11 10 11 11 11 10 10 9 9 9 8 7 3 7 7 7
85 lb
85 lb
85 lb
PRR
ASCE
P.R.R
A.S.C.E
ASCE
281 282 283 284 285 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 296 297 298
Upper Limit
Lower Limit
Upper Limit
Upper Limit
Lower Limit

PLATE 3.

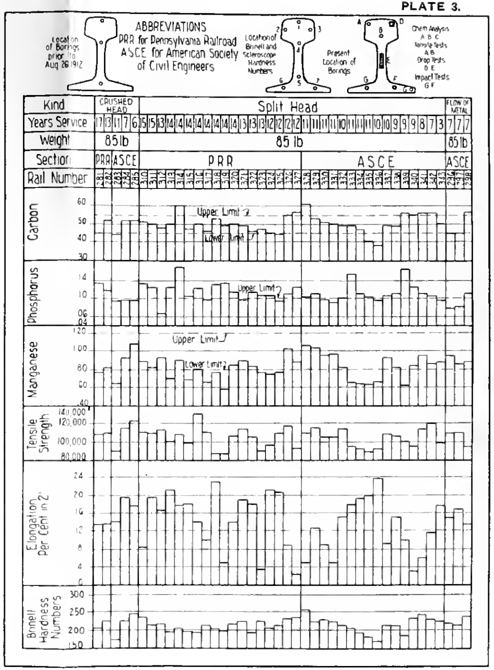

Location of Borings prior to Aug 26 1912
ABBREVIATIONS
PRR for Pennsylvania Railroad
ASCE for American Society of Civil Engineers
Location of Brinell and Scleroscope Hardness Numbers
1
2
3
4
5
6
7
Present Location of Borings
A
B
C
D
E
F
G
Chem Analysis A B C
Tensile Tests A B
Drop Tests D E
Impact Tests G F
Kind
CRUSHED HEAD
Split Head
FLOW OF METAL
Years Service
17 13 11 7 6
15 15 13 14 14 14 14 14 14 14 14 13 13 13 12 12 12 12
11 11 11 11 10 11 11 11 10 10 9 9 9 8 7 3
7 7 7
Weight
85 lb
85 lb
85 lb
Section
PRR
ASCE
PRR
ASCE
ASCE
Rail Number
281 282 283 284 285
310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327
328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343
296 297 298
Carbon
60
50
40
30
Upper Limit
Lower Limit
Phosphorus
14
10
06
04
Upper Limit
Manganese
120
100
80
60
40
Upper Limit
Lower Limit
Tensile Strength
140,000
120,000
100,000
80,000
Elongation Per Cent in 2"
24
20
16
12
8
4
0
Brinell Hardness Numbers
300
250
200
150

PLATE 4.

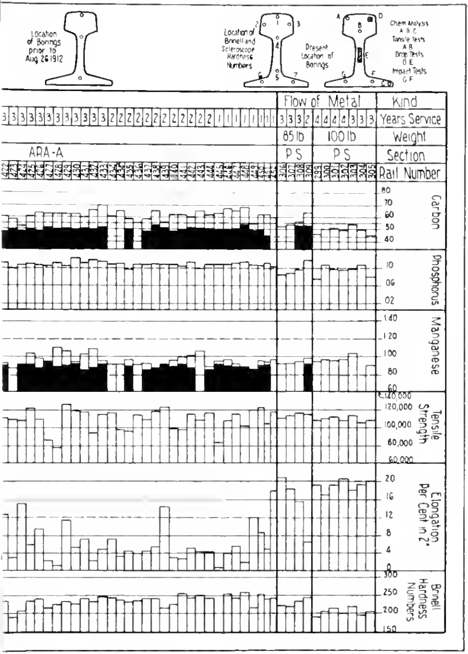

Location of Borings prior to Aug 26 1912
Location of Brinell and Scleroscope Hardness Numbers
1
2
3
4
5
6
7
Present Location of Borings
A
B
C
D
E
F
G
Chem Analysis A B C
Tensile Tests A B
Drop Tests D E
Impact Tests G F
Flow of Metal
Kind
3 3 3 3 3 3 3 3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 1 1 1 1 1 1 1 3 3 3 2 4 4 4 4 3 3 3
Years Service
85 lb
100 lb
Weight
ARA-A
P S
P S
Section
422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 306 307 308 309 299 300 301 302 303 304 305
Rail Number
80
70
60
50
40
Carbon
.10
.06
.02
Phosphorus
1.40
1.20
1.00
.80
.60
Manganese
140,000
120,000
100,000
80,000
60,000
Tensile Strength
20
16
12
8
4
0
Elongation Per Cent in 2"
300
250
200
150
Brinell Hardness Numbers

PLATE 4.

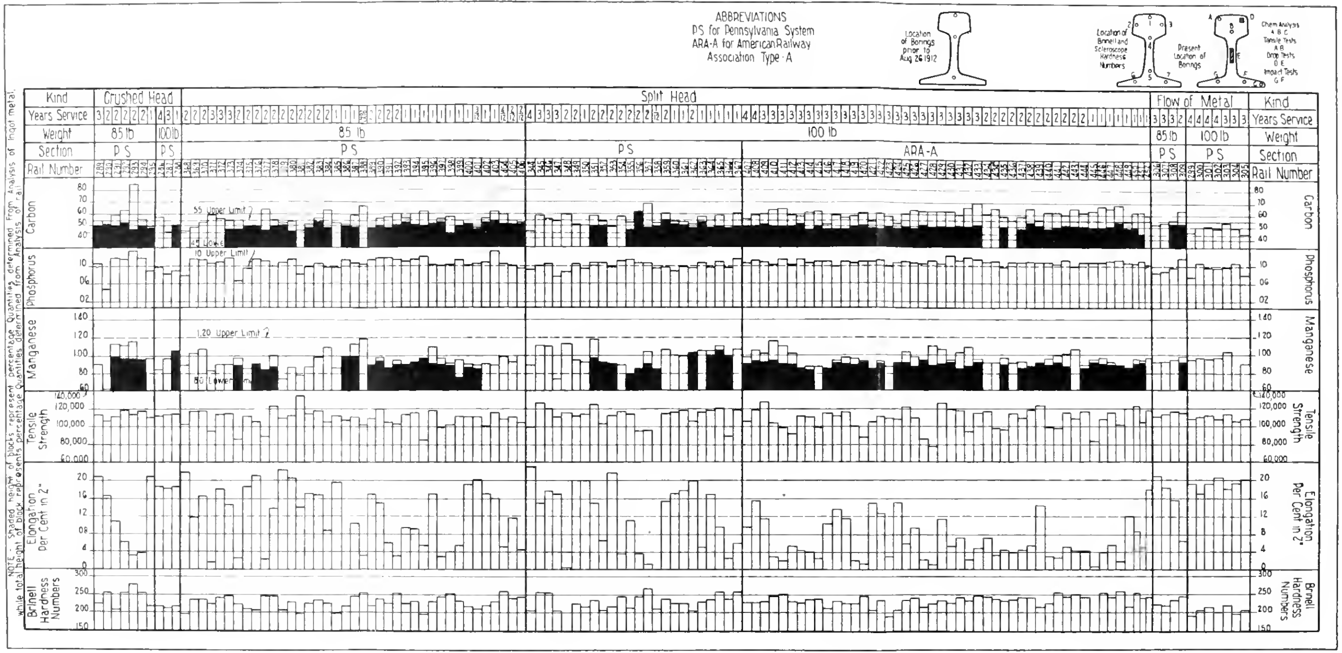

ABBREVIATIONS
PS for Pennsylvania System
ARA-A for American Railway Association Type-A
Location of Borings prior to Aug 26 1912
Location of Brinell and Scleroscope Hardness Numbers
Present Location of Borings
Chem Analysis A B C
Tensile Tests A B
Drop Tests D E
Impact Tests G F
Kind
Crushed Head
Split Head
Flow of Metal
Years Service
Weight
85 lb
100 lb
Section
P S
ARA-A
Rail Number
Carbon
55 Upper Limit ?
45 Lower
Phosphorus
10 Upper Limit
Manganese
1.20 Upper Limit ?
80 Lower
Tensile Strength
Elongation Per Cent in 2"
Brinell Hardness Numbers
NOTE - Shaded height of blocks represent percentage Quantities determined From Analysis of Ingot metal. while total height of block represents percentage Quantities determined from Analysis of rail.

PLATE 5.

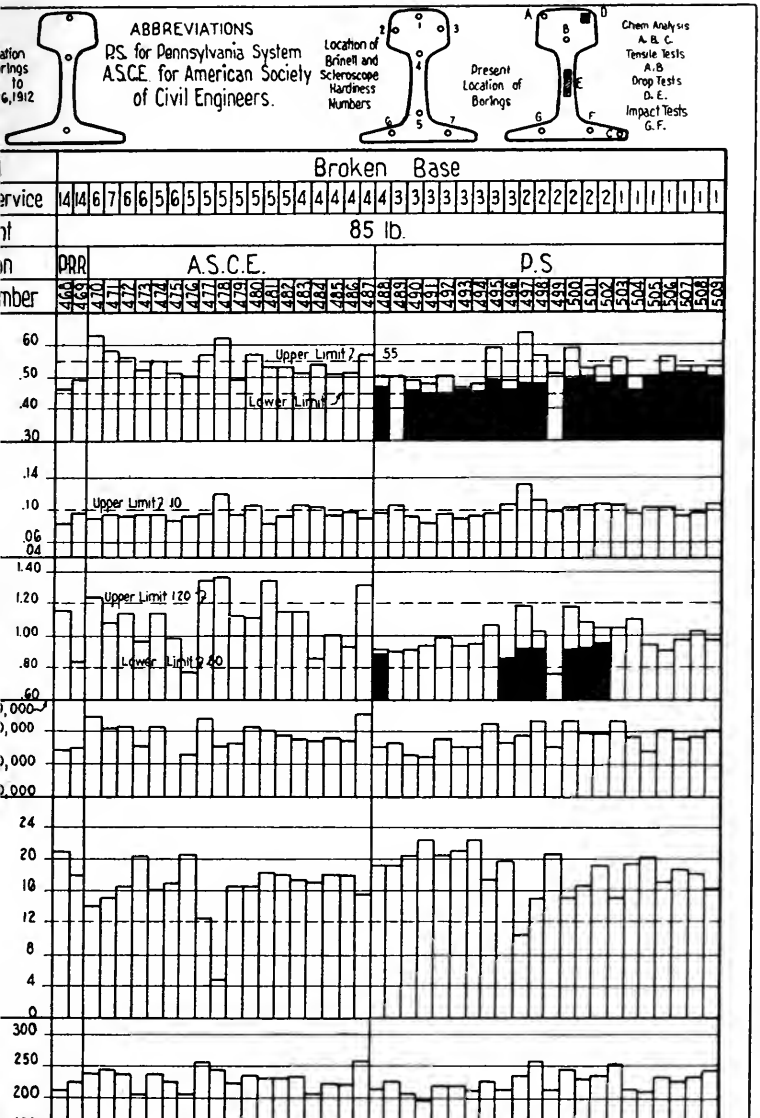
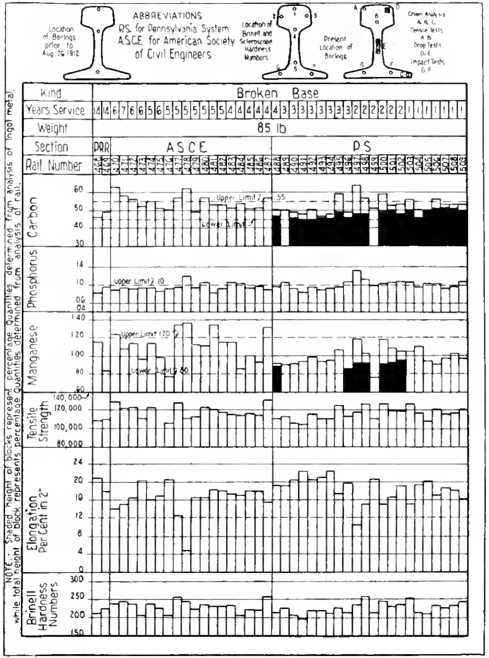

ation
rings
to
6,1912
ABBREVIATIONS
P.S. for Pennsylvania System
A.S.C.E. for American Society of Civil Engineers.
Location of Brinell and Scleroscope Hardiness Numbers
1 2 3 4 5 6 7
Present Location of Borings
A B C D E F G
Chem Analysis A. B. C.
Tensile Tests A. B
Drop Tests D. E.
Impact Tests G. F.
Broken Base
ervice
14 14 6 7 6 6 5 6 5 5 5 5 5 5 5 4 4 4 4 4 4 3 3 3 3 3 3 3 3 3 2 2 2 2 2 2 1 1 1 1 1 1 1
ht
85 lb.
on
PRR
A.S.C.E.
P.S
mber
468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509
60 .50 .40 .30
Upper Limit ? .55
Lower Limit
.14 .10 .06 .04
Upper Limit ? .10
1.40 1.20 1.00 .80 .60
Upper Limit 1.20 ?
Lower Limit ? .80
,000
,000
,000
,000
,000
24 20 16 12 8 4 0
300 250 200 150

PLATE 5.



NOTE:- Shaded height of blocks represent percentage Quantities determined from analysis of Ingot metal, while total height of block represents percentage Quantities determined from analysis of rail.

PLATE 6.

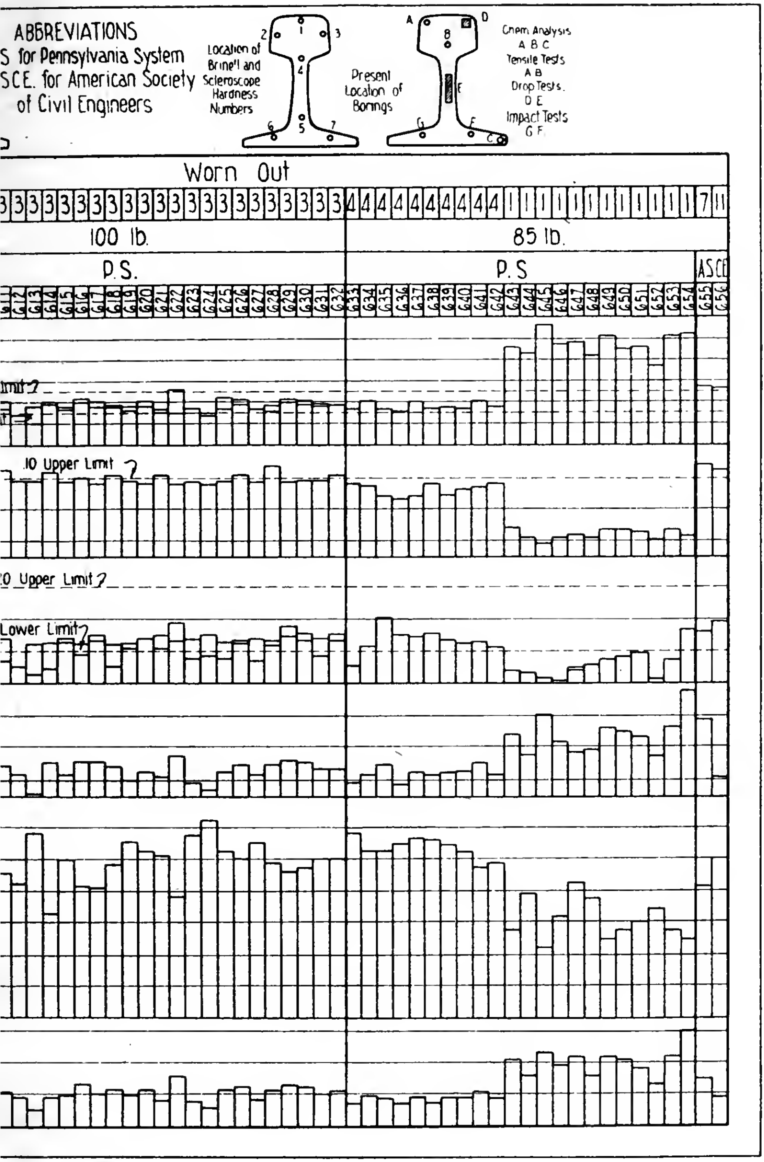
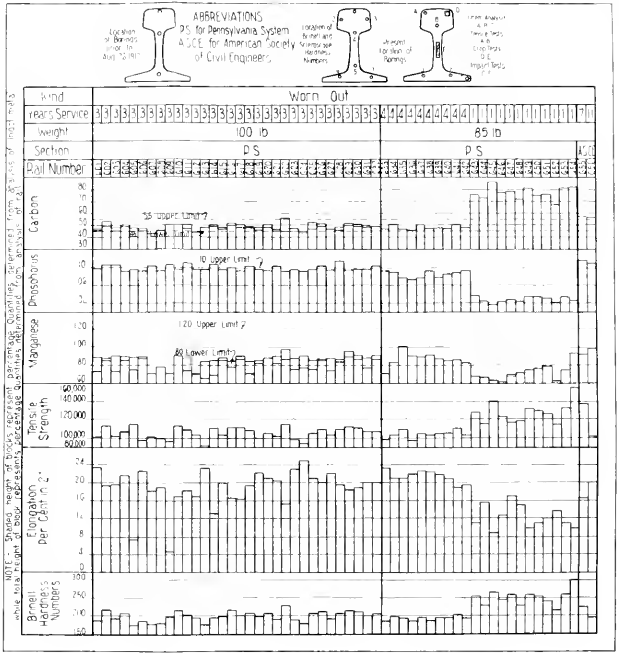

ABBREVIATIONS
S for Pennsylvania System
SCE. for American Society of Civil Engineers
Location of Brinell and Scleroscope Hardness Numbers
1
2
3
4
5
6
7
Present Location of Borings
A
B
C
D
E
F
G
8
Chem Analysis A B C
Tensile Tests A B
Drop Tests D E
Impact Tests G F
Worn Out
100 lb.
85 lb.
P.S.
P.S
ASCE
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
Limit
.10 Upper Limit
.20 Upper Limit
Lower Limit

PLATE 6.



NOTE - Shaded height of blocks represent percentage Quantities determined from analysis of ingot metal while total height of block represents percentage quantities determined from analysis of rail