PROCEEDINGS

OF THE

ELEVENTH ANNUAL CONVENTION

OF THE

American Railway Engineering and Maintenance of Way Association

HELD AT THE

CONGRESS HOTEL, CHICAGO, ILLINOIS

March 15, 16 and 17, 1910

VOLUME 11
PART I

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TUESDAY, MARCH 15, 1910.

MORNING SESSION.

The convention was called to order by the President, Mr. William McNab, Principal Assistant Engineer, Grand Trunk Railway System, at 9 a. m.

The President:—As President of the American Railway Engineering and Maintenance of Way Association, I declare the eleventh annual convention open for business.

It gives me pleasure to welcome you to this session. It seems to me that a spirit of optimism prevails throughout the Association, and we have met this year under particularly favorable circumstances. We are holding our sessions in a new room—commodious and artistic, with good ventilation and acoustic properties. The Committee reports, which have been in your hands for some time, contain excellent material, and I trust they will be discussed in a manner deserving of their importance.

The first order of business is the reading of the Minutes of the last annual convention. As these Minutes have been printed and a copy furnished to each member, the reading will be dispensed with, and they will be considered as approved, unless there is objection. There being no objection, the Minutes will stand approved as printed.

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

PRESIDENT'S ADDRESS.

To the Members of the American Railway Engineering and Maintenance of Way Association:

At the close of the eleventh year of the existence of your Association, it is gratifying to note that general progress and steady increase in activity have been manifested in every department of its work.

This progress is due not merely to additions in the Association's membership and to the zeal of its officers, the committees and individual members in promoting the objects for which it was formed, but it lies also in the possession of a greater degree of that direct influence in the practical railway world, which it has always been the aspiration of the Association to attain. Seldom before have greater or more important problems in transportation matters, where such influence can be an aid, come before railway managements in general, than at the present time, and these conditions must be apparent to everyone who has kept pace with the improvements, as well as the methods of practice everywhere in evidence. More especially must they appeal to those who realize the value of technical and specialized knowledge as applicable to railways. Railways need specialists, and to produce the best results, specialization is desirable, in fact, is a necessity.

The various committees of this Association may be looked upon as specialists, as they are, in a complete sense, representative of every department of railway construction. In the assignment of work under the care or investigation of these committees, it is the aim of the Board of Direction to establish a line of policy which, if adhered to, will attain certain results, a policy the effects of which will demonstrate in a practical manner that in order to produce economic efficiency in train operation and the consequent permanent beneficial results in railway administration, economics as a science must be more carefully studied and more generally applied in every feature of railway location, construction, operation and maintenance.

Although these committees are composed of specialists—and there is much efficacy in such a status—the Association itself, acting as another great force, is predominant in blending into one harmonious whole the various interests involved. The influence, therefore, acquired by the Association through the means of its conventions and supplemented by its Manual of Recommended Practice, serves as a great balance wheel in preserving that equilibrium of forces necessary for the success of any undertaking.

During the year 1909, 4,886 miles of railway—exclusive of second, third and fourth tracks—were constructed and placed in operation in the United States and Canada, 1,138 of which were in Canada. Compared with the construction records of some former years, the amount added in 1909 did not increase the aggregate mileage to an appreciable degree, and, notwithstanding the recovery from the general stagnation in transportation matters which had existed, it might be a question whether or not during the year new railway enterprises and extensions of existing lines have kept pace with the increase in the industrial features of the country and its immediate needs, due to the rapid advancement in agricultural development now going on.

It is not, however, the purpose of this address to consider the reasons why the percentage of mileage added during the year was not greater, for it may be said that beyond having an interest of a general nature, such as may be accepted as universally shared in, it seldom comes within the special purview of the railway engineer to study in detail economic laws which govern eras of commercial prosperity. Neither does it directly belong to his province to question the attitude of the Federal or State Legislatures toward railway interests, or to analyze the complex factors which frequently produce the conditions leading to business stagnation or financial crises.

To the engineer in such matters the prime feature of import for the time being is trade and economic conditions as they exist, and it is in the degree in which such conditions are active that becomes the potential in his everyday life and avocations. From an engineer's standpoint, it is more desirable to anticipate the future and to consider and plan what has yet to be done, rather than to view the present situation in the light of what has not been accomplished. This statement, however, by no means implies that retrospect of work that has actually been done is unprofitable, for the members of an Association such as this can well afford to review the records of construction of some portions of lines built during the past year. In the official descriptions of such construction it is clearly indicated that many novel and interesting engineering problems presented themselves for solution, and the progressive methods used in every branch of the work show that system, as applied to railway operation, has made a substantial advance and become more highly developed than in any other of the industrial arts.

In regard to lines and portions of lines built and placed in operation during the year, a review of the situation in general is convincing of the fact that certain extensions with a view to "transcontinentalism," and the construction of new roads with a similar object, was not only a feature of the year, but it contributed largely to the gross mileage built.

It is not possible, and even if it were so, it would not be desirable in this address, to enumerate or analyze the general work of railway construction during the past twelve months. Suffice it in the meantime to quote one or two instances. The year 1909 has witnessed the advent at the Pacific Coast of two of the large railway systems, which had not until then physical access to that important section of the country. The Chicago, Milwaukee & St. Paul Railway System has been extended from the Missouri River to Seattle, Washington, a distance of 1,400 miles, 687 of which were built and placed in operation last year; and the Western Pacific, as representing the Gould System, has been opened for traffic from Salt Lake City, Utah, to Oakland, California, a distance of 924 miles, 440 miles of which were built in 1909. Two other roads, at present under way, viz., the Spokane, Portland & Seattle Railway, and the Kansas City, Mexico & Orient Railway also will, when completed, form parts of transcontinental systems respectively.

Another undertaking, transcontinental in a complete sense, and greater in magnitude than any other single railway proposition that has been built at one time on this Continent, viz., the Grand Trunk Pacific and the National Transcontinental, is at present being rapidly constructed on the most approved modern lines from the Atlantic to the Pacific and entirely within the Dominion of Canada. The length of the main track of this railway will be 3,561 miles. Of a total of 1,500 miles now constructed, 500 miles were built and placed in operation in 1909, and 1,200 miles more of main track are at present under construction. It is interesting to note that the whole of the main line of this railway has been permanently located. It crosses the Rockies at an elevation of only 3,712 feet, and is being constructed on an entirely low-grade basis. It has only one summit between the prairies and its western terminal, Prince Rupert on the Pacific Coast, and with the exception of a stretch of 20 miles where the grade is 1 per cent., its ruling grade through the mountains is 0.4 of 1 per cent. It will not be difficult to realize, therefore, that the line will be admirably conditioned for heavy traffic, and further that exceptional features concerning location have been the means of obtaining at the very outset this unique condition.

Such revision work, double-tracking and other permanent betterments (as distinct from ordinary maintenance) as have been undertaken throughout the country have been characterized by mature judgment in carrying them to completion. The longest individual stretch of double-tracking an existing line which had been in course of construction (but actually completed during the year), was on the Canadian Pacific, from Fort William, Ontario, to Winnipeg, Manitoba. The distance between these two points is 417 miles. In conjunction with this work the limiting grades against eastbound traffic were reduced from 1 per cent. (not compensated) to 0.4 of 1 per cent. (compensated). In order to obtain such a reduction reasonably it was found desirable and more practicable to take advantage of the physical conditions of that section of the country, and locate the new eastbound track in some places beyond the right-of-way of the existing line, in lengths varying from 0.6 of a mile to 5 miles, and in distance from the original track of 500 feet to 7 miles. The ruling grade of the westbound track was at the same time also reduced from 1 per cent. to 0.4 of 1 per cent., except for a distance of 54 miles, which is still 1 per cent. and operated as a pusher proposition.

Among the most notable of the railway engineering structures which were completed during the year may be mentioned the Susquehanna Bridge of the Baltimore & Ohio Railroad at Havre de Grace, Md., a double-track structure, the total weight of the steel being 16,000 tons. Three of the piers of this bridge were sunk in the bed of the river by the caisson process to solid rock foundations at depths varying from 60 to 75 feet below tide.

Also the Lethbridge viaduct over the Belly River on the Crow's Nest branch of the Canadian Pacific Railway. This bridge has 66 spans of through-plate girders and one deck lattice truss which are carried on rigidly braced steel towers. The magnitude of this work may be realized when it is stated that the steel structure is 5,327 feet long, 314 feet from the bed of the river to rail, and contains 12,200 tons of steel.

The new bridge of the Pittsburg & Lake Erie Railroad over the Ohio River at Beaver, Pennsylvania, is so nearly completed as to be consistently mentioned at the present time. This structure is a double-track one, 1,787 feet long, and replaces a single-track bridge. The new channel span is 769 feet as against 443 feet in the old. The old bridge was erected in 1878, at a time when the use of falsework was permitted, but the present one being of the cantilever type, has been erected without interruption to navigation. The trusses were designed for Class E-55 locomotives, and the floors for Class E-60 locomotives, with full allowance for impact. The superstructure contains 16,500 tons of steel.

The new spiral tunnels of the Canadian Pacific Railway in the Rocky Mountains are particularly worthy of mention as being the first introduction of this particular system of tunnels on this Continent. The original line of this railway between Field Station and Hector Station (known as the Kicking Horse Pass) was constructed for a distance of 4.50 miles, with a 4.5 per cent. grade. In order to improve such conditions only one proposition was feasible, namely, a development one, involving certain tunneling, with a consequent doubling back for some distance as well as crossing the Kicking Horse River twice. There are two tunnels, one of them 3,255 feet long, on a reverse curve, and the other 2,921 feet long, partly on a 10 degree curve and partly on a tangent. The curves have 300 feet of spiral at each end. The new grade in general on this deviation has been reduced from 4.5 per cent. to 2.2 per cent. compensated, except in the tunnels, where 6.10 per cent. is used. Work on the tunnels was started from both ends and, despite the complicated work caused by the spiral shape, the two headings met, with the levels checking in one case to 1/100 of a foot and in the other to 2/100 of a foot. The reduction in gradient from 4.5 per cent. to 2.2 per cent. on this particular section necessitated an increase in length of track of 4.50 miles.

It is interesting also to note that in the month of November last, although not as yet completed for ordinary operation, a Pennsylvania

Railroad train passed through the Hudson River Tunnel for the first time.

In the carrying to completion of the railway engineering structures mentioned, and many others built during the past year, as well as in most of the great number in course of construction throughout this great country, an influence traceable primarily and directly to the organization and working of the American Railway Engineering and Maintenance of Way Association, and which has already been referred to, is apparent, and such influence has been manifested as well in the development of every important detail connected with this particular section of industrial activity.

As far as the direct interests of the Association and the work of your Committees for the past year are concerned, it will be observed that for satisfactory reasons the reports of two of these committees are merely those of progress, but they are indicative of excellent material which will be worked upon and from which practical information will eventually be obtained. A reference to the other reports will be self-convincing of the businesslike and scientific manner in which the details under investigation have been dealt with and focused to conclusions by these respective Committees, and which you will be asked to pass upon in open convention.

The American Railway Association has placed at our disposal the means for employing an expert to superintend the tests of rails at the several mills on a uniform and scientific basis. Such tests will be carried on under the direct auspices of your Committee on Rail. Valuable results are confidently expected from the work thus to be undertaken. Good rail being of fundamental importance to a railway, this Committee has been most zealous in its determination to leave nothing undone that will bring about conditions in design and manufacture that will be satisfactory to the railways in general.

The Board of Direction has for some time past been considering the advisability of revising the existing Constitution of the Association. Some of the changes proposed are minor in character, while others are more far-reaching in their scope. The present form and the proposed form have been printed and issued to the members for their consideration, and it is suggested that each one of the proposed changes be carefully studied in order that the final vote may be looked upon as given after earnest consideration of future effects.

Last July our esteemed Treasurer, Mr. W. S. Dawley, who had occupied that honorable office acceptably since the formation of the Association in 1899, tendered his resignation as such, to undertake railway construction work in China. The Board of Direction realizes that the Association had in Mr. Dawley an efficient officer, and desires to place on record its regret at losing one who had rendered valuable services, not only as a member of the Board but also as a custodian of the finances of the Association during the past ten years.

We have lost a number of valuable members by death during the year, among them being H. F. Baldwin, at one time a Director of the Association; James Keys, Vice-Chairman of the Committee on Wooden Bridges and Trestles (Mr. Keys has contributed very materially to the success of the Committee and we are indebted to him for a large amount of valuable data); G. A. Casseday, another member of the same Committee; J. W. Schaub, a valued member of the Masonry Committee for a number of years; E. J. Randall, H. M. Steele, and James C. Gray.

At the close of your President's term of office as such he desires to acknowledge his appreciation of the hearty co-operation of the Board of Direction, as well as of the membership in general, in his efforts to satisfactorily administer the affairs of the Association. It affords him much pleasure to feel that the Association stands on a high plane, and having been intimately connected with its work from the beginning he would be devoid of proper spirit did he not feel that his practical interest in that work would never lessen. (Applause.)

The President:—The next business will be the report of the Secretary and Treasurer.

Secretary E. H. Fritch presented the following report:

REPORT OF SECRETARY AND TREASURER.

March 15, 1910.

To the Members of the American Railway Engineering and Maintenance of Way Association:

The following report is respectfully submitted:

FINANCIAL STATEMENT.

Receipts during the year	$19,758.08
Expenditures during the year	21,203.40
Excess of expenditures over receipts during the year	$ 1,445.32

IMPACT FUND.

Amount collected during the year for impact tests	$ 4,191.10
Amount expended during the year for impact tests	1,368.09
Balance of fund on hand	$ 2,823.01
Balance on hand March 12, 1910	$16,403.01

EXPENDITURES IN DETAIL.

Stationery and printing	$ 721.26
Proceedings	4,563.79
Bulletins	6,635.53
Postage	541.34
Salaries	4,031.96
Officers' expenses	35.90
Annual meeting expenses	981.89
Telephone and telegrams	99.13

Committee expenses	422.84
Rents	720.00
Expressage	680.62
Exchange	38.80
Office supplies	139.83
Light	17.60
Equipment	89.82
Impact test	1,368.09
Miscellaneous	145.00
Total expenditures during the year	$21,203.40

MEMBERSHIP.

Total number of members at last annual convention			784
Members admitted during the year		101	
Deceased during the year	7		
Withdrawals	4		
Dropped	5		
	16	16	
Gain		85	85
Membership March 12, 1910			869

(On motion of Mr. Hunter McDonald, the report was accepted and ordered filed.)

The President:—The first report is that of the Committee on Rules and Organization, Mr. Jos. O. Osgood, Chief Engineer of the Central Railroad of New Jersey, chairman.

(See report, pp. 35-43; discussion, pp. 44-49.)

The President:—The next report is that of the Committee on Signals and Interlocking, Mr. A. H. Rudd, Signal Engineer, Pennsylvania Railroad, chairman.

(See reports, pp. 51-78, 79-84; discussion, pp. 85-102.)

The President:—We will now take up the report of the Committee on Electricity. In the absence of the chairman of the Committee, Mr. George W. Kittredge, Mr. J. B. Austin, Jr., Engineer Maintenance of Way, Long Island Railroad, the vice-chairman, will present the report.

(See report, pp. 103-105; discussion, p. 105.)

The President:—The next report will be that of the Special Committee co-operating with the National Conservation Commission, of which Mr. A. S. Baldwin, Chief Engineer of the Illinois Central Railroad, is chairman. In the absence of the chairman, Mr. Moses Burpee, Chief Engineer, Bangor & Aroostook Railroad, will present the report.

(See report, pp. 106-114.)

The President:—An invitation has been received from the Chicago Engineers' Club extending the privileges of the Club to the members of the Association during this convention.

AFTERNOON SESSION.

The President:—The report of the Committee on Iron and Steel Structures will be next in order. Mr. J. E. Greiner, Consulting Engineer, Baltimore & Ohio Railroad, chairman.

(See report, pp. 115-159; discussion, pp. 160-172.)

The President:—We will now take up the report of the Committee on Wooden Bridges and Trestles, Professor Henry S. Jacoby, of Cornell University, chairman.

(See report, pp. 173-227; discussion, pp. 228-234.)

(Adjournment until eight o'clock.)

EVENING SESSION.

(Vice-President L. C. Fritch in the chair.)

Vice-President Fritch:—The first order of business is the report of the Committee on Rail, Mr. Chas. S. Churchill, Chief Engineer, Norfolk & Western Railway, chairman.

(See report, pp. 235-559; discussion, pp. 560-580.)

Vice-President Fritch:—The next order of business is a special paper by Mr. J. W. Kendrick, Vice-President of the Santa Fe Railroad, on the subject of "Conservation of Cross-ties by Means of Protection from Mechanical Wear," and illustrated by lantern slides. I know we will all be pleased to hear from Mr. Kendrick on this most interesting subject, and that we will be benefited by what he has to say.

Mr. J. W. Kendrick (Atchison, Topeka & Santa Fe Railroad):—It is a common remark that the present generation owes nothing to posterity because posterity never did anything for it. But this is a narrow and untenable view. Moreover, any question of the conservation of timber in this country is one which does not wholly affect posterity, because there are many here to-night who will live to witness the disappearance of the American forests.

(Mr. Kendrick then presented the paper. See pp. 581-630.)

Vice-President Fritch:—We are certainly all indebted to Mr. Kendrick for his entertaining and instructive address, and I am sure I express the sentiments of the members present in thanking Mr. Kendrick for his most interesting paper. (Applause.)

WEDNESDAY, MARCH 16, 1910.

MORNING SESSION.

The President:—Before taking up the consideration of reports, the chair would ask the unanimous consent of the meeting to vary from the order of procedure and have the ballots for the election of officers canvassed this morning, so that the result may be announced before we adjourn in the middle of the day. If there is no objection, it is so ordered. I will appoint as tellers of election Messrs. K. J. C. Zinck, C. H. Spencer and C. H. Fisk.

The President:—The first report to be considered is that of the Committee on Economics of Railway Location, Mr. A. K. Shurtleff, Office Engineer, Chicago, Rock Island & Pacific Railway, chairman.

(See report, pp. 631-708; discussion, pp. 709-733.)

The President:—We will next take up the report of the Committee on Wood Preservation, Professor W. K. Hatt, of Purdue University, chairman.

(See report, pp. 735-857; discussion, pp. 858-860.)

The President:—The tellers appointed at the opening of the session have presented their report, as follows:

To the Members of the American Railway Engineering and Maintenance of Way Association in Convention:

The undersigned Committee, appointed to canvass the ballots for officers and directors of your Association for the coming term, beg leave to report that after careful count and examination of all the ballots cast, we find the number of votes cast for the different officers and directors to be as follows:

Total ballots cast 448

FOR PRESIDENT.

L. C. Fritch	442
S. B. Fisher	3
Robert Trimble	1
M. L. Byers	1
C. F. Loweth	1

FOR VICE-PRESIDENT.

Chas. S. Churchill	446
Thomas H. Johnson	2

FOR SECRETARY.

E. H. Fritch	448

FOR TREASURER.

C. F. Loweth	446
D. W. Lum	1
L. C. Fritch	1

FOR DIRECTORS (Three Years Each).

Robert Trimble	443
F. S. Stevens	442
J A. Atwood	5
M. L. Byers	2
J. B. Berry	1
Geo. F. Morse	1
L. S. Rose	1

Respectfully submitted,

C. H. Fisk,
K. J. C. Zinck,
C. H. Spencer,
Tellers.

AFTERNOON SESSION.

The President:—The first report to be considered is that of the Committee on Ties. In the absence of the chairman, Mr. E. B. Cushing, the vice-chairman, Mr. E. E. Hart, Chief Engineer, New York, Chicago & St. Louis Railroad, will present the report.

(See report, pp. 861-900; discussion, pp. 901-905.)

The President:—The next report will be that of the Committee on Ballast, Mr. John V. Hanna, Chief Engineer, Kansas City Terminal Railway, chairman.

(See report, pp. 906-929; discussion, pp. 930-933.)

The President:—The next report in order will be that of the Committee on Track, Mr. L. S. Rose, Signal Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway, chairman.

(See report, pp. 934-943; discussion, pp. 944-955.)

The President:—The next report is that of the Special Committee on Standard Specifications for Cement. Mr. Howard G. Kelley, Chief Engineer, Grand Trunk Railway, chairman, will present the report.

(See report, pp. 956, 957; discussion, p. 958.)

The President:—The next report is that of the Committee on Masonry, Mr. A. O. Cunningham, Chief Engineer, Wabash Railroad, chairman.

(See report, pp. 959-1018; discussion, pp. 1019, 1020.)

THURSDAY, MARCH 17, 1910.

MORNING SESSION.

The President:—The first business is a consideration of the report on Buildings, Mr. O. P. Chamberlain, Chief Engineer, Chicago & Illinois Western Railroad, chairman.

(See report, pp. 1021-1047; discussion, pp. 1048-1060.)

The President:—We will next take up the report of the Committee on Roadway, Mr. G. H. Bremner, Engineer Illinois District, Chicago, Burlington & Quincy Railroad, chairman.

(See report, pp. 1061-1086; discussion, pp. 1087-1096.)

The President:—We will next consider the report of the Committee on Records and Accounts, Mr. H. R. Safford, Chief Engineer Maintenance of Way, Illinois Central Railroad, chairman.

(See report, pp. 1097-1136; discussion, pp. 1137-1142.)

AFTERNOON SESSION.

The President:—We will now take up the report of the Committee on Water Service, Mr. C. L. Ransom, Resident Engineer, Chicago & Northwestern Railway, chairman.

(See report, pp. 1143-1218; discussion, pp. 1219-1227.)

The President:—The next report is that of the Committee on Signs, Fences and Crossings, Mr. W. D. Williams, Chief Engineer, Cincinnati Northern Railroad, chairman.

(See report, pp. 1229-1245; discussion, pp. 1246-1248.)

The President:—The chair would ask the convention to take a recess for a few minutes. The President of the United States will be here to address the convention, and if there is no objection, we will suspend the business of the convention temporarily.

Mr. George W. Kittredge (New York Central & Hudson River):—While we are waiting for the President's visit, I desire to offer the following resolution:

Resolved, That the members of the American Railway Engineering and Maintenance of Way Association, in annual convention assembled, desire to express their hearty appreciation of the efforts made and the admirable results obtained by the Railroad Age Gazette in its daily issue during this convention;

Resolved, That the cordial thanks of the Association be extended to its managing officers and editorial staff;

Resolved, That a copy of these resolutions be spread upon the minutes of this convention and a copy transmitted to the Railroad Age Gazette.

The President:—It is unnecessary to ask you if you are ready for the question, but I do ask you to signify your approval in a good, hearty way.

(The resolution was adopted unanimously.)

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I desire to offer the following resolution:

Resolved, That the members of the American Railway Engineering and Maintenance of Way Association, in annual convention assembled, desire to express their hearty appreciation of the efforts made and the admirable results obtained by the Railway and Engineering Review in its daily issue during this convention;

Resolved, That the cordial thanks of the Association be extended to its managing officers and editorial staff;

Resolved, That a copy of these resolutions be spread upon the minutes of this convention and a copy transmitted to the Railway and Engineering Review.

(The resolution was adopted unanimously.)

Mr. Edwin F. Wendt (Pittsburg & Lake Erie):—I am sure that all who attended the Coliseum this week were impressed with the splendid exhibition of railway appliances. I, therefore, move that as an Association we recognize the merits of the exhibition referred to and commend the Road and Track Supply Association for the high standard on which the exhibition has been conducted, and that a copy of this resolution be forwarded by our Secretary to the officers of the Road and Track Supply Association.

(The motion was adopted.)

The President:—We are fortunate in having with us four of our Past-Presidents, and I will request them to assist me by taking chairs here on the platform.

Mr. C. F. Loweth (Chicago, Milwaukee & St. Paul):—While we are waiting for the President of the United States, at this stage of the proceedings I would like to inquire what is the matter with our retiring President? Is he all right?

The Members: He's all right.

Members: Who's all right?

Members: McNab. (Applause and calls "McNab.")

President McNab:—Gentlemen, I thank you for that ovation, but I feel considerably embarrassed. I am not naturally nervous, but at the present time one needs to have his wits about him. I was accused last night by my own countryman of being a story teller. You know what "story teller" means. In Scotland it means those who trace their lineage back to Ananias and Sapphira. I do not think our honored friend, Mr. Graham, meant that my lineage extended that far back, or in that direction. I belong to the north of Scotland. We have other characteristics than story telling. They are all good ones, though.

Gentlemen, I take this opportunity, as I may not get it again at this convention, of expressing to you my appreciation of your kindness to me while I have occupied this honored chair. I do not think that there is any position in this country where railway engineers are concerned, that is more honorable than being President of this Association, and I only wish that it could be that it would come to you all in turn, but that is impossible. Let me, however, put it up to you as an ambition to look forward to, and I am sure that you will find that what I have said is correct, that there is no position in the railway engineering world more to be desired than the presidency of this Association. I, perhaps, can speak with a little feeling on that point, as I have been connected with the Association since its inception. I have seen it grow. I have been in close touch with the majority of our members. I have been associated with my honored friends here on the platform since the Association was started, and have observed it wield a great influence in the railway world, which it has to-day. I am perfectly satisfied that the physical status of the great railways, the great trunk lines and most of the railways of this country could not be in the condition in which they are were it not for the exercise of the principles and practice recommended by this Association. If we have attained the prominence in which we find ourselves to-day in ten years, what will it be in a few years hence? It is almost incredible that previous to eleven years ago there was no such Association as this and that every railway was acting according to the dictates of its own conscience. I do not know whether conscience always prompted it in the right lines or not. Probably in some cases it did not.

I feel pleased that my successor has been identified with the Association since its beginning. You all know him; he knows the Association, and I am sure that the office of President will be conducted with the dignity that it deserves. I feel perfectly satisfied, perfectly happy in retiring from this chair, leaving the Association on the high plane it is on to-day. The climax to it all is that we are to have a visit from his Excellency, the President of the United States. (Applause.) I would be very glad to have some gentleman belonging south of parallel 49 to finish up for me what I ought to have said.

Past-President Hunter McDonald:—Gentlemen, I am no mind-reader; I do not know exactly what our President did intend to say.

The only thing that I believe I could say here that would be at all applicable to what he intended to say is that in the song that was given us yesterday afternoon to sing at the banquet, I think I was put down there as being very greatly delighted at hearing "Dixie" sung. I simply want to say it always gives me very great delight to hear it sung north of Mason and Dixon's line.

Past-President Kittredge:—I remember very well the first time I sat behind a table in front of an audience, not nearly as large as this, in the early days of the Association's existence, and I remember the feelings of misgivings I had when I started my first annual address. I think I owe it to your indulgence that I got along as well as I did. I want to repeat the sentiments which Mr. McNab has expressed in regard to parting from the Association. When I turned the Association over to my successor, it was with a feeling of affection and regard for the Association that was very difficult to put into words. The Association has been in good hands and has prospered splendidly and it has a great future before it. (Applause.)

Past-President Kelley:—I had hoped that my watch would get far enough past four so that I would not be called on. I think, with my fellow Past-Presidents, that the Maintenance of Way Association has done a work which has never been equaled by any scientific or technical body of men in the world. We have brought together all of our ideas. I said to some of my men yesterday: "If you will get up and talk in the convention, the first thing you will learn is that all of your preconceived notions will be knocked out. You will find that there are three hundred or more men in the room who have been thinking upon the same subject, and they have been thinking well, and all your rough corners and ill-judged opinions will be knocked out first, then brought back and set in the wall where they belong." And that is the result of the unity of our work in the eleven years of the Association. The Proceedings have become more valuable each year. I am a member of a number of technical associations; I can freely say that to one book of reference that I take down from my shelf for information, there is one of all those of the technical associations I belong to that I go to one hundred times to one time to the others—our own Proceedings—because they reflect the thoughts, the experience and the results that several hundred minds working in the same direction, on the same problems, have arrived at, and give precise, well-settled results. All of our companies realize it. The sales of our Proceedings are increasing. I am a member of the Institute of Civil Engineers of Great Britain. I was incautious enough to send them at one time the first four volumes of our Proceedings. I thought that was quite enough. Next year I forgot it, and I got a very polite letter from the Secretary, saying: "My Dear Mr. Kelley: If your Association has published another volume, we want it." So I sent that, and I forgot it another year, not intentionally; I received another reminder, saying: "You are two years behind in the volumes. We must have them in this Institute." Now, gentlemen, that is the way the work of this Association is looked upon abroad, and it is not because of the efforts of one or two men, but the efforts of hundreds of men composing this Association. I thank you. (Applause.)

Mr. C. E. Lindsay (New York Central & Hudson River):—Mr. President, one of the greatest pleasures we have had here is the greeting of familiar faces. There are some faces that we miss, and some that have not yet gone beyond recall. I, therefore, move that we send a message of esteem and regret at their absence.

Mr. J. P. Snow (Boston & Maine):—Gentlemen, I second that motion with all my heart.

The President:—I will ask you, gentlemen, to show your appreciation of the motion by a standing vote.

(A unanimous rising vote was then taken on the adoption of Mr. Lindsay's motion.)

The President:—Gentlemen, I wish to say that I think no one knows better than I do Mr. E. H. Fritch's ability in taking care of the work of this Association. I belong to a number of technical societies, and I know of none in which the amount of work is accomplished with such a small force as is found in our office in Chicago, but it is a force and that force is E. H. Fritch. There is just one fault that he has. He is too modest. During a convention of this kind the tax upon the mental faculties of the incumbent of an office like that is very severe. We have had our experience with Mr. Fritch, and he has never failed yet; but I think at the present time he has just about gone through all he can and I am going to suggest to our Board of Direction, at its first meeting, that we give Mr. Fritch a little leave of absence to get up good, robust health. He is painstaking in the highest degree, and in regard to his work you have only to point to the volume of Proceedings and the excellent manner in which it is gotten up. Mr. Fritch's early training, of course, helps him to a large extent. I have much pleasure in asking the Association to testify their appreciation of their Secretary's work by a good, rousing cheer. (Cheers.)

VISIT OF PRESIDENT WILLIAM HOWARD TAFT.

(At 4:30 p. m. President Taft arrived at the meeting, and after advancing to the right of President McNab, the latter greeting the President, addressed him as follows:)

Mr. President: In the name and in behalf of the officers and members of the American Railway Engineering and Maintenance of Way Association, it is my pleasing duty, as well as privilege, to extend to you a hearty welcome to our Eleventh Annual Convention, and may I be permitted to say that your visit is none the less appreciated by reason of its informality.

I am quite aware that the objects of this body are as familiar to you as they are to those who have the immediate direction of the location, construction, operation and maintenance of railways.

Let me trust that it will not be looked upon as being beyond the limits of modesty if it be said by me that the excellence of the physical status of our great trunk lines, as well as that of most of our roads, has not been produced merely by the amount of money expended upon it. It is due also to the manner in which the work involving such expenditure was made, and this has been brought about largely through the influence of and exercise of the principles and practice recommended by this Association.

Mr. President, this Association is American in name and domiciled in the city of Chicago, yet as far as the science of railroading (in its broad sense) is concerned, it is not circumscribed by mere national lines. To-day its chief executive officer is one not a citizen of the United States, and on that account he would be deficient of ordinary human nature did he not feel and did he not appreciate in the highest degree the unique honor and privilege he possesses at the present time of presenting the President of the United States of America to this convention, with a request for a few words from your Excellency. (Applause.)

President Taft:—Mr. Chairman, and Gentlemen of the Maintenance of Way Association: I am very glad to meet and cultivate the good graces of a Canadian just at this time. (Applause.) I suppose that I shall surprise you if I tell you that I have done a good deal in the way of railroad repair and railroad construction. There was a time, between 1893 and 1900, when I occupied the position of United States Circuit Judge in that part of the country where most of the railroads went into the hands of a receiver, and if you know anything about receiverships, as I doubt not most of you do, as you are railroad men, the first thing that a good receiver does is to consult his maintenance of way man and his engineer to see how much in the way of receiver's certificates he ought to issue to make the road safe for the carriage of passengers. I was an undertaker in the burial of, I do not know how many railroad companies in the Sixth Circuit, and in the reconstruction, under the system of receiver's certificates of thousands of miles of railway, and at that time I was able to follow with a good deal of interest the price of steel rails and how far a million dollars would go in helping along a railway that needed new steel. I came then to know what I ought to know, at any rate, that the maintenance of way man is the man, after all, into whose keeping is given the safety of ninety millions of people. The engineers who make the roadbed and direct the laying of the track and the building of the bridges are the persons who effect not only our comfort as we go over the road, but our safety, and make the question whether we will return to our wives a certain one or otherwise. I traveled 14,000 miles this year, and I am bound to say that the travel was in every respect delightful. The ways were well maintained and when we had a jolt we attributed it, not to the engineer of the road, but, knowing something about those things, to the carelessness of the locomotive engineer. (Applause.)

But I did not come, gentlemen, to make a speech on the subject of railroads. I know that I am looking into the faces of the men who have the brains used in railroad construction of this country, and I am glad to be here and to extend you a congratulatory word on the improvement that has gone on in railway construction and railway repair and railway roadbeds within the memory of the youngest of us. So that to-day you who can look back a generation can see an improvement that you certainly did not expect when you began your profession. We have not in this country followed you in the perfection of laws that shall protect the public against accident. I mean not the traveling public, because I think there the statistics are not so unfavorable and compare well with foreign railroads, but the law I refer to is the law which keeps the roadbed free from trespassers (applause), and which requires gateways and such protection against the negligence of the public itself as to reduce to a minimum the killing and wounding of people, who, when they are wounded, have only themselves to blame. (Applause.)

Gentlemen, I do not know whether this is the fifth or sixth speech that I have attempted to make to-day, but I know you will excuse me from saying anything further than to express my great pleasure at your welcome, and especially at the hands of one who comes from our Northern neighbor. (Applause.)

The President:—We will now resume the regular order of business and take up the report of the Committee on Yards and Terminals, Mr. F. S. Stevens, Superintendent, Philadelphia & Reading Railway, chairman.

(See report, pp. 1249-1308; discussion, pp. 1309, 1310.)

The President:—This completes the consideration of reports of committees. The next order is that of New Business. Has any member anything to offer in the way of new business?

Mr. Ewing:—This Association has been signally honored by a visit to the eleventh annual convention by the President of the United States, and I think we should extend a vote of thanks to Mr. L. C. Fritch, to whose successful efforts we are indebted for the honor conferred on this Association.

The President:—In presenting that motion to the convention, I desire to say that it is one of the greatest honors that can be conferred on any scientific body to have a visit from the Chief Magistrate of the country. I know how proud they feel in a certain bordering country in having such a visit from their Chief Executive, and I know that Mr. Fritch has been most assiduous in his efforts to secure this honor for our Association. There was a time when it looked a little gloomy as to whether he would succeed, but when Mr. Fritch once sets his mind on anything he does not let up until he carries it to a successful issue.

Personally, I feel honored in having such an occasion mark the close of my tenure of office as President of this Association.

(The motion was put to vote and carried.)

Mr. W. L. Seddon (Seaboard Air Line):—Under the head of new business, I have a matter to bring before the Association. I do not know that any of my railroad friends are having the experiences we are having down in the southeastern section of this country regarding the requirements for structures over navigable streams. The definition of navigable streams has been very much extended in the last few years, and under the present situation, while the matter is left somewhat in the discretion of the United States Engineering Officer of the district, it is very often in such shape as to put him in a rather awkward position, and I believe the time is ripe for something to be done on that line. I have talked to several army officers about the matter, and I believe if this Association would appoint a Committee to confer with the Chief of Engineers, considerable help could be had for the railroads in that respect and one that we need very much in my part of the country where the small motor boat is causing us to put in very expensive structures on streams with no other navigation.

The President:—The Board of Direction will take that matter under consideration.

Gentlemen, I have very much pleasure in presenting to you Mr. L. C. Fritch, whom you have elected as your President for the ensuing year. I will ask Mr. Wendt and Mr. Cushing to escort Mr. Fritch to the chair. (Applause.)

President-Elect Fritch:—I appreciate very deeply, gentlemen of the Association, the honor you have conferred upon me. I am following a long line of illustrious predecessors, who have brought this Association up from its humble beginning until it is now the strongest railroad association in the United States. I sometimes think that the membership at large and the railway managers and executives do not fully appreciate what this Association is doing for the railroads. I believe that the Recommended Practices of this Association are saving the railroads of this country hundreds of thousands, perhaps millions of dollars, annually.

My only hope, gentlemen, is that I may fill the duties of this office to the satisfaction of the Association. I know that with the co-operation of the Board of Direction, the officers, the Committees and the membership at large, and with my own effort, I will render to the Association the very best that is in me. I thank you. (Applause.)

President-Elect Fritch:—Gentlemen, I beg leave to offer a resolution of thanks of this Association to our retiring President, Mr. William McNab. He has given the Association almost two years of untiring effort as the guiding hand of this organization. You might say that most of the success of this Association is due to the efforts of the President. He is the executive officer who is in charge of the destinies of the Association, and its success is proportioned to the amount of zeal and energy that he puts into the work. I think that this convention marks the very zenith of the success of this Association, and I think it is largely due to the efforts of our retiring President. I want to ask you all to rise in a vote of thanks for our retiring President.

(The members rose and cheered the ex-President.)

Past-President McNab:—Mr. President and gentlemen, just let me say this: I appreciate the vote of thanks you have passed, and all I want to say now, which I could not say during my term of office, is that the office of President of this Association is not a sinecure.

Mr. F. R. Coates:—I desire to offer a resolution of thanks to the Irish Fellowship Club of Chicago for the assistance they gave us in securing the attendance of the President of the United States at this meeting.

President-Elect Fritch:—I think the resolution is happily put for the reason that credit is largely due to the local committee of the Irish Fellowship Society for having the President with us to-day.

(The motion of Mr. Coates was put and carried.)

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I move that we adjourn.

President-Elect Fritch:—I now declare the eleventh annual convention of the American Railway Engineering and Maintenance of Way Association formally adjourned.

The twelfth annual convention of the American Railway Engineering and Maintenance of Way Association will be held at the Congress Hotel, Chicago, Ill., Tuesday, Wednesday and Thursday, March 21, 22 and 23, 1911.

E. H. Fritch, *Secretary.*

COMMITTEE
REPORTS AND DISCUSSIONS

COMMITTEE XII—ON RULES AND ORGANIZATION.

(Bulletin 119.)

To the Members of the American Railway Engineering and Maintenance of Way Association:

Your Committee was instructed by the Board of Direction to:

1. Consider revision of Manual, both generally and with a view to consistent general grouping of heads, uniformity of numbering and similarity in language covering similar rules.

2. Confer with allied committees which have heretofore presented rules which have been adopted by the Association with a view of harmonizing all such rules as have been considered by this Committee.

The Committee has held two meetings during the year, the first on June 18, at which six members were present, and the second on November 19, at which five members were present.

The work under the first instruction has mainly occupied the time of the Committee, and this year's report does not attempt to deal with the second.

The General Rules for the Government of Employes of the Maintenance of Way Department, heretofore adopted by the Association, have been carefully reviewed by your Committee, the revision being a more logical arrangement of the rules, and minor changes in wording without change in substance.

Some progress has been made, however, in compiling and arranging the rules originating with other committees, and it is proposed during the remaining months of the year to confer with such committees with a view to obtaining their assent to the changes in arrangement which may be found desirable.

Your Committee recommends that the General Rules shall be as follows:

GENERAL RULES FOR THE GOVERNMENT OF EMPLOYÉS OF THE MAINTENANCE OF WAY DEPARTMENT.

GENERAL NOTICE.

1. To enter or remain in the service is an assurance of willingness to obey the rules.

2. The service demands the faithful, intelligent and courteous discharge of duty.

3. Obedience to the rules is essential to the safety of passengers and employés, and to the protection of property.

4. Employés must exercise the greatest care and watchfulness to prevent injury or damage to persons or property, and in case of doubt take the safe course.

5. Employés must do all in their power to prevent accidents, even though in so doing they occasionally perform the duties of others.

6. Co-operation is required between all employés whose work or duties may be jointly affected.

7. Anything that interferes with the safe passage of trains at full speed is an obstruction.

8. Employés in accepting employment assume its risks.

9. To obtain promotion, capacity must be shown for greater responsibility.

ORGANIZATION.

1. The Maintenance of Way Department on each division is in charge of the .... (Title) ...., who will report to and receive instructions from the.................. (Title)

2. The work of the Department will be subdivided under the following heads:

Track Supervisors.
Supervisors of Structures.
Signal Supervisors.

RULES GOVERNING TRACK SUPERVISORS.

1. Track Supervisors shall report to, and receive instructions from, the .... (Title) ....

2. They shall be responsible for the safe condition and proper maintenance of track, roadway, right-of-way, station grounds and driveways, and must inform themselves of the condition of structures. They must make temporary repairs of such defects as may endanger or delay the movement of trains, and promptly report defective conditions to the ....(Title).

3. They must make frequent inspections of track, roadway, right-of-way, station grounds and driveways, and have necessary repairs made as promptly as conditions require.

4. They shall, as necessary, employ men for carrying out the duties for which they are responsible.

5. They must know that foremen are familiar with the operating rules in regard to train signals and flagging, and that they fully understand and comply with them.

6. They must, in case of obstruction or damage to track or roadbed, proceed to the place with the forces at their command and do all in their power to promptly clear and repair the track.

7. They shall investigate and report on Form No. ...... accidents which may be attributable to defects in, or result in damage to, track, roadbed or structures.

8. They shall conform to the prescribed standards and plans in the execution of work under their charge.

9. They must know that foremen are supplied with tools and materials necessary for the efficient performance of their duties, and see that these are properly used and cared for.

10. They must not, except by proper authority, permit experimental trials of appliances or devices, nor give out information of the results of any trial.

11. They shall keep themselves informed in regard to all work performed in their districts by contractors, or others who do not come under their charge, and see that nothing is done by them that will interfere with the safety of track or the movement of trains.

12. They shall have immediate supervision of work train service for the maintenance of track and employ such service only when authorized by the .... (Title) ....

13. They must know that foremen are provided with the rules. circulars, forms and special instructions pertaining to their duties, and that they fully understand and comply with them.

14. They shall see that the vicinity of all bridges and trestles is clear of all combustible matter, and that bridge seats, tops of piers and other readily accessible portions of bridges and trestles are clear of cinders and dirt and that water barrels are full of water.

15. They shall see that waterways and the approaches and outlets thereto are free from obstructions.

16. They shall see that no encroachment upon, or occupancy of, any portion of the Company's buildings, right-of-way or station grounds is permitted, except by proper authority.

RULES GOVERNING TRACK FOREMEN.

1. Track Foremen shall report to, and receive instructions from, the .... (Title).

2. They shall be responsible for the proper inspection and safe condition of the track and roadway under their charge, and shall do no work thereon that will interfere with the safe passage of trains, except under proper protection.

*3. They must go over their sections, or send a reliable man, with suitable tools, at least once a day to make a thorough inspection, to see that the track, highway crossings, signals, culverts, bridges, fences, telegraph lines, etc., are in safe condition.

4. They shall employ men as the .... (Title) .... directs, and see that they properly perform their duties. They must keep the required records of the time of their men and of the materials used.

5. They must each have a copy of the current time-table, and be thoroughly familiar with the rules and regulations therein, and with the

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*Amend by inserting at beginning of rule, "Unless otherwise directed."

time of trains over their sections. They must carefully observe signals displayed by all trains, and assure themselves before obstructing track that all trains and sections due have passed. No notice will be given of extra trains, and employés must protect themselves as prescribed by the Rules. Foremen must provide themselves with reliable watches, and when possible compare time daily with a standard clock or with conductors' watches.

6. If, in the judgment of the Track Foreman, the track or any bridge or culvert is not safe, he must at once put out the proper signals to warn approaching trains, notify the proper officers of its condition, and do all in his power to make necessary repairs.

7. Track Foremen must, in case of accident, promptly render all assistance in their power, whether the accident occurs on their own or adjacent sections. They shall investigate and report on Form No. ..... all accidents occurring on their sections, which may be attributable to, or result in damage to, track, roadbed or structures.

8. They shall conform to the prescribed standards and plans in the execution of work under their charge.

9. They shall be responsible for the proper care and use of tools and materials necessary for the efficient performance of their duties, and shall make requisition to the .... (Title) .... from time to time as additional supply becomes necessary.

10. They must not, except by proper authority, permit experimental trials of appliances or devices, nor give out information of the results of any trial.

11. They shall keep themselves informed in regard to all work performed on their sections by contractors, or others who do not come under their charge, and see that nothing is done by them that will interfere with the safety of the track or the movement of trains.

12. They must limit the use of handcars to the service of the Company, and must not, except by proper authority, permit anyone except employés of the Company, engaged in the performance of duty, to ride thereon. They must not permit, except by proper authority, the running of hand or velocipede cars belonging to private parties over the tracks of the Company.

13. During heavy storms, whether by day or night, whereby the track or any portion of the Company's property becomes liable to damage, foremen and trackmen must be on duty; and at such times they must go over their sections to make sure that the track is safe, taking danger signals with them.

14. They must keep the vicinity of all buildings, bridges and trestles cleared of all combustible matter, such as chips, bark, dry grass, etc. They must keep bridge seats, tops of piers, and all other readily accessible portions of bridges and trestles cleaned of cinders and dirt. Where water barrels are furnished, they must keep them filled with water.

They must keep a careful lookout for fires along the track, and prevent, if possible, the destruction of fences, wood or other material, and the spread of fires into adjoining fields. They must not permit fires to be started unless they have sufficient force to keep them under control.

15. They must use constant care to see that waterways and the approaches and outlets thereto are kept free from brush, driftwood and other obstructions.

16. They must not permit encroachment upon, or occupancy of, any portion of the Company's buildings, right-of-way, or station grounds, except by proper authority.

RULES GOVERNING SUPERVISORS OF STRUCTURES.

1. Supervisors of Structures shall report to, and receive instructions from, the .... (Title) ....

2. They shall be responsible for the safe condition and proper maintenance of structures. They must make temporary repairs of such defects as may endanger or delay the movement of trains, and promptly report defective conditions to the .... (Title).

3. They must make frequent inspections of structures and have necessary repairs made as promptly as conditions require.

4. They shall, as necessary, employ men for carrying out the duties for which they are responsible.

5. They must know that foremen are familiar with the operating rules in regard to train signals and flagging, and that they fully understand and comply with them.

6. They must, in case of damage to structures, promptly assemble forces, tools and materials and make necessary repairs.

7. They shall investigate damage to structures resulting from train accidents or other causes and make prompt report to the....(Title)....

8. They shall conform to the prescribed standards and plans in the execution of work under their charge.

9. They must know that foremen are supplied with tools and materials necessary for the efficient performance of their duties, and see that these are properly used and cared for.

10. They must not, except by proper authority, permit experimental trials of appliances or devices, nor give out information of the results of any trial.

11. They shall keep themselves informed in regard to all work performed on bridges and structures in their districts by contractors, or others who do not come under their charge, see that nothing is done by them that will interfere with the safety of structures, and report promptly to the ....(Title).......... if the work is not done in accordance with the prescribed standards.

12. They shall have immediate supervision of work-train service for the maintenance of structures, and employ such service only when authorized by the .... (Title) ....

13. They must know that foremen are provided with the rules, circulars, forms and special instructions pertaining to their duties, and that they fully understand and comply with them.

14. They shall see that water barrel rests at all timber bridges and trestles are in repair and supplied with barrels and buckets, and that station and other structures are equipped with the necessary water barrels, buckets and other appliances.

15. They shall, in period of flood, observe and record the flow of water of the various streams passing under the track, and report to the proper officer any case in which the opening seems insufficient.

RULES GOVERNING BRIDGE AND BUILDING FOREMEN.

1. Bridge and Building Foremen shall report to, and receive instructions from, the .... (Title).

2. They shall be responsible for the proper inspection and safe condition of the structures under their charge, and shall do no work thereon that will interfere with the safe passage of trains, except under proper protection.

3. They must make such inspections of the structures in their district as the ....(Title)..........may direct, and report their condition on Form No. ......

4. They shall employ men as the .... (Title) .... directs, and see that they properly perform their duties. They must keep the required records of the time of their men and of the materials used.

5. They must each have a copy of the current time-table, and be thoroughly familiar with the rules and regulations therein, and with the time of trains over their districts. They must carefully observe signals displayed by all trains, and assure themselves, before obstructing track, that all trains and sections due have passed. No notice will be given of extra trains, and employés must protect themselves as prescribed by the Rules. Foremen must provide themselves with reliable watches, and when possible compare time daily with a standard clock or with conductors' watches.

6. They must, in case of damage to structures in their districts, promptly proceed to the place with the men, tools and materials at their command, and do all in their power to make necessary repairs.

7. They must, in case of accident coming under their observation, report the facts to the .... (Title).

8. They shall conform to the prescribed standards and plans in the execution of work under their charge.

9. They shall be responsible for the proper care and use of tools and materials necessary for the efficient performance of their duties, and shall make requisition to the..........(Title)..........from time to time, as additionaal supply becomes necessary.

10. They must not, except by proper authority, permit experimental trials of appliances or devices, nor give out information of the results of any trial.

RULES GOVERNING SIGNAL SUPERVISORS.

1. Signal Supervisors shall report to, and receive instructions from, the .... (Title).

2. They shall be responsible for the safe condition and proper maintenance of signals and interlocking plants. They must make temporary repairs of such defects as may endanger or delay the movement of trains, and promptly report defective conditions to the....(Title)....

3. They must make frequent inspections of signals and interlocking plants and have necessary repairs made as promptly as conditions require.

They must see that all failures of signals and interlocking plants are promptly investigated and report made on Form No. .....

4. They shall, as necessary, employ men for carrying out the duties for which they are responsible.

5. They must know that foremen are familiar with the operating rules in regard to train signals and flagging, and that they fully understand and comply with them.

6. They must, in case of damage to signals or interlocking, promptly assemble forces, tools and materials, and make necessary repairs.

7. They shall investigate and report on accidents which may be attributable to defects in, or result in damage to, the signal apparatus.

8. They shall conform to the prescribed standards and plans in the execution of work under their charge.

9. They must know that foremen are supplied with tools and materials necessary for the efficient performance of their duties, and see that these are properly used and cared for.

10. They must not, except by proper authority, permit experimental trials of appliances or devices, nor give out information of the results of any trial.

11. They shall keep themselves informed in regard to all work performed in their districts by contractors, or others who do not come under their charge, see that nothing is done by them that will interfere with the safe operation of signals, and report promptly to the .... (Title) if the work is not done in accordance with the prescribed standards.

12. They shall have immediate supervision of work-train service for the maintenance of signals and interlocking plants in their districts, and employ such service only when authorized by the....(Title)....

13. They must know that foremen are provided with the rules, circulars, forms and special instructions pertaining to their duties, and that they fully understand and comply with them.

RULES GOVERNING SIGNAL FOREMEN.

1. Signal Foremen shall report to, and receive instructions from, the .... (Title).

2. They shall be responsible for the proper inspection and safe condition of signals and interlocking plants under their charge, and shall do no work thereon that will interfere with the safe passage of trains, except under proper protection.

3. They must make such inspections of the signals and interlocking plants in their districts as the ....(Title)........may direct, and report all defects found on Form No. .....

4. They shall employ men as the.........(Title....).....directs, and see that they properly perform their duties. They must keep the required records of the time of their men and of the materials used.

5. They must each have a copy of the current time-table, and be thoroughly familiar with the rules and regulations therein, and with the time of trains over their districts. They must carefully observe signals displayed by all trains, and assure themselves, before obstructing track, that all trains and sections due have passed. No notice will be given of extra trains, and employés must protect themselves as prescribed by the Rules. Foremen must provide themselves with reliable watches, and when possible compare time daily with a standard clock or with conductors' watches.

6. They must, in case of damage to signal or interlocking apparatus in their districts, promptly proceed to the place with the men, tools and materials at their command and do all in their power to make necessary repairs.

7. They shall investigate and report on accidents which may be attributable to defects in, or result in damage to, the signal apparatus.

8. They shall conform to the prescribed standards and plans in the execution of work under their charge.

9. They shall be responsible for the proper care and use of tools and materials necessary for the efficient performance of their duties, and shall make requisition to the ....(Title).......... from time to time as additional supply becomes necessary.

10. They must not, except by proper authority, permit experimental trials of appliances or devices, nor give out information of the results of any trial.

11. They must not make nor permit any permanent rearrangement or change in the signals or interlocking plants without proper authority.

CONCLUSION.

Your Committee recommends that the revised General Rules for the Government of Employés of the Maintenance of Way Department, submitted herewith, be approved and incorporated in the Manual of Recommended Practice.

Respectfully submitted,

Jos. O. Osgood, Chief Engineer, Central Railroad of New Jersey, New York, *Chairman.*

F. L. Nicholson, Chief Engineer, Norfolk & Southern Railway, Norfolk, Va., *Vice-Chairman.*

C. C. Anthony, Assistant Signal Engineer, Pennsylvania Railroad, Philadelphia, Pa.

F. D. Anthony, Chief Engineer, Quebec, Montreal & Southern Railway, Montreal, Canada.

M. S. Blaiklock, Engineer Maintenance of Way, Grand Trunk Railway, Montreal, Canada.

G. D. Brooke, Division Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

W. H. Elliott, Signal Engineer, New York Central & Hudson River Railroad, Albany, N. Y.

A. S. More, Engineer Maintenance of Way, Cleveland, Cincinnati, Chicago & St. Louis Railway, Wabash, Ind.

J. B. Myers, Division Engineer, Baltimore & Ohio Railroad, Cumberland, Md.

J. A. Peabody, Signal Engineer, Chicago & Northwestern Railway, Chicago, Ill.

Committee.

DISCUSSION.

Mr. Jos. O. Osgood, Chairman (Central Railroad of New Jersey): —There is not very much to say about the work of the Committee. The changes that have been made in the rules to be presented and discussed, and some of them to be passed upon by the Association, are only such as seemed necessary to conform to the instructions of the Board of Direction, with some few additions, also in accordance with a sentiment expressed by the previous convention. The instructions were, as you know, to "consider revision of Manual, both generally and with a view to consistent general grouping of heads, uniformity of numbering and similarity in language covering similar rules." We have gone through all the matter which was before us, with that instruction in mind, and by reading over the rules as prepared you will see the changes are very slight. We have made a change in the titles, which are now "Track Supervisors," "Track Foremen," "Supervisors of Structures," "Bridge and Building Foremen," "Signal Supervisors," "Signal Foremen," but only for the sake of euphony and to make the wording a little more to conform with common practice. I have before me a comparison showing the changes, so that if any member desires to inquire for the reasons for any particular change I shall be glad to give him such information as I can.

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—There is some objection to one rule as it stands in the report, under the rules governing Track Foremen, paragraph 3. In the second line of that paragraph are the words, "at least once a day." It is thought by some members, and I think so myself, that it is unnecessary to prescribe that a track foreman or a trackwalker should every day go over all sections of a railroad, and there ought to be some modification of this rule. A railroad man would modify this rule if he were to apply it to his own road, especially if he had only one train a day or one train a week on the road. He would probably allow the engineer to be the inspector or the trackwalker, and I think there ought to be some slight change in that rule.

The President:—Mr. Rose, you have studied this rule. What change do you suggest? Have you anything to submit in place of the rule presented by the Committee?

Mr. Rose:—I ought not make an objection without having a remedy. It would apply to Class A track or Class B track.

Mr. Osgood:—Some of these rules, and notably the one to which Mr. Rose has referred, should properly take the place of the rules prepared by the Committee on Track. I wrote to Mr. Rose advising him of what we had done, calling his attention to the revision of the rules, and especially to the rules which had been prepared, which would naturally take the place of those prepared by the Committee on Track, and asked him if the rules as we had prepared them were satisfactory to the Committee on Track, stating some discussion might be avoided if they were. He replied he saw no objection to them, and later he advised me that one member of his Committee took the position which he now states in regard to this particular rule being too severe, too onerous on roads of very small business. As I understand Mr. Rose in what he has just stated and what he wrote to me, it seemed a hardship that a road having a small amount of business should be obliged to send a man over the track every day, and I can conceive of a case in which that might be a hardship; but our idea in preparing these rules has been that they could not be made to fit every condition; that all we could do would be to prepare rules which would be satisfactory in ordinary cases and which could be adopted where ordinary conditions prevailed, and where traffic was very heavy they would doubtless have to be added to materially, and there might be some exceptions made. I am afraid it would be difficult indeed to frame any set of rules so comprehensive as to meet the conditions Mr. Rose mentions and all other conditions, and not make a volume of it—a volume containing exceptions, interlineations and many things which would be hard to take care of.

Mr. G. A. Mountain (Canadian Railway Commission) :—I agree with the Committee that it is a proper rule. The fact that you have one train or twenty trains a day over a piece of track that is not inspected is of little consequence. One train may go into a washout, and probably the twenty trains would go through all right. Probably the track should be walked over every day of the year. I feel very strongly on that point and I back the Committee in it. I think it is a good rule, and a rule I am satisfied the Canadian Railway Commission will enforce in Canada.

Mr. Rose:—The last speaker has stated my position. If you have passenger trains, I think you have Class A track. You may have a railroad where you have mixed trains; I think there is considerable mileage of that sort of railroad in this country, where the trains run slowly and the track is poor, and if there is a washout the engineer will have time to see it and stop. If this Association adopts such a rule, some of the railroad commissions will get us on the carpet and cite this rule and the action of this Association. If it is put up to a railroad manager he will understand what is unnecessary. The Track Committee after receiving Mr. Osgood's letter about the overlapping of the rules (those in the Manual, page 66), voted to withdraw all the rules under "Inspection of Track." They have no objection to withdrawing those rules, and I have been authorized by the Committee to make such a statement, although this recommendation is not incorporated in our report. We feel that the rules as outlined in the report of this Committee are proper.

Mr. C. E. Lindsay (New York Central & Hudson River):—I would like to call attention to one or two minor points in the rules governing the general organization and the rules governing Track Supervisors. The first rule on organization says that the man in charge of the Maintenance of Way Department receives instructions from and reports to the .... officer; the rule governing the Track Supervisors, rule 1, transposes this expression. He first reports to and receives instructions from .... These two might be made to read the same. In rule 2 of the rules governing Track Supervisors, I think the tunnels of a railroad are quite of sufficient importance to be placed as definitely under the responsibility of the Track Supervisors as the station grounds, and they are of sufficient importance to warrant mention in the rules, not only in rule 2 but also in rule 3. I think, also, that the Committee has not incorporated a rule for Track Supervisors, which is a very essential one, and that is that it is the duty of the Supervisor not only to select men but to train men for the position of foreman. I think the railroads of the country to-day are suffering more, perhaps, from the lack of properly trained and competent foremen than any other thing in the labor world.

In rule 5 I would like to suggest that the Supervisor must not only know that the foremen are familiar with the operating rules, but that they are supplied with the proper signaling and flagging appliances.

Another duty that devolves upon the Track Supervisor is the removal of snow and ice, which seems not to have been mentioned specifically by the Committee.

The President:—The points which Mr. Lindsay has brought up are pertinent and should commend themselves to the Committee.

Mr. Osgood:—The first point raised, as to the words "the Maintenance of Way Department on each division is in charge of the ......," which appears under "Organization," and the words "Track Supervisors shall report to and receive instructions from the ....," which appear under "Rules Governing Track Supervisors," and the fact that these read somewhat differently, I think is simply because attention was not called to the matter. I do not think we should make any difference one way or the other; it would be better to have them both read the same way. As to the other question of including tunnels, etc., I do not think that that was discussed. My opinion is, if we begin to mention tunnels and all details of roadway—I will not say tunnels—but going too much into details of the roadway, that we are simply adding to the length without increasing the efficiency of the rules. It may be open to question whether it would be wise to put "tunnels" in—I am not prepared to say that it is not—but I am very much opposed to the general proposition that we should add to the rules, because I believe when we add one detail, then the omission of another is evident, and we have got to add another, and so it goes on until the thing becomes so large and extensive it is of no use.

The President:—Any matters connected entirely with the English grammatical construction of the rules might be safely left with the Editorial Committee—such as one of the features Mr. Lindsay referred to—but the including of tunnels and requiring that the foremen should not only be familiar with, but know the people are possessed of certain appliances, that is a different matter.

Mr. L. A. Downs (Illinois Central):—In the last sentence of paragraph 5, it reads: "Foremen must provide themselves with reliable watches and, when possible, compare time daily with a standard clock, or with conductors' watches." It specifies that there are only two ways of getting the correct time, or one other way besides a comparison with a standard clock. I think that should be changed to read: "Foremen must provide themselves with reliable watches and, when possible, compare time daily with a standard clock, or with the watches of other employés whom they know have the standard time."

Mr. Osgood:—That was discussed at considerable length, although I do not think the particular expression mentioned was thought of, but our conclusion after discussion pro and con was that it was better to leave it as it is, not adding anything more to it. If the convention thinks otherwise, we are open to correction.

Mr. Downs:—Am I to understand that the foreman could not get the time from an engineer?

Mr. Osgood:—Not at all; it does not prevent his getting the time from the engineer. We do not undertake to tell him all he should do. We undertake to have him clearly understand that he must be supplied with the correct time.

Mr. Downs:—My idea was to make the rule more broad.

Mr. Osgood:—I do not see any serious objection to it, except that it adds length to the rule.

Mr. J. E. Taussig (Wabash):—I suggest that it be changed to "trainmen's watches," for the reason that all trainmen are subject to the standard watch inspection rules—permit the foremen to confer either with the engineer, conductor or brakeman.

Mr. W. G. Brimson (Quincy, Omaha & Kansas City):—I agree heartily with the Committee. Under the standard rules the last duty of a conductor is to get the time from a standard clock, and coming directly from the source of time, the section foreman, if he gets his time from the conductor, will be getting just as near to a standard clock as possible. I doubt very much if other trainmen would generally have watches which would be comparable with that of the conductor. I think the conductor has the most reliable time, next to the standard clock.

Mr. James Burke (Erie):—I agree with Mr. Downs that if any trainman should have the time, the locomotive engineer especially should have it. Sometimes the section foreman may be standing close to an engineer, whereas he would have to go to the rear end of the train to get the conductor's time.

Mr. Lindsay:—I am in hearty agreement with Mr. Downs, but in order to keep the discussion seriatim, I move to amend rule 2 by the omission of the words "station grounds and driveways." It seems to to me those words are not of sufficient importance to warrant specific mention in the rules.

Mr. G. D. Brooke (Baltimore & Ohio):—Before that motion is put, I would like to say that the reason those words were included is that the station grounds and driveways, especially the station grounds, are apt to be neglected by the section men unless they are brought particularly to their attention; therefore, the Committee thought it proper to include these words in the rule.

(Mr. Lindsay's motion was lost.)

Mr. C. Dougherty (Cincinnati, New Orleans & Texas Pacific):—As a compromise I move to strike out the word "driveways." These are generally on the station grounds and to that extent the word might be considered as redundant.

(Mr. Dougherty's motion was lost.)

Mr. Downs:—In order to put the matter before the convention I move that in paragraph 5, in the last sentence, we substitute the words, "standard watches of other employés," in place of the words, "with conductors' watches."

Mr. Lindsay:—The practice on the New York Central is to go further and permit the section foreman to compare his watch with trainmen's watches. All trainmen have their watches inspected and certified, so that every trainman's watch is a certified watch. We also require Supervisors of Track to have certified watches, so that the foremen could compare their watches with the watches of the Supervisors of Track, if there were no trains on the road. I will heartily endorse the motion made by Mr. Downs, except that the word "certified" be used instead of "standard," and hope it will prevail.

Mr. Rose:—It seems to me the fact is overlooked that the section foreman might get his time from the telegraph office, if he were around while the time was being sent.

Mr. T. C. Newbegin (Bangor & Aroostook):—On many sections the section foreman on duty in outlying places never sees a conductor except on trains going by. Unless the rules permit him to compare time with any employé who carries a standard watch he has no means of securing this standard time.

Mr. C. C. Anthony (Pennsylvania Railroad):—I object to the words "certified watches," for the reason that some railroads do not have the watches certified. I suggest that the exact wording of the change be left to the Committee. The Committee understands now what is wanted—to get a broader provision for securing the correct time.

(Mr. Downs' motion was lost.)

Mr. Rose:—In order to get the question which I advocated before the convention I move that rule 3 governing Track Foremen be changed by prefixing the following to the rule: "Except in case of roads with very light traffic," they must go over their sections, etc.

The President:—Do you not think, when you express it that way, that you leave it to individual discretion of what "light traffic" means? If you specify it in some description of the road, Class A, or Class B, do you not think that would be better?

Mr. Rose:—I think it would be, but I am not prepared to frame up a rule. I took the words from the rules under "Inspection of Track." It is satisfactory to me if the Committee will frame the rule. It is the idea I want to get into this rule.

The President:—I hardly think we can put that responsibility on the Committee, Mr. Rose, because they are in accord with the wording as it is. I think the mover should frame up the wording.

Mr. Rose:—The present rule in the Manual reads as follows: "Except in cases of roads of very light traffic all main tracks shall be inspected each day by section gang or trackwalker." That is in the Manual of Recommended Practice, page 66. The idea I am trying to get before the convention is that I think it should be incorporated in rule 3.

Mr. C. C. Anthony:—I think we are now getting rules and specifications mixed up. These are rules addressed to the track foremen, and it certainly would not be his province to decide that the traffic was so light that he did not need to go over his section once a day. If a change is to be made, it seems to me it should be worded in this way: "Unless otherwise directed." Then it is left to his superior officer to tell him whether or not to go over the road.

Mr. Osgood:—The Committee will accept the modification suggested by Mr. Anthony, if it is satisfactory to Mr. Rose.

Mr. Rose:—That is all right; it is the idea that I want to get in there.

(On motion the report was adopted as amended.)

The President:—The Committee is relieved, with the thanks of the Association.

REPORT OF COMMITTEE X—ON SIGNALS AND INTERLOCKING.

(Bulletin 119.)

To the Members of the American Railway Engineering and Maintenance of Way Association:

SUBJECT NO. 1—REVISION OF MANUAL.

Following the general instructions of the Board of Direction, a circular letter was issued October 27, 1909, instructing that "each Committee give careful consideration to its own subject matter now included in the Manual, in order that the new edition will contain only what represents good practice, and all obsolete matter eliminated." Subject No. 2 involves a considerable number of revisions, but in view of the former action of the Board of Direction in submitting it to the American Railway Association for approval, it is assumed that the subject will not be finally settled for a year at least. The Committee has, therefore, not attempted to offer revisions covering the present report, but simply to bring the Manual up to date, and recommends the following revisions of the 1907 edition:

Page 129. Definitions. From the Standard Code of the American Railway Association, the Code having been revised. Insert between "Block Station" and "Block Signal" the following:

"FIXED SIGNAL.—A signal of fixed location, indicating a condition affecting the movement of a train."

"DISTANT BLOCK SIGNAL.—A fixed signal used in connection with a Home (or Advance) Block Signal to regulate the approach thereto."

Instead of "TELEGRAPH BLOCK SYSTEM," "MANUAL BLOCK SYSTEM.—A block system in which the signals are operated manually."

CONTROLLED MANUAL BLOCK SYSTEM.—A block system in which the signals are operated manually, and so constructed as to require the cooperation of the signalmen at both ends of the block to display a clear *or a caution* Block Signal.

MAST.—No change in definition. To be removed from within the bracket, as it is not an American Railway Association definition, and placed in its proper alphabetical position among the definitions.

Eliminate entirely definition for Arm Casting, Page 130.

Insert between Blade and Bracket Post the definition, BRACKET MAST.—A mast mounted on a bracket post.

Insert between Bracket Post and Chain Wheel, the definition, BRIDGE MAST.—A mast mounted on a signal or other overhead bridge.

Insert between Locking Dog and Permissive Block System, the definition, "OPERATED UNIT.—A switch, signal, lock or other device in signaling, operated by a lever or other operating means."

Page 131. Eliminate SPECTACLE.—See "Arm Casting." Insert in its place, "SEMAPHORE SPECTACLE.—That part of a signal which holds the colored glasses and to which the blade may be attached."

Page 134. Sub-heading TOWER INDICATORS to read "INTERLOCKING OR BLOCK STATION INDICATORS."

The following changes in conventional signs, pp. 132 to 138, inclusive.

In accordance with data given on Revised Form M. W. 1021, on pp. 831-833, inclusive, of Vol. 10, Part 2, 1909, of the Proceedings.

Battery Box.
Train Order Signal.
Home Automatic Block Signal.
Distant Automatic Block Signal.
Home Interlocking Signal.
Distant Interlocking Signal.
Home Disc Signal.
Distant Disc Signal.
Signal Bridge.
Interlocked Switch.
Interlocking Station.
Automatic Bell.
Derail.

Page 138. Compensation of pipe lines; sixth recommendation, page 140, with the next succeeding paragraph and all matter on pp. 141 to 146, inclusive, and page 151, to be eliminated, as pertaining to mechanical specifications which were ordered out by the Association last year. Also Paragraphs (3) and (4), top of page 148.

Page 147. Title should read, "MANUAL AND CONTROLLED MANUAL BLOCK SIGNALS," instead of "Telegraph, etc."; a similar change first line Paragraph (1).

Page 148. Title should read, "LOCATION OF MANUAL BLOCK SIGNALS."

Paragraph (1), to read as follows:

"The arrangement shown in Fig. 14 is good practice for use on single track line as a train-order signal, and a block signal. Distant signals may be used."

Eliminate Paragraph (2).

Number Paragraph (3), (2), and eliminate last clause.

Page 149. Number Paragraph (4), (3), and change it to read:

"The double track arrangement as shown in Figs. 17 and 18 is recommended as good practice."

Bottom of page 149 and page 150. Eliminate entire subject of "Location of Automatic Block Signals," together with pp. 152 to 158, inclusive, as these cuts are in conflict with later actions endorsing upper quadrant signals; the drawings are incorrect, and of no particular use.

Page 159. Eliminate Paragraph (8), as it is a mechanical specification, and renumber the succeeding paragraphs.

Eliminate "Specifications for Mechanical Interlocking and Material for Construction Work," pp. 161 to 172, inclusive, in accordance with the action of the 1909 convention.

Insert "Specifications for Rubber Insulated Wire—*600 volts and less," pp. 150 to 156, inclusive, Vol. 10, Part 1, in accordance with the action of the 1909 convention.

SUBJECT NO. 2—ENTIRE COMMITTEE.

The inception of the Committee's work on a system of signal indications and aspects is set forth in the report of 1908 (Proceedings, 1908, Vol. 9, page 41). Certain requirements previously adopted by the Association, which have served as the basis of the Committee's subsequent work, are quoted from the Manual on pp. 42 and 44, of the same volume.

In 1907 the Committee had progressed so far that it was able to submit as a progress report a list of indications to be given by fixed signals, page 70, and a series of aspects, pp. 86 to 89, Proceedings, 1907, Vol. 8. In the same report twelve principles or requisites specifying the general features of the aspects, were presented (same volume, page 71); of these the first three, providing for the use of red, yellow and green lights, and three-position semaphores working in the upper right-hand quadrant, were adopted and published in the Manual, with the following expression of the purpose of the Association:

"The adoption of the following principles is recommended in view of the recent trend of the development of the art, and should not be understood as condemning the present practice endorsed by the Association as recommended good practice."

In 1907 the Joint Committee on Interlocking and Block Signals of the American Railway Association requested the submission to it of reports pertaining to Rules and Requisites of Installation, and Committee X therefore felt that, before giving further attention to the signal aspects in detail, it should give additional study to the indications and draw up requisites of installation, so modified from those in the Standard Code as to permit of the development of aspects on the lines already laid down. It seemed possible at that time that the indications and requisites, formulated by the Committee, might be the subject of action by the American Railway Association, which would guide the Committee in the completion of its uniform system. As a result of this work a revised and systematized list of indications, and a set of requisites of installation, together with typical (Stop) aspects, were reported in 1908 (Proceedings, 1908, Vol. 9, pp. 46 to 53), and, after amendment, were adopted.

No action having been taken by the American Railway Association, the Committee proceeded with its work, first again revising the list of indications and then developing the aspects for the "primary" indications. These were embodied in a section of the report of 1909, ac-

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*Change to read "660."

cepted as a progress report (Proceedings, 1909, Vol. 10, pp. 162 and 163).

During the current year the indications have again been revised as to details and the primary aspects have been changed but slightly from those reported in 1909. In addition, two tables of primary aspects have been prepared to meet simpler operating conditions than those for which the complete aspects are designed, and aspects for the secondary indications have been developed.

SUCCESSIVE REPORTS COMPARED.

For convenience of comparison the lists of indications submitted in 1908 and 1909 are here reprinted in connection with those presented in this report; as a complete table of primary aspects was not included in the report of 1908, and the changes since last year are slight, it is not deemed necessary to reproduce the previous tables, but attention will be called to the changes.

An inspection of the three lists of indications will show that the changes are almost entirely in the grouping and wording. The fact that, during three years, the Committee has found no occasion to change materially the number or intent of the indications at first assumed to be necessary, may fairly raise a presumption that the basis of its system is now well established.

Changes in the grouping of the indications have been made with a view to bringing out more clearly the relation between the indications, and their relation to the control of the train. Aside from this, the "permissive block" indication has been transferred from the secondary to the primary classification for reasons given elsewhere in this report. Changes in the wording have been made:

(1) To attain as great a degree of brevity as seemed consistent with clearness.

(2) To eliminate references to conditions, such as, "unlimited speed route," "next signal at proceed," and make the indications specify solely the required control of the train.

The Committee has not only endeavored to improve the wording of the indications, but has thought it proper to eliminate two appearing in the report of 1909, namely, "Proceed at normal speed—prepare to pass next signal at normal speed," and "Proceed at limited speed—prepare to pass next signal at normal speed." On due consideration it appeared that these indications called for no different handling of the train than that required by "Proceed" (without restriction), and "Proceed at limited speed," respectively, and were therefore superfluous.

As stated above, the aspects have been changed but slightly from those submitted in 1909. Indeed it is a significant fact that after most careful and deliberate study of the subject and consideration of other schemes, the Committee still adhered to its original primary aspects, and those submitted at this time do not differ materially from the aspects for equivalent indications tentatively presented in 1907.

The changes made in the primary aspects since the report of 1909 was prepared affect the automatic block signal and the slow sign. There has been much difference of opinion in the Committee as to the wisdom of recommending the use of two arms with ends in diagonal line for the day "Stop" aspect of the automatic block signal. In 1907 it was agreed that, while two lights in diagonal line should be recommended for the night aspect, one arm of distinctive form would give with sufficient clearness by day the indication, "Stop—then proceed," and an arm with pointed end was shown in the report of that year; the second arm was shown on those signals only that would have to give the indication now worded, "Proceed—prepare to pass next signal at limited speed." In 1908 two alternatives were agreed to and shown on the diagram of typical aspects—two arms with square ends in diagonal line and one arm with pointed end (a second arm to be added where required, as before). In 1909, with the purpose of showing the aspects as they were expected to appear in the most complete development of the system, the single arm with pointed end was omitted from the diagram; but in this report the Committee, yielding to continued protest against the required use of a fixed second arm on all automatic block signals even in the complete scheme, has again shown the arm with pointed end as the universal mark of distinction in aspect No. 2, and has shown the second arm as optional (dotted on the diagram), or to be used on signals requiring it for aspect No. 8 B. At the same time an optional low-speed arm has been added to provide for movement past automatic block signals without stopping on ascending grades, and the automatic block signal therefore appears in the aspects for indication No. 14 (14 B).

The slow sign has been shown as an aspect for indication No. 14 instead of No. 13, as the action required by a slow sign is better expressed by that indication. The only other changes are the elimination of two repetitions of aspects, former No. 8 being the same as No. 6 and No. 12 the same as No. 10, where indications have been eliminated, and the addition of "permissive block" aspects for the indications transferred to the primary classification, as previously explained.

OBJECT OF THE REPORT.

There seems to be a grave misapprehension among railroad men at large as to the objects of the report and the results which would ensue should it be adopted. As the Committee has frequently stated, evolution, not revolution, is intended and advocated. Present practices are not, and cannot be, discredited, for they are good. Of course, taking the country over, there are some methods which might be improved, but as a general rule the systems prevailing are those which the railroad managements have found by experience adequate and fitted to their needs. Doubtless many roads require more interlockings and a greater number of automatic signals, for instance, than they have so far been able to install, but the general trend would be to continue installing them in accordance with the practice which each road has found satisfactory. Our object is not to make radical changes in these practices, but to so modify them that they may eventually result in a uniform system the country over. This can only be accomplished after a long term of years; does not involve sudden or extensive changes; and would be slowly evolved by the use of the recommended aspects for all new work and renewals. While uniformity in signaling is not absolutely necessary, it is conceded by all to be highly desirable.

It is obvious that if uniformity is to be secured, the roads must adopt a uniform practice, and should they elect so to do, it should be thoroughly understood that such action is taken solely for the purpose of uniformity, the advantages of which were pointed out on page 55, Vol. 9, Proceedings.

The Government has required the equipment of rolling stock with automatic couplers and continuous brakes; the railroads, recognizing the advantage of uniformity, have provided certain standards. Such standards are practically a necessity on account of the interchange of cars. The situation in signaling is somewhat different. The reason for uniformity is not so much a matter of safety as it is of convenience, and chiefly of economy, as only by adopting uniform aspects can uniformity of apparatus be attained.

The position of the Committee is fully set forth on pp. 55 and 56, Proceedings, Vol. 9, but it seems necessary to reiterate this position to avoid misunderstandings and misconceptions of the scope of this undertaking. Several very good schemes have been considered, but your Committee, after patient and painstaking labor, is fully convinced that they were (and will, as our railroad development progresses, prove more and more) inadequate to meet all requirements.

The Board of Direction instructs that "The advantages and disadvantages of the present and recommended practices should be set forth."

Present practice is so diverse that it is difficult to cover it in condensed form. However, it may be stated that at the present time there are three well-established types of automatic signal aspects. The one-arm two-position semaphore or single-disc signal; the home and distant system, either with semaphores or discs, and with either both arms or discs on one mast or on separate masts some distance apart dependent upon the exigencies of traffic; and the one arm three-position semaphore. The single-arm system is most generally installed on lines of light traffic, each signal being a home or stop signal, and each governing to the next signal, but with the circuits so arranged that if, on account of track curvature, fog, or other obstructions to view, the engineman cannot see the signal in time to stop at it, he may with safety overrun it, a distance not exceeding the length of the overlap; or, stated somewhat differently, while he must make every effort to stop at the home signal, the actual danger point is some distance beyond (in advance of) it. The home signal in such a case becomes in a way a distant signal, with the point at which he *must* stop or cause disaster beyond it. This method avoids the expense of distant signals, but has the disadvantage in frequent cases of practically forcing the engineman to pass a stop signal. However, it is amply sufficient for the needs of important roads and actual practice shows that it is satisfactory in operation.

The home and distant signal system practically places the overlap in the rear of the signal in that the distant signal gives advance information of the condition that may be expected at the home which is located at the danger point, or entrance to the block. The distant signal at caution informs the runner that he must get under such control that he can stop at the home signal, although by the time he reaches it, it may have changed to clear through the passage of the preceding train from the block it protects, and in the clear position informs him that he may proceed, without reducing speed, and may expect to find the home signal at proceed. The Committee endorses this practice as proper, safe, and desirable, as it gives advance information to which an engineman is entitled. It is admitted that the engineman must observe each signal and keep a sharp lookout, so that if from any cause (such as a switch opened after he has passed a clear distant, a derangement of the signal apparatus, a wreck on an adjoining track fouling his own, or any like occurrence) the home signal indicates stop, he may obey it as quickly as possible. It is held by some that this practice is dangerous, and that the distant signal should not be so used, but if indicating caution the train must at once reduce speed prepared to stop at any obstruction short of the home signal, even if the latter is located a mile away, and if indicating proceed shall not give the runner any right to assume that the home is at proceed, but shall simply show a clear track to the home signal.

The third method of using a one-arm three-position signal carries into effect the home and distant principle, but instead of employing two two-position arms, one three-position arm is used. This method is more economical in installation and cheaper to operate and maintain, especially with types of signals lately designed and is endorsed by the Committee for new work and renewals for the reason that it embodies all the advantages of the home and distant system at a minimum cost.

Disc signals are used on a number of roads, the principal advantage aside from low operating and maintenance cost being their distinctiveness from the semaphore, indicating to those governed by them that they may stop and then proceed (Indication No. 2), while the semaphore at stop indicates Stop (and Stay) Indication No. 1. The advantage of this distinction was early recognized by this Association (see Manual for 1907, page 159), and the Committee has provided it by the staggered lights in the final scheme (Aspect 2—Exhibit 2), or the number plate (Aspect 2—Exhibits 3 and 4).

In view of the preponderance of sentiment throughout the country in favor of the semaphore, and the increasing numbers being installed, they have been recommended for the uniform system, although the advantages of the disc signals have been fully considered.

The Committee then has not attempted to dictate new methods of operation, or specify the especial use of a signal as embodied in the practice of a few roads, but has considered the country as a whole, and has in the automatic work made recommendations which involve the least change in practice of by far the greatest number, and it has been demonstrated by actual practice, where the new system has been tried in whole or in part, that the proposed automatic signals can be installed in stretches between the old types without danger, confusion or delay to traffic.

As to the aspects themselves, general practice is a one-arm home with arm either square or pointed, either two or three position, usually with a number plate (see Exhibits 3 and 4); or a two-arm or disc home and distant with two lights. The Committee recommends the one-arm three-position semaphore with number plate through the transition period, the final proposition being one pointed arm, three-position, with a red marker light at the left of the mast, making a distinction from the interlocking signal clearly displayed by night as well as by day, and providing a stop signal if the active light is extinguished.

There are various arrangements of interlocking signals, one, two, three, and even as high as five arms being used on a mast, each arm as a general practice being two-position. Some roads using two-position signaling make some interlocking signals three-position, the middle position admitting trains to an occupied block. Three-position signaled roads generally use the middle position for indicating that the next signal in advance is at Stop. However, without exception as far as the Committee knows, the top arm on a mast governs the through or high speed route, and the second arm, some or all diverging routes. That is, throughout the country, the top arm, whether on a manual block, automatic or interlocking signal, governs the through track, and diverging routes are indicated in every case by separate arms lower down the mast. If two arms only are used on any road, the lower arm governs to all diverging routes; if more than two arms are used, the second generally governs to the route of secondary importance, usually with traffic, and a third arm against traffic, into yards, etc. This principle in universal practice the Committee endorses and carries out, recommending, however, that on account of the long, flat turnouts becoming increasingly numerous in modern track layouts, the second arm should govern over such turnouts which may be taken with medium speeds, and that the third arm should be assigned to govern over short turnouts or over routes which require slow speed, such for instance as against traffic, into yards, or spur tracks, etc. This, in principle, is the practice to-day where three arms are used; the Committee defines the meaning and supplies what it conceives to be an omission in the Standard Code, which does not provide, in so many words, for a divergence from the main track. It will be seen, therefore, that in the interlocking as well as automatic work the Committee adheres to general and ordinary practice. It has been pointed out that the general (though not universal) practice on roads using the permissive block, is to give the indication "Proceed—block occupied," by the middle position of the semaphore arm. This indication is, of course, not given in automatic signal limits. The Committee retains this position, but provides a distinctive aspect, it having developed that it is advantageous to make some distinction between this aspect and one indicating "Proceed—prepare to stop at next signal." As the American Railway Association provides for the use of the permissive indication, it has been transferred from its former assigned place among the secondary indications and aspects to the primary table. Three innovations have been recommended; first, the use of the middle position of the interlocking signal arm to give the same indication as the same position of the automatic signal arm, namely, "Proceed—prepare to stop at next signal." This is the practice on roads using three-position signals in automatic territory and removes one of the inconsistencies of general practice, namely, displaying the distant signal at caution, the home signal at clear, and the advance signal at stop, and provides that if the advance signal is at stop the home, as well as the distant, shall indicate caution. The second is the use of the middle position of the low speed arm to advance a train through an interlocking with track occupied, which can only be done with slotted signals at present by hand signal, although several roads using both semaphores and disc signals advance trains in this way by clearing the home signal which indicates position of switches, with disc signal at stop, this being treated as automatic. The third innovation is the "continue" indication to cover a switchstand showing main line switch closed, but not giving any indication as to occupancy of track, and to provide for "block office" closed, an indication which is needed, and for which the practice is very diverse, it being generally admitted that some improvement is desirable.

Summing up then: First—The table of primary indications recommended for adoption. There is nothing in this table not employed in general practice except 8-10-11-12, limited speed signals, none of which is needed unless long crossovers are in place and being made full use of, and all of which are needed under such conditions; and 4, Continue, and 14, Proceed at low speed—prepare to stop, the need of both of which is very apparent. Second—The table of primary aspects, Exhibit 2. The innovations are the marker light, Aspect 2, the dotted third arm in same aspect, for use in the rare cases where on steep grades it may not be considered desirable to stop heavy trains at automatic signals; 4-b for block office closed, and the distinguishing mark on the permissive signal, including the use of the new lunar white light at night. Regarding the latter, the Committee presents the following report from Dr. Archibald G. Thomson, Official Oculist of the American Railway Association:

"As you requested, I have made certain tests (as regards the practicability of the use of a lunar white light and the probable result of elimination tests of locomotive engineers for indistinct color perception), as was requested by the Committee of the Railway Signal Association, July 21, 1909. My tests were made both on individuals with normal color perception and ones which were color-blind. In the cases of normal color perception I found the lunar white was quickly and promptly recognized and not confused with any other signal colors, for example, red, green or blue-purple. In the case of the color-blind (two cases of which I happened to have at my disposal), the color was recognized promptly and not confused with red and green. Both these cases confused the ground glass with the red and green when presented at the opening of the lantern. The fact that the lunar white was not confused with these colors, I presume, was due to the amount of blue which this light contains.

"In my opinion, the only light which might appear to an engineer that there would be any danger of lunar white being confused with, might be the ordinary arc light; but, first, as this light, when used as a railroad signal, shall be transmitted through a semaphore lens, cutting out the rays and paralleling them and, secondly, always shown in conjunction with the yellow signal as directed by your proposal in signaling, I think it would insure always being recognized promptly both by the normal and color-blind eye. I can see no reason whatsoever why the lunar white light should in any way conflict with the present methods of testing the color-blind which are now in vogue on any of the railroads, and especially so as the vast majority of individuals with defective color perception are dichromic in type (for red and green), (and this light shows a bluish tinge), that it should not be used with perfect safety as a contrast signal with the yellow and at the same time be a most valuable addition to the signal colors already in use on the railroad."

The list of secondary indications has been reduced by consolidation and elimination from that presented last year, and the secondary aspects are presented this year for the first time.

There is a difference of opinion in the Committee as to the Requisite Indications and a very substantial majority believe that present practice should be followed as closely as possible consistently with uniformity, it being taken for granted that our operating officers are not as a rule giving useless information to their enginemen. In fact, the entire tendency of the American Railway Association in its Standard Code is to eliminate all useless verbiage in its train orders, and leave only the essence. Similarly it can well be presupposed that the indications and aspects in common use are required.

The Committee was confronted on the one hand by suggestions for conveying considerable information not heretofore given, and on the other by a similar demand for simplicity of aspects, even at the cost of elimination of necessary indications. It has, it believes, taken a middle ground, and while providing all the information which is necessary and advisable for the safe and proper operation of a large and complicated railroad system, has supplied a path (Exhibits Nos. 3 and 4) by which the roads of light traffic can, while signaling safely and sufficiently for their needs, lead up to a uniform system without loss of material and labor during the transition stage, the progress being gradual but constant.

The Committee has attempted to codify the indications now in general use, and provide uniform aspects for them rather than to eliminate many (on the ground that they are unnecessary) and "simplify" the system by making it incomplete.

The Committee recommends that each member of the Association canvass the situation carefully on his own road, and be prepared to discuss the table of indications on the basis of such road's present and future needs.

If the American Railway Association should later decide that less indications are needed, those not required by users of the Code may be eliminated, while those roads feeling the need of them, are provided with the machinery for their display; this, in the minds of the Committee, being preferable to presenting a system so designed as to be incapable of expansion along logical and natural lines.

INDICATIONS.

EXPLANATION OF PRIMARY INDICATIONS.

Of the three Stop indications it is sufficient to say that it is believed to be common in present practice to make equivalent distinctions in the aspects more or less clearly; that the action required is distinctly different in each case; and that it is therefore right so to word the indications as to define the proper action.

No. 1, Stop, without qualification, obviously leaves the trainmen no alternative but to remain until authorized to proceed; No. 2, Stop—then proceed (Rule 504), specifies briefly the regular procedure in the case of automatic block signals; under No. 3, Stop and investigate, the trainmen are left to deal with the situation themselves, set an open switch normal or ascertain if a signal is improperly displayed, and proceed when they are satisfied that it is safe to do so.

Indications No. 4, Continue, and No. 5, Resume Speed, are sufficiently explained in the first column of Exhibit No. 1.

Indication No. 6, Proceed, is the most favorable indication of any signal that may give Indication No. 1 or No. 2, involving no restriction that may be indicated by that signal.

In case of Indication No. 7, Proceed—prepare to stop at next signal, it is assumed by the Committee that, if two signals that may give indication No. 1 or No. 2 are located within "stopping" distance of each other, the first should give an "approach" indication for the one in advance; that is, a manual block or interlocking home signal should give Indication No. 7 when the advance signal, if there is one (manual or automatic), is at stop; and so on. While this is not yet common practice, it is the practice on some roads and, in the opinion of the Committee, is to be recommended.

It is further assumed that indication No. 7, under the conditions stated, includes clear track to the next signal; the only restriction imposed is that providing for a stop at the next signal. The indication, with a change of wording for the sake of uniformity, is, therefore, in effect, the same as that given in the Standard Code for one position of a three-position automatic block signal, "Approach next home signal prepared to stop." In the case of an outlying distant signal it is simply a matter of choice whether indication No. 2 (or possibly No. 1) shall be given when a train is between the distant and home (the present practice on one or more roads), or indication No. 7 shall not positively assure clear track from such signal to the home signal, the condition of that portion of the track being indicated by, or at, a preceding block signal on block-signaled roads.

Indication No. 8, Proceed—prepare to pass next signal at limited speed, is a definite wording for the indication now practically given in numerous instances by the second arms of two-arm distant signals, and is deemed necessary if full advantage is to be derived from the indication of three gradations of speed at home signals.

Indication No. 9, Proceed—prepare to stop short of any obstruction in the block, is believed to be a better wording, following closely that of the Caution Card in the Standard Code, for the "permissive block" indication numbered 19 in the report of 1909, and there placed under the heading "Secondary System." The Committee believes that it will be supported by many railway officers in the view that this indication is so different from No. 7, or still more from No. 10, in the character of the instructions given to the engineman and the handling of the train required, that different indications and aspects are needed for consistent signaling.

Indication No. 10, Proceed at limited speed. It is hardly necessary to elaborate on the lack of uniformity that has prevailed in the significations of the different arms of interlocking home signals. After an exhaustive study of the subject the Committee became convinced that, in a consistent and universally applicable system of signaling, the safe speed at which the turnouts or crossovers set up in a given case could be taken, should be indicated in a uniform manner by the signals; and that it is wholly impracticable to provide for the intelligible indication of individual routes in all situations, by semaphore signals. The conclusion of the Committee is concisely expressed as follows:

"That inasmuch as interlocking signal plants were introduced to make the passage of trains safe at speed over track layouts more or less complicated by crossovers, turnouts and crossings, the object in arranging interlocking signals is primarily to indicate *routes* for trains, and secondarily, as a necessary consequence, *speeds* for trains." The Committee also concluded that three gradations of speed could successfully be indicated by semaphore arms. Indication No. 6, Proceed, permits unlimited speed so far as the signal indication is concerned, subject, of course, to such general limitation as may be in force at a particular point. For the next, or intermediate, rate the Committee proposes the phrase "limited speed," and for the third, "low speed."

It is obvious that the idea of "speed signaling" may be expanded to include the indication by signal of reduced speed made necessary by conditions other than movement over turnouts or crossovers, but it is also clear that the latter condition will always be a prominent occasion for such indications. Under indication No. 10, as relating to passage over turnouts or crossovers, safe movement will evidently be secured if the train maintains, but does not exceed, the specified speed when passing the signal and until it is beyond the switches. In practice the distance to be traveled at limited speed might be defined by a signal in advance, the Proceed indication of which would cancel the limited-speed indication of the first signal, or might be prescribed by rule, the distance fixed being sufficient to cover any series of turnouts or crossovers to be met with. In any case, however, with due regard for both safe and expeditious train movement, it must be conceded that the indication, Proceed at limited speed, without added qualification, will be fully carried out if the train keeps up to the specified rate of speed to the next signal.

Indication No. 11, Proceed at limited speed—prepare to stop at next signal, and No. 12, Proceed at limited speed—prepare to stop short of any obstruction in the block, are qualifications of No. 10, formed in exactly the same as Nos. 7 and 9 are formed from No. 6 and seem to need no further explanation than that given in connection with those indications.

Indications No. 13, Proceed at low speed, and No. 14, Proceed at low speed—prepare to stop, are recommended with a view to expediting train movement. No. 13, like No. 10, imposes no restriction other than maintenance of the specified speed for a distance prescribed by rule or defined by a signal in advance, which must then give some Proceed indication; if it indicated Stop, indication No. 14 would be given at the first signal. Indication No. 14, imposes the greatest restriction; not only low speed which may be necessary for safe movement through short turnouts or crossovers, but preparation to stop because of possible obstruction ahead or because the route may lead to a short spur or a siding blocked with cars.

It is hardly necessary to say that indication No. 13, like several others in the list, would not be used at all on a road on which it was felt that the advantage would not justify provision for displaying the aspects; the instructions to the Committee would seem to require that it recommend a sufficient number of primary indications to provide for all operating conditions with which it was familiar.

EXPLANATION OF SECONDARY INDICATIONS.

Indications No. 15, Get orders, and No. 16, Take siding, it will be noted, replace four indications in the table accompanying the report of 1909. In the case of the indication for orders the Committee recognized a demand for consistent means of giving these indications in connection with block and interlocking signals, in place of flags and lamps displayed at the station on many roads at present. On further consideration, however, it appeared that the requirement is, not to indicate by signal whether 31 or 19 orders are to be received, but to indicate whether the train shall stop for orders (31 orders) or may proceed and pick up orders (19 orders). It follows that a single secondary indication, Get orders, should be sufficient, as, if it is given in connection with a primary Stop indication, the meaning will be Stop—get orders, and in connection with any Proceed indication, Proceed—get orders.

The Take-siding indication may be given by a separate signal (No. 16, Exhibit No. 5) located at or near the switch to be used, or by a proper combination of aspects at a block station, when the train may be required to take the siding adjacent to the station or the next siding beyond that station. In either case, one secondary indication seems to the Committee sufficient, as, in the second case, the primary indication in connection with which the Take-siding indication is given, will determine which siding is intended; that is, if Stop is indicated, the train must take siding "here," as it has no authority to proceed in the block, while, if any Proceed indication is given, the train may proceed in the block to the next siding beyond the station and take siding there.

Indications Nos. 17 and 18 are inserted as a basis for aspects which it seemed necessary to provide in order to avoid conflict with the other aspects of the recommended system.

ASPECTS.

EXPLANATION OF PRIMARY ASPECTS.

Exhibits Nos. 4, 3 and 2, in that order, are designed to show how a road with few requirements may be signaled without conflict with the Committee's recommended complete system, and may be in position, as its increasing requirements warrant, to develop in an orderly manner to that system. It is assumed that, in the first stage, as there will be few interlockings, limited-speed indications will be unnecessary. As interlockings increase in number and limited-speed indications become desirable, it will be good practice to use the necessary arms and lights on signals giving those indications and omit them on other signals. Finally, as the number of "active" arms increases and the advantages of uniform two-light signaling become apparent, the necessary fixed arms and lights may be added to round out the complete system shown on Exhibit No. 2.

EXPLANATION OF SECONDARY ASPECTS.

In submitting the aspects for secondary indications No. 15, Get orders, and No. 16, Take siding, and their combinations with primary aspects, Exhibits Nos. 5 and 6, the Committee feels that practical and intelligible aspects are offered, and that those shown on Exhibit No. 5 provide for the indications recommended. As some roads, however, might wish to give the other primary indications in connection with Get orders, or might wish to give the Take-siding indication on a block signal, and as the 45-degree downward position of the secondary arm was available, the Committee deemed it proper to submit the additional aspects, Exhibit No. 6, to be used if desired.

It should be noted that, in both sets of "combination" aspects (Exhibits Nos. 5 and 6), the "primary" arm always takes the same position and has the same color of light to the right of the mast for a given primary indication, as in the simple primary aspects; and the "secondary" arm is always down vertically, with no light to the left of the mast, when no secondary indication is given, 45 degrees downward, with a purple light, for the Siding indication, and horizontal, with a red light, for the Order indication, whatever the position of the "primary" arm.

The yellow light to the left of the lunar white in aspects Nos. 9 and 12 is independent of a "secondary" arm (which may or may not be present), and is provided for contrast with the lunar white in the case of these main-track governing aspects; the red and purple lights in aspects Nos. 9 + 15 and 9 + 16 serve the same purpose, in addition to giving the secondary indications.

It is to be understood that the secondary arm and light, shown at the top of the mast on Exhibits Nos. 5 and 6, may be applied in connection with any arm of any signal (except the second arm of an automatic block signal, where they could serve no useful purpose).

The Committee shows two simple aspects for flag-station signals, sufficiently different from any other main-track signal aspects recommended, to make confusion unlikely. Some roads use aspects for both indications, others display a signal only when there are passengers, and, for the sake of eliminating one aspect, satisfactory results might also be obtained by displaying a positive signal when there are no passengers, and no signal when there are passengers, with the requirement that trains scheduled to stop on signal should not pass the station in the absence of the aspect indicating No Passengers. The Committee is of the opinion that either of the three plans would be good practice, as no question of safe train movement is involved.

It seemed proper to submit uniform aspects for siding switches and derails (Exhibit No. 5), which explain themselves; but hardly necessary to include the indications on Exhibit No. 1.

CONCLUSIONS.

The Committee therefore presents Exhibits Nos. 1, 2, 3, 4, 5 and 6, and recommends the adoption of the following conclusions:

(1) That the indications, Exhibit No. 1, are adequate; permit of a uniform system of signaling; are not in conflict with existing systems, and are recommended to the American Railway Association for approval.

(2) That the Primary Aspects, Exhibit No. 2, are practicable; form an adequate and proper basis for the display of the Primary Indications; provide an excellent means for attaining a uniform, universal system of signaling; and are therefore endorsed by this Association, and submitted to the American Railway Association for such action as may be necessary to enable roads desiring to use them to do so with the approval of that Association.

(3) That Exhibit No. 4 provides a simple means of signaling, adequate for the needs of many roads and branches, and is a proper method of signaling which, while not providing for uniformity, may be developed through the scheme shown on Exhibit No. 3 into the complete system, Exhibit No. 2. The outlines shown on Exhibits Nos. 3 and 4 are, therefore, endorsed by this Association and submitted to the American Railway Association for such action as may be necessary to enable roads desiring to use them to do so with the approval of that Association.

(4) That the secondary aspects, Exhibit No. 5, form a simple and proper means of conveying certain necessary instructions, and are therefore received by this Association and submitted to the American Railway Association for its information.

(5) That the additional secondary aspects in combination with primary aspects, Exhibit No. 6, are suitable and proper aspects for use where desired, and are therefore received by this Association and submitted to the American Railway Association for its information.

The indications are given by blades operating in the upper right-hand quadrant, as in previous reports. The use of the upper left-hand quadrant is now under discussion in Committee on account of action of the Railway Signal Association.

EXHIBIT NO. 1.—OUTLINE OF INDICATIONS FOR METHOD OF UNIFORM SIGNALING, 1908.

			Requisite Indications.	Typical Applications.
	Stop.		1. Stop here until authorized to proceed	a Interlocking signals. b Manual block signals.
			2. Stop here and then proceed	c Automatic block signals.
			3. Stop here and investigate	d Stop signs. e Home switch signals.
			4. Stop within certain limits*	f Train-Order signals.
Proceed.	Clear.		5. Proceed on unlimited speed route; next signal at proceed	a Interlocking signals.
			6. Proceed on limited speed route; next signal at proceed	a Interlocking signals.
			7. Proceed	a Interlocking signals. b Manual block signals. c Automatic block signals.
			8. Continue	e Switch signals. g Track tank signs.
			9. Restriction removed	h Signs (removing slow sign restriction).
	Caution.	Approaching.	10. Proceed prepared to stop at indicated point ahead	m Distant signals for Nos. 1, 2, 3.
			11. Proceed on unlimited speed route; next signal is at stop	a Interlocking signals.
			12. Proceed on limited speed route; next signal is at stop	a Interlocking signals.
			13. Proceed prepared to pass next signal at limited speed	n Distant signals for No. 6.
		Here.	14. Reduce speed	o Slow signs.
			15. Proceed on low speed route; next signal at proceed	a Interlocking signals.
			16. Proceed at low speed	a Interlocking signals.
			Supplementary Indications.	Applications.
			"A" Take siding here	b Manual block signals.
			"B" Take siding at next station	b Manual block signals.
			"C" Proceed, block is occupied	b Manual block signals.

Note.—Manual Block includes Telegraph Block, Staff Block, Controlled Manual Block.

Note.—Indication No. 8.—This indication may also be given at Interlocking Signals which are not Block Signals where Permissive Blocking is used, at Block Signals (Block Station Closed), at Train-Order Signals (No Orders), and at Flag Station Signals (No Passengers).

Note.—Indication No. 14.—This indication may also be given at a Signal to show that "19" orders are to be received. Eliminated by vote of the Railway Signal Association. Recommended by vote 9 to 5, Committee No. 10.

*See amendment, page 57, Vol. 9, 1908.

EXHIBIT No. 102.—ACCOMPANYING REPORT OF THE COMMITTEE ON SIGNALING PRACTICE TO THE AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION CONVENTION OF 1909.

Primary System						Secondary System
Basic Diagram.				Indications.		Indications.
Control	Immediate Control	Stop		Stop	1. Stop until authorized to proceed.	15. There are orders for you (31)
					2. Stop and proceed.	16. There are orders for you (19)
					3. Stop and investigate.	17. Take siding here.
		Proceed	Continue.	Proceed	4. Continue.	18. Take siding at next station.
			Resume Normal Speed		5. Resume normal speed.	19. Proceed—block occupied.
			Proceed at Normal speed		6. Proceed at normal speed.	20. Stop for passengers.
					7. Proceed at normal speed—prepare to stop at next signal, 6+A.	21. There are no passengers for you.
					8. Proceed at normal speed—prepare to pass next signal at normal speed, 6+B.	
					9. Proceed at normal speed—prepare to pass next signal at limited speed, 6+C.	
			Proceed at Limited speed.		10. Proceed at limited speed.	
					11. Proceed at limited speed—prepare to stop at next signal, 10+A.	
					12. Proceed at limited speed—prepare to pass next signal at normal speed, 10+B.	
			Proceed at Low speed.		13. Proceed at low speed.	
					14. Proceed at low speed—prepare to stop.	
	Future Control	A—Prepare to stop at next signal.		Indications eliminated as unnecessary	6+D 10+C 10+D 13+B 13+C 13+D	
		B—Prepare to pass next signal at normal speed.				
		C—Prepare to pass next signal at limited speed.				
		D—Prepare to pass next signal at low speed.				

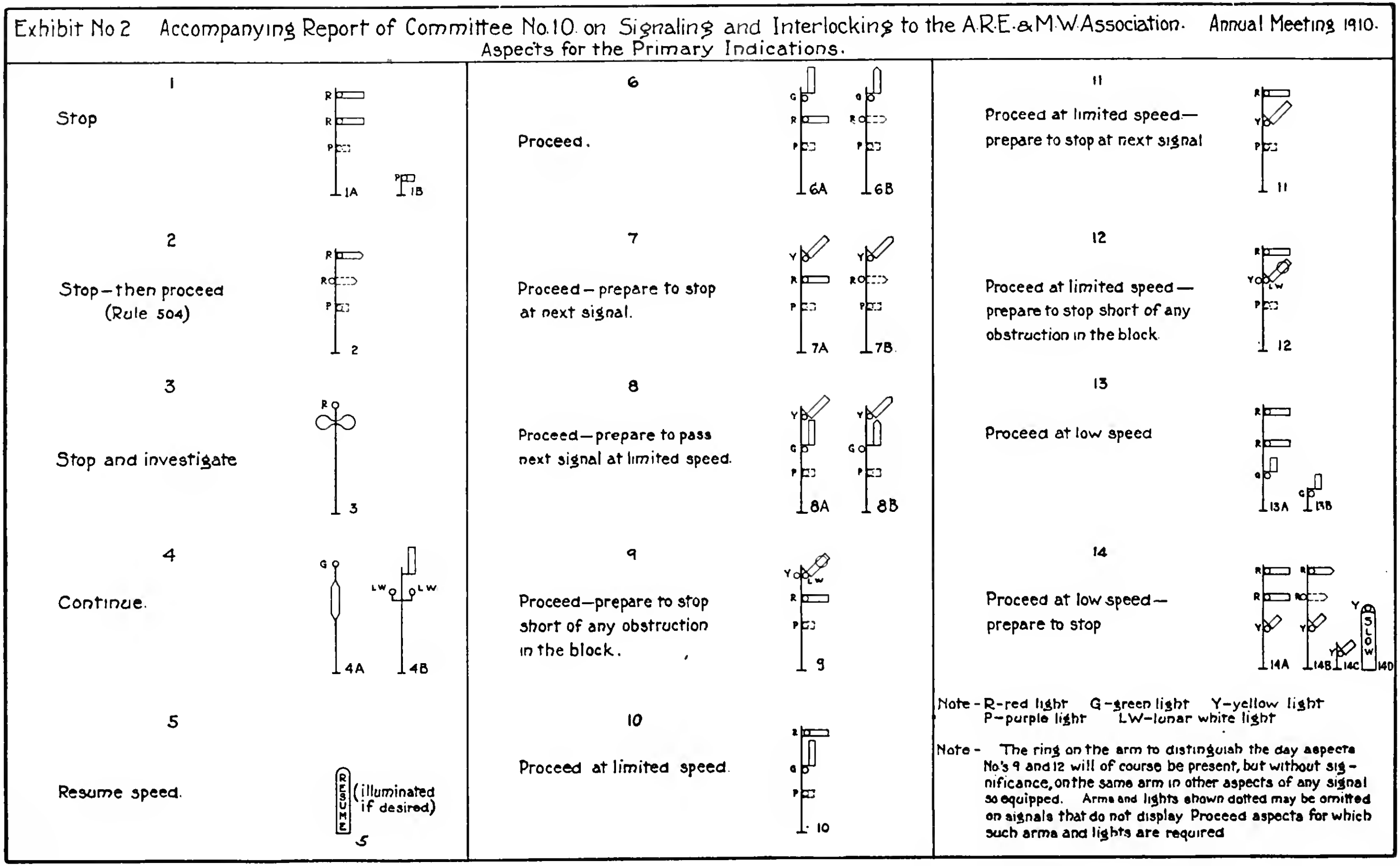
Exhibit No 1 Accompanying Report of Committee No. 10 on Signaling and Interlocking to the A.R.E. & M.W. Association.

Annual Meeting 1910.

Basis of Primary Indications.				Primary Indications		Secondary Indications.
Control of the Train	Immediate	Stop	including or not including action to be taken after stopping	Stop	1. Stop 2. Stop-then proceed (Rule 504) 3. Stop and investigate.	15. Get orders. 16. Take siding. 17. Stop for passengers (Flag Stop) 18. No passengers.
		Proceed	Because of the indicated absence of restriction at the point where the indication is given but not in disregard of a restriction previously imposed; the control indicated, for example, when a main track switch is normal or a block station is closed. As a specific name for the indication the word "Continue" is proposed. Because the restriction imposed by a slow sign, but no other restriction, is here removed Without or with restriction of speed to be observed at the point where the indication is given.	Proceed	4. Continue. 5. Resume speed 6. Proceed. 7. Proceed—prepare to stop at next signal 8. Proceed—prepare to pass next signal at limited speed 9. Proceed—prepare to stop short of any obstruction in the block 10. Proceed at limited speed 11. Proceed at limited speed—prepare to stop at next signal 12. Proceed at limited speed—prepare to stop short of any obstruction in the block. 13. Proceed at low speed 14. Proceed at low speed—prepare to stop.	Note — Indication No. 4 may be given by main track switch signals, block signals when block station is closed, signals at interlocking stations that are not block stations where permissive block is used, and train-order signals when there are no orders.
	Future.		After the immediate control indicated in a [illegible], preparation To stop at next signal; To pass next signal at limited speed, To stop at any point.			

Exhibit No 2 Accompanying Report of Committee No.10 on Signaling and Interlocking to the A.R.E.&M.W.Association. Annual Meeting 1910.

Aspects for the Primary Indications.



1 Stop

2 Stop—then proceed (Rule 504)

3 Stop and investigate

4 Continue.

5 Resume speed.

(illuminated if desired)

6 Proceed.

7 Proceed—prepare to stop at next signal.

8 Proceed—prepare to pass next signal at limited speed.

9 Proceed—prepare to stop short of any obstruction in the block.

10 Proceed at limited speed.

11 Proceed at limited speed—prepare to stop at next signal

12 Proceed at limited speed—prepare to stop short of any obstruction in the block.

13 Proceed at low speed

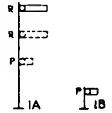
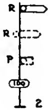
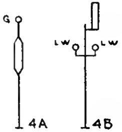
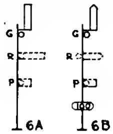
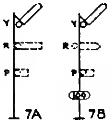
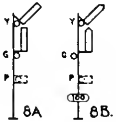
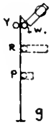
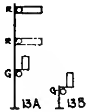
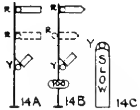
14 Proceed at low speed—prepare to stop

Note - R-red light G-green light Y-yellow light
P-purple light LW-lunar white light

Note - The ring on the arm to distinguish the day aspects No's 9 and 12 will of course be present, but without significance, on the same arm in other aspects of any signal so equipped. Arms and lights shown dotted may be omitted on signals that do not display Proceed aspects for which such arms and lights are required

Exhibit No. 3. Accompanying Report of Committee No. 10 on Signaling and Interlocking to the A.R.E. & M.W. Association. Annual Meeting 1910

Aspects for the Primary Indications—First Modification—Omitting Arms and Lights not Required for Proceed Aspects.

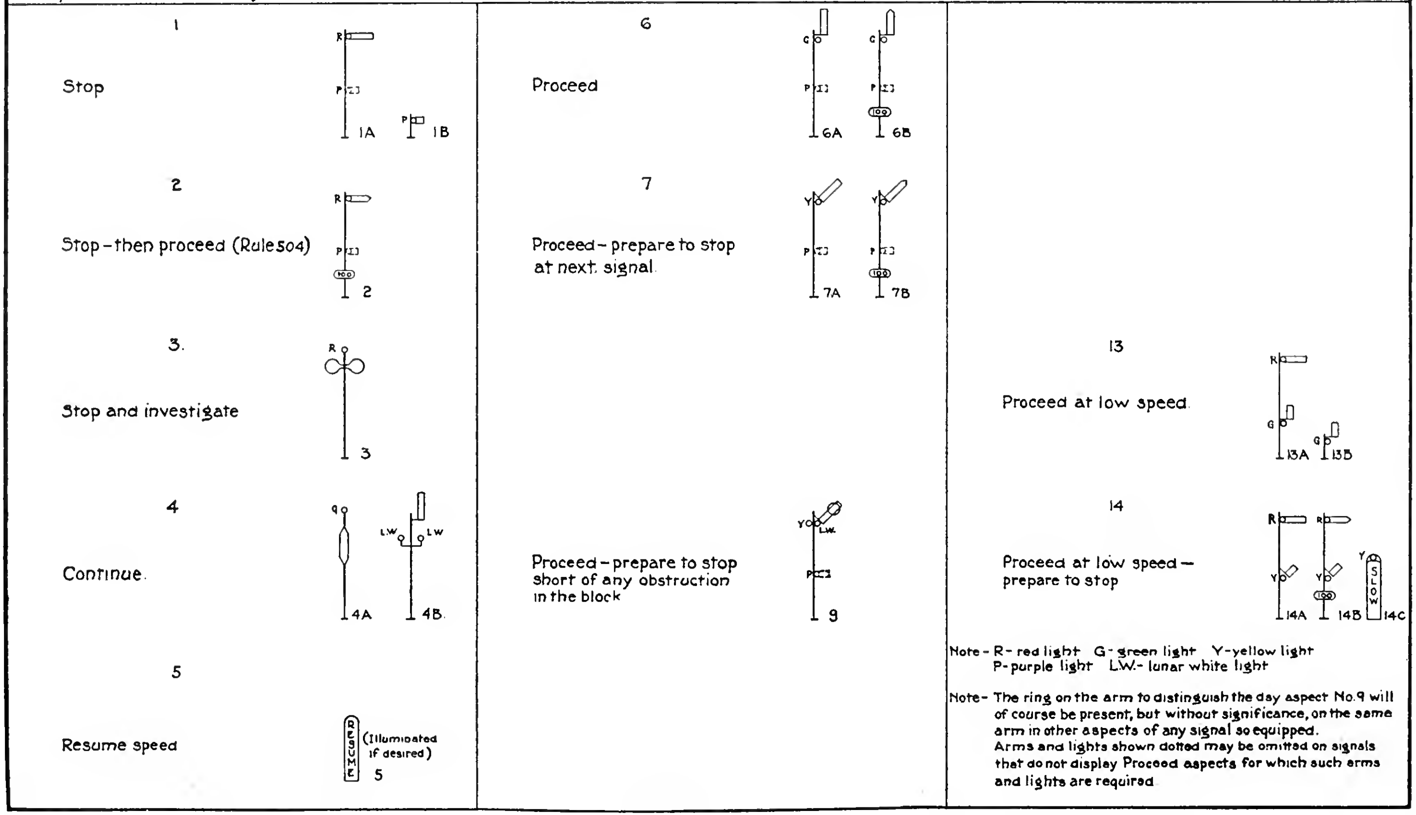
1	Stop.	
2	Stop—then proceed (Rule 504)	
3	Stop and investigate.	
4	Continue.	
5	Resume speed	 (illuminated if desired)
6	Proceed.	
7	Proceed—prepare to stop at next signal.	
8	Proceed—prepare to pass next signal at limited speed.	
9	Proceed—prepare to stop short of any obstruction in the block.	
10	Proceed at limited speed.	
11	Proceed at limited speed—prepare to stop at next signal.	
12	Proceed at limited speed—prepare to stop short of any obstruction in the block.	
13	Proceed at low speed	
14	Proceed at low speed—prepare to stop.	

Note—R-red light G-green light Y-yellow light.
P-purple light LW-lunar white light.

Note— The ring on the arm to distinguish the day aspects No's 9 and 12 will of course be present, but without significance, on the same arm in other aspects of any signal so equipped. Arms and lights shown dotted may be omitted on signals that do not display Proceed aspects for which such arms and lights are required.

Exhibit No. 4 Accompanying Report of Committee No. 10 on Signaling and Interlocking to the A.R.E. & M.W. Association. Annual Meeting 1910

Aspects for the Primary Indications—Second Modification—Omitting Provision for Limited Speed Indications.



Note—R—red light G—green light Y—yellow light
P—purple light L.W.—lunar white light

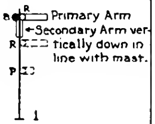
Note—The ring on the arm to distinguish the day aspect No. 9 will of course be present, but without significance, on the same arm in other aspects of any signal so equipped.
Arms and lights shown dotted may be omitted on signals that do not display Proceed aspects for which such arms and lights are required.

Exhibit No. 5. Accompanying Report of Committee No. 10 on Signaling and Interlocking to the A.R.E.&M.W. Association Annual Meeting 1910

Aspects for the Secondary Indications and for Switches in Sidings and Yards.

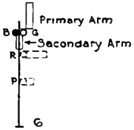
1

Stop (no orders)



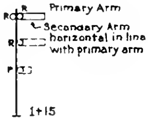
6

Proceed (no orders)



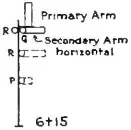
1+15

Stop – get orders.



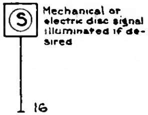
6+15

Proceed – get orders



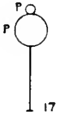
16

Take siding



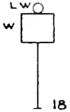
17

Stop for passengers.



18

No passengers



Non-interlocked siding derail open

Switch in siding or yard normal – non-interlocked siding derail closed.

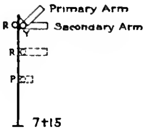
Switch in siding or yard reversed

Note – R-red light G-green light Y-yellow light
P-purple light (or target) LW-lunar white light
W-white target. B-blanked light
It is good practice to display aspect 17 and omit 18 or to display 18 and omit 17

Exhibit No.6 Accompanying Report of Committee No.10. on Signaling and Interlocking to the A.R.E.&M.W. Association. Annual Meeting 1910.
Additional Aspects for Secondary Indications No.'s 15 and 16 in Combination with Primary Indications.

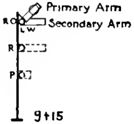
7+15

Proceed — prepare to stop at next signal — get orders.



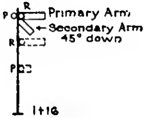
9+15

Proceed — prepare to stop short of any obstruction in the block — get orders.



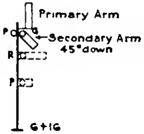
1+16

Stop — take siding here.



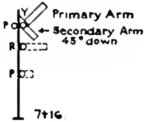
6+16.

Proceed — take next siding beyond this station.



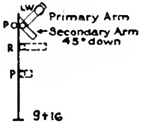
7+16

Proceed — prepare to stop at next signal — take next siding beyond this station.



9+16

Proceed — prepare to stop short of any obstruction in the block — take next siding beyond this station.



Note - R-red light G-green light Y-yellow light
P-purple light LW-lunar white light.

Note - The ring on the primary arm to distinguish the day aspect No.'s 9+15 and 9+16 will of course be present, but without significance, on the same arm in other aspects of any signal so equipped.

Note - The secondary arm may be applied in connection with any arm of any signal except the second arm in aspects No.'s 2, 6B, 7B, 8B, and 14B, and application in connection with that arm would serve no useful purpose.

SUBJECT NO. 3—STANDARD AGREEMENT FOR THE CONSTRUCTION, RENEWAL, MAINTENANCE AND OPERATION OF JOINT INTERLOCKING PLANTS.

September 11, the Chairman submitted to Chairman Ackerman, of the Committee on Uniform General Contract Forms, copies of agreements "A," 'B" and "C," and asked that he check against these proposed agreements as instructed by the Board of Direction and supply his comments. No advice other than acknowledgment of receipt of papers has been received. Through oversight the Signal Association Committees were not instructed to prepare a table of the relative values of the various functions; this will be remedied during the current year, the instructions to the various Committees interested being to submit lists of the comparative values to be given to the operating units with which each has to do, based on an arbitrary value of 10 for a one-arm three-position power operated signal, and it is hoped to have this information presented to the Signal Association next October so that it will be available for the use of this Committee in time for our next report. The elimination of the division of expenses from the report as ordered by the 1909 convention emasculates the subject to such an extent that it is almost impossible to treat it intelligently or in a comprehensive manner. Considering all the circumstances, therefore, your Committee feels that it is not in a position to make any definite recommendations this year and presents this explanation as a progress report.

SUBJECT NO. 4.

Committee III, having this subject in charge, was notified of the appointment of the Sub-Committee, and did not arrange for a conference. We, therefore, can only report progress.

SUBJECT NO. 5.

This subject has been under discussion for three years; last year a progress report only was presented, no conference being held, largely on account of the report of Committee X being accepted as a progress report. Owing to important engagements members of this Sub-Committee were unable to attend a conference on the date arranged this year. Any delay must, therefore, be charged to Committee X.

SUBJECT NO. 6.

Sub-Committee E, Messrs. Ames, Ellis, and Elliott, Chairman, has held no meetings, as none will probably be necessary unless and until report of this Committee on Subject No. 2 is adopted.

SUBJECTS 7 AND 8—ELECTRICAL AND MECHANICAL SPECIFICATIONS.

At the last convention Subject 7 was referred back to the Committee, with instructions to include wrought-iron pipe, as well as steel, and at the request of the Committee the mechanical specifications were eliminated from the Manual.

Subject 8. Electric interlocking specifications were referred back to be revised and resubmitted with statements of the results of experience. In view of this attitude of the Association, and of the numerous other subjects assigned to the Committee, it was considered best to postpone the presentation of any specifications for a year or two in order that, as they had been adopted by the Railway Signal Association, they might be given a thorough trial, amended where necessary, and presented for adoption here just previous to the publication of the next Manual. The Sub-Committee, therefore, in conjunction with manufacturers and the Chairmen of Railway Signal Association Committees having these matters in charge, has occupied its time largely in harmonizing; making the specifications as far as possible identical in arrangement and wording.

We quote here a part of our report to the Railway Signal Association:

"(a) Harmonizing of the specifications was undertaken as the first work, as it was considered important that the three main, practical subjects on signaling and interlocking should be brought into shape so that the chairman in charge of each of the subjects would have time to put his specification into final form for the Secretary, the length and technical nature of each specification requiring a careful checking before publication in the Manual. Therefore, the first two meetings were held jointly with the three chairmen and the time was devoted entirely to harmonizing work."

"(b) Large railroads and systems have had standards for a number of years; some have committees working on the subject of standard designs. In the circumstances, it is obviously necessary that your Committee acquaint itself with the work done, and what is being done, in this line, and also to have assurances that the standard designs as issued by the Railway Signal Association be used, or our work will not have accomplished its purpose. With these things in view, the March meeting was held with the New York Central Lines Signal Committee, and as the personnel of your Sub-Committee on these subjects consists of members of the Pennsylvania, Chicago & Northwestern, Baltimore & Ohio, Atchison, Topeka & Santa Fe and New York Central Lines, this combination represented a large mileage. We are pleased to advise that hearty co-operation was assured, and the Pennsylvania and New York Central Lines, the Baltimore & Ohio, the Southern, and other important lines, have arranged to adopt the standards already submitted to the Association by this Committee."

"(c) The April and May meetings were held jointly with chairmen of committees on specifications, and also with manufacturers' representatives, who work in conjunction with your Committee on standard designs. The morning sessions were devoted to harmonizing of specifications, the manufacturers' representatives meeting separately. In the afternoon, the Chairmen of Committees on specifications held a separate meeting and the Committee met with the manufacturers' representatives on standard designs. This method of procedure enabled us to carry work forward on both subjects. With one or two exceptions, it will be noted there was a full attendance at each meeting, except that the American Railway Signal Company and the Continental Signal Company did not send representative members."

"Work Done: (a) The General Specifications under each of the subjects, (1) Specifications for Mechanical Interlocking, (2) Specifications for Power Interlocking, (3) Specifications for Automatic Block Signaling, are completed up to and including paragraph 16. Each specification was very carefully gone over, and, while there is still some work to be done by the three chairmen in detail specifications, it is intended that early in August they will be ready for the Secretary. This work places at the disposal of the public a set of very valuable specifications and great credit is due the chairmen of these committees for the successful accomplishment of a difficult task.

"(b) Standard Designs and Specifications for Materials: Owing to the fact that most of our time was devoted to the harmonizing of specifications, our standard designs have not progressed as rapidly as they otherwise would. However, the important and difficult subjects of standard spacing of signal arms and standard semaphore spectacles and height of masts received very careful and continued study.

"(c) Progress has been made on various other subjects, but your Committee, not having reached final decision, is not prepared to offer plans and specifications at this time. The subjects which have been taken up during the year are as follows:

1. Signal Lamps.
2. Specifications for Fiber for Insulating Rail Joints.
3. Specifications for Battery Zincs and Coppers.
4. Specifications for Binding Posts and Screws.
5. Standard Layout for Single Switch.
6. Foundations for Cranks, Compensators and Wheels.
7. Signal Mast Fittings (including Straight and Bracket Masts)."

The Sub-Committee has, in addition, prepared specifications for wrought-iron signal pipe, in conformity with the instructions of the Association, voted at the 1909 Convention. These specifications, however, have not been submitted to the Committee as a whole, and have not been acted upon by the Railway Signal Association. Under these circumstances it has been considered best not to embody them in this report, and the Sub-Committee reports progress, which the entire Committee indorses.

Respectfully submitted,

A. H. Rudd (*Director*), Signal Engineer, Pennsylvania Railroad, Philadelphia, Pa., *Chairman.*

Azel Ames, Kerite Insulated Wire & Cable Company, New York, N. Y.

C. C. Anthony, Assistant Signal Engineer, Pennsylvania Railroad, Philadelphia, Pa.

H. S. Balliett, Engineer Maintenance of Way, Grand Central Terminal; Signal Engineer, Electric Zone. New York Central & Hudson River Railroad, New York, N. Y.

H. S. Cable, General Superintendent, Chicago, Rock Island & Pacific Railway, Davenport, Ia.

C. A. Christofferson, Signal Engineer, Northern Pacific Railway, St. Paul, Minn.

C. E. Denney, Signal Engineer, Lake Shore & Michigan Southern Railway, Cleveland, O.

W. J. Eck, Electrical Engineer, Southern Railway, Washington, D. C.

W. H. Elliott, Signal Engineer, New York Central & Hudson River Railroad, Albany, N. Y.

G. E. Ellis, Federal Signal Company, Albany, N. Y.

M. H. Hovey, American Railway Signal Company, Cleveland, Ohio.

A. S. Ingalls, Assistant General Superintendent, Lake Shore & Michigan Southern Railway, Cleveland, O.

J. C. Mock, Electrical Engineer, Detroit River Tunnel Company, Detroit, Mich.

F. P. Patenall, Signal Engineer, Baltimore & Ohio Railroad, Baltimore, O.

J. A. Peabody, Signal Engineer, Chicago & Northwestern Railway, Chicago, Ill.

Frank Rhea, General Electric Company, Schenectady, N. Y.

H. H. Temple, Superintendent, Baltimore & Ohio Railroad, New Castle, Pa.

Edwin F. Wendt (*Director*), Assistant Engineer, Pittsburg & Lake Erie Railroad, Pittsburg, Pa.

Committee.

Not concurring,

L. R. Clausen, Superintendent, Chicago, Milwaukee & St. Paul Railway, Chicago, Ill. (*Vice-Chairman*).

W. J. Harahan, Assistant to President, Erie Railroad, New York, N. Y.

W. B. Scott, Assistant Director Maintenance and Operation, Harriman Lines, Chicago, Ill.

Thos. S. Stevens, Signal Engineer, Santa Fe System, Topeka, Kan.

J. E. Taussig, Terminal Superintendent, Wabash Railroad, St. Louis, Mo.

MINORITY REPORT.

COMMITTEE X—ON SIGNALS AND INTERLOCKING.

To the Members of the American Railway Engineering and Maintenance of Way Association:

The minority members of your Committee respectfully dissent from the report submitted by the majority, for reasons briefly referred to in the following:

(a) This minority report is made only after serious consideration by the members signing it. It is made with a full appreciation of the desirability of devising some plan of Uniform Signaling. Further, it is made with a desire that, when this plan is finally adopted, it shall be in accordance with the best thought, not only of the signal experts of the country, but of operating officials as well. The scheme of signaling presented by the majority, however, represents the opinions of signal experts rather than those of men actually engaged in railway operation.

(b) The minority apparently represents a comparatively small percentage of the total membership of the Committee. If examination is made of the interests involved, however, it will be found that eleven roads or systems only are represented, four of which are in the minority. Discussion of the Committee's report during the past year has developed a substantial objection to the same on the part of Signal Engineers of the West, by reason of the criticisms we have suggested.

(c) Assurance is given by the majority that the acceptance of the Committee's report will only have the effect of selecting such forms of signaling as are deemed best for the purpose of producing uniformity. We, however, respectfully call attention to the fact that the adopted report must, in a measure, define correct signaling practice if it is to have any value whatsoever. It is the first complete scheme of signaling to be submitted to any association. If it receives the approval of this Association, and of the Railway Signal Association as well, it will, of necessity, be accepted as the opinion of the signal experts of the country. This fact will not be altered if future investigation develops that the American Railway Association cannot approve the scheme.

(d) There are seven well-defined objections to the scheme of signaling presented by the majority:

FIRST: "Two of the four principles, upon which it is based, have been accepted without full investigation, viz.:

(a) "The 45-degree position of the arm shall indicate the position of the arm on the next signal in advance.

(b) "The location of the arm on the mast shall indicate the speed at which the movement shall be made."

(a) There is little or no support for the arbitrary use of the 45-degree position to indicate the position of the arm on the next signal in advance. In present practice, this position of the arm is used indiscriminately for caution signals, whether such caution signals are used for permissive block purposes, for distant signal purposes or for some other purpose. Very little discussion has been given to the correctness of the Committee's action in this matter. That it is best to use the 45-degree position of the signal arm to indicate the position of signal arms in advance, is apparently held by the majority as axiomatic. This question has not been discussed in full Committee.

(b) There is little support in present practice for the assignment of the different arms on a mast to different speeds. The three-arm interlocking signal, which is the signal on which the scheme of aspects is based, has always been a route signal. It cannot, in our opinion, be divorced from this function of indicating routes. It is true the Association has adopted a scheme for a simple grouping of routes at interlocking plants, based on the allowable speeds at which the divergencies can be made. When this scheme of grouping was adopted, however, it was specifically stated that primarily, routes were to be indicated, and secondarily, as a necessary consequence, speed was to be indicated.

The assignment of the arms on a mast to different speeds, while it has had some study in Sub-Committee, has never been open for full discussion in full Committee.

SECOND: "The scheme has too many aspects and indications which are difficult to remember and understand and will be confusing to the trainmen and enginemen."

Examination of the number of aspects in Exhibit No. 1, which may be used to signal a railroad using one, two or three-arm signals, shows 96 aspects or pictures for the engineer. Fourteen of these give high-speed proceed indications. With the complete scheme, Exhibit No. 2, and the secondary aspects, 59 aspects can be used, 7 of them giving high-speed proceed indications.

We take the position that a scheme of signaling, embracing this number of aspects, is impracticable and unnecessary. Regardless of the number of aspects shown or used, the engineer will classify certain of them as "Stop" signals, certain as "Caution" signals and certain as "Proceed" signals. He has, in fact, little time to interpret them in any other manner. The engineer of a high-speed train should never be in doubt as to the meaning of a signal if he is to run safely. The signal should mean something perfectly definite to him, which he cannot mistake. In our opinion this result cannot be obtained by the use of the large number of indications and aspects presented by the majority.

When it is attempted to show more on the face of a signal than "Stop," "Caution" and "Proceed" (the indications used by the American Railway Association), complication enters, and doubt is raised in the mind of the employé. To the engineer, too many aspects are confusing and carry the same element of danger as too many train orders. Experience has clearly shown the wisdom of curtailing orders to the minimum length and number, and not burdening enginemen and trainmen with information not of immediate concern, or orders too far in advance of their execution.

THIRD: "While a multiplicity of aspects is provided, they are incomplete. The operation of railroad signals to-day is based upon the principle that the absence of a signal, where one is usually displayed, shall indicate 'Stop.' For example: Indication No. 7 (Proceed—prepare to stop at next signal) is equivalent to saying, 'Proceed—the next signal is in the 'Stop' position." The absence of the 45-degree position or change to the 90-degree position, gives the engineman permission by inference to assume that the next signal is clear, but this is not covered by an indication. The same criticism applies to other similar indications. In other words, in order to complete a system of signals along the lines presented, it is necessary to provide *additional* indications."

In the previous list of indications presented to this Association by Committee X, will be found the following:

In Exhibit No. 1, outline of indications for method of Uniform Signaling, 1908, "Proceed on unlimited speed route, next signal at proceed," "Proceed on limited speed, next signal at proceed." In Exhibit No. 2, accepted report on Committee of Signal Practice to the American Railway Engineering and Maintenance of Way Association, 1909, will be found "Proceed at normal speed—prepare to pass next signal at normal speed," "Proceed at limited speed—prepare to pass next signal at normal speed." In the outline of indications presented this year, it will be found that the reference to routes has been eliminated and also all reference to "Next signal at Proceed" or "Prepare to pass next signal at normal speed."

We maintain that when the indications "Prepare to stop at next signal" and "Prepare to pass next signal at limited speed" are given in a specific way, the indication "Prepare to pass next signal at normal speed" is compulsory; that if a specific restriction is placed on the movements of a train, this restriction must also be removed.

We hold, therefore, that the diagram of indications is not complete because it does not provide the converse of its restrictive indications.

FOURTH: "There is no well-defined basic principle that may be followed interpreting the aspects. The scheme has many interpretations which are not covered by, or in harmony with, the standard code."

The majority scheme is based on the assumption that the top arm should always indicate normal speed movements and the second arm should always indicate limited speed movements; yet, in Aspect No. 8, we have the top arm at 45 degrees, which should refer to normal speed movement, and the lower arm at 90 degrees, which should refer to limited speed movements. The confliction is apparent.

Another inconsistency appears in that either the top arm or secondary arm at 45 degrees can indicate the position of the next signal in advance. Where green is used for "clear," it is associated with a normal speed movement and yellow with a reduced speed or cautionary movement. The majority scheme before you, however, allows a normal or high-speed movement under either a green or yellow light on the top arm, and a reduced speed movement to be made under either green or yellow light on the second arm.

FIFTH: "There are too many red lights displayed."

The display of red lights on an interlocking signal, when a train can run by it at its usual speed, has always been an objection in the eyes of operating officials. This report, which is presented to bring about *uniformity*, is based, it will be noted, on the principle that a red light should be displayed to every train on every signal when trains can pass at usual speed.

We believe that this feature of the proposed scheme is a step backward rather than forward.

SIXTH: "The same aspects are used for different indications and different indications for the same aspects."

SEVENTH: "Definite or precise information of considerable variety not required in the practical operation of a railroad, is provided throughout the scheme. In order to maintain the distinctions, much complication is introduced which may lead to considerable difficulty. For example: Instead of one Caution signal, there is provided a special signal for each of the several occasions requiring caution. The scheme provides specific information about conditions in advance; notably the indication of next signal. The Distant signal is used as a repeater of the Home and is bound to teach enginemen to relax vigilance and depend upon advance information which is subject to change, and, therefore, unreliable. The plan of providing repeaters for Home signals will eventually lead to a demand for still further repeaters and checks of various kinds upon fixed signal systems, such as cab signals, and ultimately automatic stops, all of which tend to a laxity in the proper degree of attention on the part of employés."

It will be noted throughout the report that such phrases as "Prepare to stop at next signal," "Prepare to pass next signal at limited speed," "Prepare to stop short of an obstruction in block," are provided, thus defining the purpose for which reduced speed is necessary.

We feel that any specific reference to the obstruction is conducive to a lack of vigilance, that it is far safer to require reduced speed or caution by some signal display and leave it to the engineman's vigilance to discover what the obstruction is. It is our opinion that, in this way, safer operation will be obtained than if the engineman's attention is attracted away from general supervision and centered on some specific thing. This is aside from the objections to the complication introduced when so much specific information is provided.

It will be noted that, after this report is completed, only two or three reasons for "Caution" are specified, and that if any other necessity arises for which a "Caution" or reduced speed indication is necessary, more aspects will have to be developed, introducing further complications.

One of the underlying principles of this scheme is that several separate and distinct caution indications should be provided, but until all caution indications which are required have been provided, the practicability of this scheme will not be shown.

The majority has attempted to restrict the use of the present-day caution signal to that of repeating signals in advance. We object to this practice because of the unreliability of the information conveyed. The Distant or Caution signal is very frequently found in the Caution position, when the Home signal is found clear on the approach of trains, due to other trains passing out of block ahead, etc. Again, the Distant or Caution signal is not infrequently found in the Clear position and the Home signal in the Stop position, due to a change in conditions after the train has passed the Distant signal. Because of these facts, it is obvious that the value of a Distant signal as a repeater of signals in advance, is extremely doubtful. In fact, the engineer is not safe in relying upon the information so given and soon learns to place a signal so used in the same category with employés who give violent signals when slow signals would serve the purpose.

In addition to the above criticisms, it should be noted that in indications 7, 8, 9, 11, 12, there are two actions prescribed for the guidance of the engineman. In 7, 8 and 9 he is told to "Proceed," while, according to the majority's interpretations, means "Proceed without restrictions," and then he is told to "Prepare to stop at next signal," or "Prepare to pass next signal at limited speed," or "Prepare to stop short of any obstruction in the block, as the case may be. We claim that discipline cannot be maintained with indications of this character. First, because they are conflicting, and, second, because it must be left to the discretion of the engineman when he shall cease regarding the first part of the indication and begin obeying the second part; when, for instance, he should stop "Proceeding without restriction" and start "Preparing to stop at next signal." It should be the railroad's responsibility to decide where it is necessary for trains to start reducing speed, because of Stop signals or other obstructions in advance.

In conclusion: Attention should be given to the fact that only a part of this report is submitted for acceptance, the remainder being submitted as a progress report. It is manifestly undesirable for this Association to accept part of the report unless the whole scheme has been developed and the majority can show that they are able to take care of the situation.

When enginemen and trainmen can be taught to implicitly respect and place entire dependence upon signal indications given them, then, and then only, will railroad companies, their passengers and employés receive the full measure of protection available through the use of signals.

If failures and false indications are numerous to that extent unquestionably will the entire system be discredited. Operating officers throughout the country will, undoubtedly, discountenance any system which tends to encourage laxity.

Any system which says by signal indication that a clear block signal means that the *"Block is Clear,"* of necessity will encourage laxity. An engineer with this conception of the meaning of a clear block signal will not keep the sharp lookout that we must insist upon to have safety in operation. The block may not be clear. We cannot guarantee that it will be. There are many ways in which it may be obstructed, such as by runaway cars, damaged bridges, rock and dirt slides, etc.; and various others too numerous to mention. All of these obstructions must be expected without advance information, hence the imperative necessity for vigilance at all times. The clear signal should not mean *"Block is Clear,"* but *"Proceed"* only.

A simple and consistent uniform system should provide fixed signals as close together as traffic conditions may warrant. Safety in operation demands that all signals be read in the order they are met and the action taken *at the signals* instead of at the next signal or at the next station.

For the reasons above mentioned, the minority members of the Committee on Signals and Interlocking respectfully recommend that the report of the majority relative to signaling practice be referred back to the Committee for further consideration.

Respectfully submitted,

L. R. Clausen, Superintendent, Chicago, Milwaukee & St. Paul Railway, Chicago, Ill., *Vice-Chairman.*

W. B. Scott, Assistant Director Maintenance and Operation, Harriman Lines, Chicago, Ill.

Thos. S. Stevens, Signal Engineer, Atchison, Topeka & Santa Fe Railway System, Topeka, Kan.

J. E. Taussig, Superintendent Terminals, Wabash Railroad, St. Louis, Mo

DISCUSSION.

The President:—Mr. A. H. Rudd, Chairman of the Committee on Signals and Interlocking, will present the report of that Committee.

Mr. A. H. Rudd, Chairman (Pennsylvania Railroad):—Attention is called to the meetings which have been held by the Committee, so that you can see the subject under discussion has had some consideration.

I would move the adoption of the revision of the Manual, if that is necessary, shown on pp. 41, 42 and 43, Bulletin 119.

The President:—It may be assumed that those who are to take part in this discussion have gone carefully over the report and that they will give us the benefit of their views. I think it has been ruled in the past, and very wisely, that we should not attempt to take up the time of the convention with mere definitions. Our experience in the past has been that too much valuable time was consumed over definitions which, frequently, when settled upon did not make any material difference from the original. If you will leave that in the hands of the Editorial Committee, or the Board of Direction, they will see that nothing is put in but what should be put in the Manual. Further, they will be glad to receive any communications in writing in regard to definitions which the members may care to send to them.

Mr. L. C. Fritch (Chicago Great Western):—I ask the Committee if they would favor a change in the specifications for rubber insulated wire, in the requirements for voltage, making it 660 volts instead of 600.

The President:—The Committee will accept that amendment.

Mr. Rudd:—The Committee believes that its report on uniform signaling fully covers the subject, and has no additions or further explanations to make. The minority report sets forth certain objections, and it is our belief that time will be saved if an opportunity is given the Committee to answer these objections of the minority (which has studied the subject probably more carefully than any member outside the Committee), as, if we can dispose of them, the way will be cleared for action. I would, therefore, suggest that the Committee first submit its reply to the arguments of the minority and that general discussion follow.

Page 71, Bulletin 119: "(a) This minority report is made only after serious consideration by the members signing it. It is made with a full appreciation of the desirability of devising some plan of Uniform Signaling. Further, it is made with a desire that, when this plan is finally adopted, it shall be in accordance with the best thought, not only of the signal experts of the country, but of operating officials as well. The scheme of signaling presented by the majority, however, represents the opinions of signal experts rather than those of men actually engaged in railway operation.

"(b) The minority apparently represents a comparatively small percentage of the total membership of the Committee. If examination is made of the interests involved, however, it will be found that eleven roads or systems only are represented, four of which are in the minority. Discussion of the Committee's report during the past year has developed a substantial objection to the same on the part of Signal Engineers of the West, by reason of the criticisms we have suggested."

It is unfortunate that the minority included paragraphs (a) and (b) in a report to this broadgage Association. The statements are really not arguments, for if the system is a good one, the official titles of its sponsors cannot injure it, and if it cannot be commended, no such titles should be used to bolster it up—it should stand or fall on its merits. However, the statements have been made, and as they carried considerable weight in the Railway Signal Association and as they possibly affected some votes of that letter-ballot (which resulted in 235 votes for the report and 311 against it, while a two-thirds vote was necessary for adoption), it devolves upon us to answer them despite our embarrassment, for it now becomes necessary to tell you what a wonderfully well-equipped body of experts we are—a fact which should be self-evident to all men of discrimination, but upon which the minority casts a doubt. We apprehend that a Chief Engineer approving designs for a classification yard has glimmerings at least that it is to be used for the passing through it of cars, and from some of the discussions had here on the subject of momentum grades, for example, it is to be presumed that some engineers at least know something about the requirements of the transportation man; similarly it is fair to suppose that a well-equipped Signal Engineer must of necessity understand the requirements of the traffic he facilitates and safeguards, and as he makes a specialty of this work, that he is *better* fitted, if he understands his business, to devise a uniform system of signals than a Superintendent, whose desire is to attain certain ends and whose study of the means to attain these ends must perforce in most cases be perfunctory; although it cannot be denied that under the spur of the discussions in this and the Railway Signal Association, *some* Superintendents have given the subject more thought in the past four years than all the Superintendents on all the roads ever gave it before. I do not wish to be understood as implying that our honored Vice-Chairman is disqualified as an expert because he has become a Superintendent. We claim that this Committee is made up of just such well-equipped competent Signal Engineers as those referred to, and we offer ourselves as living proofs of the statement. This Committee is composed as follows: Of men who make, or have made until recently, a special study of signaling: Majority 14, minority 2; Operating men (on whom much stress is laid), majority 3, minority 3; one not signing either report; engineering in close touch with operation, majority 1. These men do not represent any roads or systems in this voluntary organization; they represent their own individuality, untrammeled by instructions of their operating officers, superior officers, or anyone else. It is true that the Pennsylvania has two men on the Committee and the Baltimore & Ohio two, and the New York Central Lines five, but the fact that these five happen to be employed on the component parts of a great system, which parts have different practices, does not warrant the implication of prejudice; and certainly a responsible position on the New York Central Lines is not *prima facie* evidence of mental disability or lack of knowledge or judgment—in fact, these are the men who are best qualified to design a uniform system, because they have to deal with the complicated as well as the simple problems of track layouts and signaling.

The Pennsylvania Railroad, for instance, has problems in no whit different from those of the Western Signal Engineers. We have approximately 456 miles of four-track, 110 miles of three-track, and 1,230 miles of two-track line, a total of 1,786 miles, and 3,500 miles of single track—two-thirds our mileage is single-track. And on 445 miles of this we had, a year ago, only from 2 to 10 movements daily and on 525 miles more, from 11 to 18 movements daily. It is true that there is less four-track west of Chicago than east of it, but the Western roads are growing and they will soon be confronted with the problems which are now vexing many of the majority members and will appreciate more fully the need of the information we propose to give and this problem covers the whole country—no East and West issue should be brought into it, and in fact some of the busiest four-track roads are right around Chicago, and they give in a different way just these very indications.

It will be noted that the minority offers no substitute scheme, but confines itself to criticizing. Last year Mr. Stevens presented a scheme and it was illustrated in the Proceedings. Mr. Clausen presented a scheme to the Committee, this scheme being discussed at the Railway Signal Association meeting last March; neither of these schemes met the approval of your Committee. It is fair to suppose these schemes were in the minds of the minority when its report was made. It states that our scheme represents the opinions of signal experts rather than those of men actually engaged in railway operation. Is this a fact? No road, to my knowledge, has adopted the basic principles of the scheme advocated by Mr. Stevens. If I am wrong, he will be able to correct me later. No road, as far as I know, has adopted the fundamentals of Mr. Clausen's scheme, and it is in two or three fundamentals only that our differences lie. There is no difference of opinion as to the advisability of upper-quadrant arms approved by this Association; little, if any, on green for "clear," approved by this Association; none on the automatic signal. The chief differences are on the use of the mid-position of the home signal arm instead of a second arm to indicate a divergence from the main track, the addition of a permissive indication for those roads which believe they require it, and the question whether the distant signal should be considered as giving the engineer a right to proceed to the home, expecting to find it clear. The Baltimore & Ohio is using the primary aspects recommended by the Committee, except green for "clear;" the New York Central operating officials have endorsed the Committee's scheme, at least to such an extent that they have adopted it for all new work and renewals, with little change. All the new interlockings on the Lake Shore & Michigan Southern are arranged in this way, and the basis of the system is being used on many others, at least this is my understanding. Transportation officers of the Pennsylvania Railroad, from General Manager down, have, with few exceptions, endorsed practically all the primary aspects (and we have adopted the three-position upper-quadrant for new work and renewals on our lines East of Pittsburg within the past week). Further, we are going to use automatic signals with one pointed arm and two lights staggered; the interlocking signals three-arm with top arm for high speed, second arm for medium speed, and third arm for low speed; distant signals approaching interlockings will have two arms with staggered lights to correspond with the high and medium speed arms on the interlocking signals; distant switch signals are to be of the one-arm automatic type. It would appear, therefore, that some operating officials of good standing approve the scheme.

Page 71, Bulletin 119: "(c) Assurance is given by the majority that the acceptance of the Committee's report will only have the effect of selecting such forms of signaling as are deemed best for the purpose of producing uniformity. We, however, respectfully call attention to the fact that the adopted report must, in a measure, define correct signaling practice if it is to have any value whatsoever. It is the first complete scheme of signaling to be submitted to any association. If it receives the approval of this Association, and of the Railway Signal Association as well, it will, of necessity, be accepted as the opinion of the signal experts of the country. This fact will not be altered if future investigation develops that the American Railway Association cannot approve the scheme."

We believe that this argument is sufficiently answered in the body of the report under the caption "Object of the Report," except as reference is made to the American Railway Association. As that Association has endorsed the upper-quadrant and made optional the use of green for "clear," and has never made any rulings on the other principles enunciated in the report which are at variance with the recommendations of your Committee, it is fair to suppose that if this system meets the approval of this Association, it will have as much chance for adoption, if the American Railway Association sees fit to recommend for adoption any uniform system, as some other which it has not been considered advisable by the minority to submit for your consideration. Certainly, if this Association should decide not to present any scheme to the American Railway Association for fear it might not approve it, the decision should be made to-day, as it is unfair to keep a Committee at work on this subject for the pleasure of having annual reports on it.

Now as to the seven specific objections (d): (a) The minority states: "The 45-degree position of the arm is at present used indiscriminately for caution signals, whether for distant signals, permissive signals, or for some other purpose." This statement is perhaps a little misleading to those who are not experts. It is used perhaps indiscriminately on one or two roads for the distant signal indication and the permissive, but on a number of roads 45 degrees is used for the distant only (at least in the new upper-quadrant installations), and on most other roads the day aspect for the distant signal at caution, is a fish-tail arm horizontal and the permissive a square-end arm inclined downward or upward from the horizontal; so they are not used indiscriminately generally to-day. As to some other purpose, the minority should amplify. We do not know of any instances where the 45-degree position of an ordinary semaphore signal is used, for instance, as a slow sign for track under repair, which requires caution, nor for diverging from the main track, as advocated in Committee by the minority members, and we would be glad to be enlightened as to other purposes for which it is used. The Committee recommends its use not as the minority states, for the distant signal indication only, but for the permissive as well, but it recommends a distinguishing mark when it is used for the latter indication, in order that the engineer may know whether he is to stop at a definite point ahead, or lookout for a train in a long block moving at perhaps varying rates of speed. While it is true that very little discussion was had on this particular point in the full Committee, it certainly had plenty in the sub-committee, and further, little discussion was needed in the full Committee, for, as the minority well states, it was (after consideration) "held by the majority as axiomatic."

(b) On page 57 you will note the indications presented in 1908, where routes were specified; the next year the word "route" was eliminated by the Vice-Chairman, who was given the task of correcting the table and bringing it into accord with his watchword, "The action required of the engineman in the control of his train." This year it appears that the original table was right. The revised table is now considered wrong. Ever since the top arm has led to the straight or through route at interlockings, it has, in the clear position, given the indication that the route was set up on which, unless prevented by some other cause, full speed could be maintained, and ever since that time the second arm has meant "reduce speed," because the train was going to diverge. Some roads displayed indicators to designate the track and then discarded them. Some roads used three arms, the second arm to govern with traffic and the third against traffic; not because of routes to be shown, according to our analysis, but because they realized it was not safe to give the same signal for different rates of speed;

in rare cases four arms were used, if there was a junction with three running tracks. I have never heard of a road having six or seven diverging routes, however, as a four-track joining a four-track, which used eight arms, signaling each route separately, the routes, as the minority say, were grouped, and not only common practice, but the action of this Association gives approval to the arrangement of the top arm for the high-speed route, second arm for medium-speed route, or routes, and the third arm for low-speed route or routes, and if it will clear the atmosphere and simplify matters in the minds of any to add the word "route," it can easily be done; the point in our minds is not important enough to require much discussion, and we have followed the wording of the American Railway Association. The statement that the assignment of arms has not had full discussion in full Committee, depends for its accuracy on the definition of the word "full." The location of arms was discussed in connection with Mr. Stevens' scheme, at the Railway Signal Association meeting last March, and at the meeting of the Committee in Philadelphia, at which Mr. Stevens was present. To the best of the chairman's knowledge, both of these matters have been *open* for discussion at all times in the Committee meetings. If they have not had full discussion, the reason is, it is believed, that most of the members were convinced of their correctness and were not disposed to join in prolonged discussion.

Page 72: "The majority scheme has too many aspects and indications which are difficult to remember and understand and will be confusing to trainmen and enginemen." As the minority does not present its so-called simplified scheme, no comparison can be made, and we are naturally at a disadvantage in argument. It is fair to state, however, that the 96 pictures will probably never appear on any one engine division, and certainly will only need to be read one at a time. In view of the fact that some roads now have, as stated by the Vice-Chairman in one of the earlier discussions, as high as 125 aspects, at the worst this scheme is simpler; as a matter of fact, the primary aspects consist of one, two or three-arm interlocking signals and an automatic block signal, and a switch target, all in use on the great majority of roads that have any signal installations of any size, a special mark to show permissive block, now shown by a distinctive position of the arm on many roads, slow track and resume speed signs of some kind are almost universally used, and a signal for block office closed is new and needed. If you have no occasion for signals, you would not need any of these aspects.

The minority says, page 73, "The engineer of a high-speed train should never be in doubt as to the meaning of the signal if he is to run safely; the signal should mean something perfectly definite to him, which he cannot mistake." We endorse this sentiment, and yet the simplified scheme presented by the minority for approval of this Committee used the 45-degree position of the upper arm when there was a train in the block, perhaps within 300 or 400 feet of it; when the next signal was at "stop;" when the next signal was at "proceed" with a route set up which could be run safely at 40 miles per hour; or for diverge right at the signal, safe speed 40 miles per hour. What a wealth of definite information *all embodied in one aspect!* It's like saying that all the letters in the English language are included in the alphabet, and if you say "alphabet" to a man you've taught him the language. If you say caution to a man when caution is not needed, you mislead that man and you set a trap for him. All of you who have had anything to do with signals know that in the days when discipline was lax, a distant signal would be left at caution by a lazy operator, sometimes for all except two or three trains daily, and that enginemen so finding it used to disregard it, and when interviewed would say: "It's always that way; it doesn't mean anything." The proposed scheme does give just that information which is needed and required by practical men on roads which have reached a considerable development. The simplifying of a system by the process of omission is a poor policy.

Precision vs. brevity is a fair summing up of the situation, but the minority advocates precision by employing brevity.

The reference to train orders is very apropos; the train orders should be brief, they *must* be exact. The application to signaling is obvious and need not be enlarged upon.

Page 73: "No additional indications are necessary." We take flat issue with the minority members. The wording is that of the American Railway Association, to quote:

"DISTANT SIGNALS.—Name as used in rules—Caution Signal; indication for enginemen and trainmen—proceed with caution to the home signal; occasion for use—home signal at 'stop'; route is not clear.

"Name as used in rules—Clear Signal; indication for enginemen and trainmen—proceed, occasion for use—home signal at 'proceed'; route is clear."

Certainly the American Railway Association is more likely to favor its own phraseology than a departure from it, made on such hair-splitting lines, and we eliminated the words quoted by the minority on page 74 for the reason that we desired to follow the American Railway Association wording as far as possible. An arm at 90 degrees giving the indication "Proceed" removes the restriction of the indication "Stop," given by the same arm horizontal; i. e., the indication "Proceed" involves no restrictions by signal indication and is the converse of "Stop." Is there any reason why the same unrestrictive indication, "Proceed," should not remove other restrictions that might be indicated by other positions of the arm or arms; any reason why it should not be the converse of other restrictive indications than "Stop"—of all restrictive indications that might be given by the particular signal?

Page 74: In the preceding paragraph we were criticized in following the Code; in this paragraph because it is said we vary from the Code.

We have discussed aspect No. 8 for the past two years, in Committee, before the Railway Signal Association, and here, and further discussion is unnecessary except to present the remedy advocated by the minority in Committee.

The Committee feel that if tracks are so arranged with long crossovers that a train may safely pass the home signal at 40 or 50 miles per hour, but cannot pass it at 70 or 80 without a bad lurch, the engineer should be warned of the safe speed, but should be allowed to take advantage of his track layout and not be required to reduce speed at the distant, prepared to stop at the home. That is, provided signals are installed to expedite movement and not simply to restrict it as much as possible. The aspect No. 8 they claim is not logical, and their suggestion for correcting it is a very simple one. Eliminate the indication entirely—do not tell him he can go when all is right, but tell him to reduce speed prepared to stop at the home signal, because forsooth the "occasion for use" is pass the home signal at 40 or 50 miles per hour. This process amplified and logically applied to a home signal would reduce that to a one-arm signal only—then stop all trains that have to diverge at low speed and flag them by.

Page 74, 5th: "There are too many red lights displayed." The Committee stands on the principle that in a completed, uniform scheme there should be two lights on each signal governing train movement; first, as a marker to distinguish between automatic and interlocking or telegraph block (the action of this Association having already asserted that a distinction of some kind is necessary), and second, as a marker to show the location of the signal if the other light is extinguished at night. If this marker should not be red and display a stop signal when the other light is out, following strictly the rule that a signal improperly displayed is to be regarded as a stop signal, what color should it be? Obviously not green—"Proceed;" obviously not yellow—"Caution;" from our point of view obviously red, and red only. From the minority standpoint of brevity and simplicity, logically eliminate it entirely; but to do this no signal should have more than one light, consequently no diverging low-speed routes could be signaled by fixed signals *logically*.

The Standard Code is admittedly a skeleton and not complete—one of its framers told me less than a year ago that it ought to be amplified and completed. Obviously in a complete scheme we give more indications than in an incomplete one—for confirmation of this statement see any good dictionary. Aspect No. 8 is absolutely consistent, in that it indicates unmistakably the position of the high and medium-speed arms at the home signal, and that is what the fast runner wants to know.

Page 74, 6th: "The same aspects are used for different indications, and different indications for the same aspects." This sounds as if there were two objections, but both clauses mean the same thing—*"the same aspects for different indications" is not an objectionable feature.* If, however, these aspects might be misread so as to convey to the engineman a more favorable indication than he should receive, then they would be objectionable. This, however, is not the case.

Page 74, 7th: "Definite or precise information of considerable variety not required in the practical operation of a railroad, is provided throughout the scheme. In order to maintain the distinctions, much complication is introduced which may lead to considerable difficulty. For example: Instead of one Caution signal, there is provided a special signal for each of the several occasions requiring caution. The scheme provides specific information about conditions in advance; notably the indication of next signal. The Distant signal is used as a repeater of the Home and is bound to teach enginemen to relax vigilance and depend upon advance information which is subject to change, and, therefore, unreliable. The plan of providing repeaters for Home signals will eventually lead to a demand for still further repeaters and checks of various kinds upon fixed signal systems, such as cab signals, and ultimately automatic stops, all of which tend to a laxity in the proper degree of attention on the part of employés."

I will read the first three paragraphs on page 51. If the members have done as the Committee requested, they can determine (with this statement of the minority as a guide) whether their operating officials are practical or impractical railroad men, and those of you who are operating in an impractical way and who have anything to do with signaling, will perhaps recollect requests from such Superintendents for more information rather than less.

The minority claims that the distant signal cannot be relied upon, and that it should not indicate next signal at proceed, but should, in the clear position, indicate proceed to the next signal. How? Obviously in the only safe way, if it cannot be relied on, that is prepared to stop. Why then display the caution aspect, which means the same thing? More elimination, more brevity, more uncertainty, more delay, and *less safety*.

On this basis, truly the American Railway Association is composed of members carrying on impractical operation, for the Code says: "Distant signal, indication proceed—occasion for use—home signal at proceed." If the minority is correct in its treatment of the distant signal, where does the American Railway Association stand? The majority believes it is on firm ground.

How many of you are ready to do away with distant signals where high speed is required, and how many are ready to say to their engineers: "A home signal at stop means stop," "a distant signal at caution means prepare to stop at any point beyond this signal," "and the distant signal at clear you have a clear track to the home, and our apparatus is arranged to comply with the American Railway Association requisites, so that in case of failure it will indicate caution, but nevertheless you must not place any dependence upon it, because it is unreliable?" In the three-position automatic system the distant and home are combined in one arm. Are you prepared to say: "When the automatic is clear, reduce speed at once, the block is clear, but we cannot rely on the indication?" Interlocking has been known to fail. Must a man prepare to stop at each clear home signal and feel his way? We endorse present practice. Do you say it is all wrong, dangerous, subversive of discipline, and that it, by its encouragement of lax discipline, will lead to the use of cab signals, automatic stops, etc.? You have the word of the minority, three of the four men being operating men of note, that discipline cannot be maintained if this use of the distant signal is allowed.

The issue is clean cut. It means that you cannot discipline a man for passing a home signal and that your men will become careless and disregard the home signals, unless you require them to reduce speed so that they may stop at any point within vision beyond the distant signal and this on a crooked road! And this is the deliberate, considered opinion of the three operating experts of the minority. The Committee states that most roads to-day use the distant signal in precisely the way condemned by these experts and asks you if discipline is lax; whether your men under this practice disregard your home signals and whether you will, by your votes, endorse the position of the minority, or will back up your Committee, in the light of your experience, bearing in mind the fact, gentlemen, that signals do not enforce discipline; that duty devolves upon the officials in charge of transportation.

Page 76: In conclusion, in recommending a portion of the report for adoption the Committee considered that this portion, covering the primary indications and aspects, had been worked out to a conclusion through several years of study and discussion, during which no radical changes had been made. In the case of the secondary indications and aspects, embodied in the progress report, various schemes have been under discussion, and the one presented was developed and agreed to within the past year. It therefore seems advisable to allow more time for consideration and possible revision before final action is recommended.

The only question affecting the wisdom of adopting a portion of the report, as recommended, seems to be, whether revision of the secondary system might make changes in the primary system necessary. On this point the Committee feels no fear whatever. The report shows that a practical secondary system, in harmony with the recommended primary system, can be devised, and the primary system is so well established that, beyond question, any desirable changes in the secondary system can and will be so made as to require no revision of the primary system.

The two following paragraphs the Committee accepts as axiomatic. The system recommended will certainly help to bring about the condition stated in the first, and involves no added mechanical or electrical complications that could result in an increased number of failures and false indications as compared with good signaling of the present day.

The minority says, "Any system which says by signal indications that a clear block signal means that the 'Block is clear' of necessity will encourage laxity." The American Railway Association Code says, "Clear Signal—Proceed. Occasion for use—Block is clear." Which is right? What use are block signals under the interpretation of the minority?

Evolution, not revolution, is the object of this Committee, and we believe of this Association. Where is the minority position short of revolution?

In the second paragraph on page 77 the minority defines what a consistent uniform system should cover. The Committee agrees with this basis, and submits its system as designed in conformity with it.

I move the adoption of the report of the Committee on subject No. 2, including the conclusions.

Mr. Thos. S. Stevens (Santa Fe):—Mr. Chairman, would it be in order for me to answer the chairman of the Committee?

The President:—Of course, gentlemen, it can be seen that this Committee as a whole is not a unit. The minority has brought in a report which seems, in a sense, to be a criticism without a substitute, and this minority report, together with the chairman's criticism of it, must be accepted simply in the form of discussion. It seems to the chair that if there is very much divergence of opinion, it might be well to have the report referred back to the Committee in order to see if it cannot as a whole harmonize some of the points at issue rather than take up the time of the convention in settling points, which the Committee has not first decided itself. Mr. Stevens, in the meantime there is a motion before the house.

Mr. Thos. S. Stevens:—Yes, I understand.

The President:—Do you wish to speak to the motion? If so, you can get in what you want to say.

Mr. Thos. S. Stevens:—I do not want to take up the time of the convention. The reason the minority, so-called, submitted no scheme of signals was purely on that account. They did not feel that this Association was a deliberative body to decide between one of two schemes. We felt that that was Committee work. I would like to answer one thing stated by the chairman. I will not answer the whole report. I want to say there are railroads in this country that are adopting the views of the minority, taking "Block occupied" and such things out of their rules for a purpose.

Mr. L. R. Clausen (Chicago, Milwaukee & St. Paul):—Mr. President, I wish to speak to Mr. Rudd's motion. The work of the Committee, as regards subject 2, method of uniform signaling, has been carried on for about four years in this Association, and for about five years in the Signal Association. The subject was suggested by the Committee itself, and probably because of the diverse practice throughout the country in the art of signaling; the need, the desirability of uniformity have not been so clearly shown, and have not been dwelt upon by the Committee in this discussion very particularly. The work was started in the Railway Signal Association, and annually reports have been presented by their Committee on signaling practice, resulting, in October, 1909, in a final report which was presented with the recommendation that it be adopted.

Each year in the Signal Association saw a change in the Committee's report. They were all progress reports until 1909, when the report was recommended for adoption. In 1909 the Signal Association voted to submit the report to letter ballot. The result of that vote was 236 votes *for* the adoption of the report and 311 *against* the adoption of the report. That 311 does not include 25 votes of the Chicago, Milwaukee & St. Paul road against the adoption of the report, which were not received in time to be counted on account of the question arising as to the number of votes we were allowed. If those 25 were counted, it would make 236 *for* and 336 *against* the adoption of the Committee's report. The report is exactly the same as subject 2, now presented to the Maintenance of Way Association with recommendation for its adoption.

The work of this Association begins with the 1907 reports, and you have the report before you in your Proceedings for 1907, 1908 and 1909, each year showing a material change in the report; and now this year, you have presented to you a report, with recommendations of the chairman and a majority of the Committee that the report be adopted, which is clearly a change from last year and which you can see for yourselves by reference to the Proceedings of the Association.

There are eighteen members of the Committee who have voted for this report. I am referring to subject No. 2 of the report only, and the minority report bears only on subject No. 2, not to any other subject of the Committee's report. Eighteen members have voted for subject No. 2 and five members have not concurred. These eighteen members represent *seven roads or systems,* five members representing five roads or systems do not concur. There are four members representing *four different roads or systems* who have voted *for* the *minority* report.

The men who compose the minority hesitated somewhat before they made the report in as much detail as they finally submitted it, because of the fact it might take up too much of the Association's time to read and discuss it. It goes too much into technical detail. In a few words, the minority's criticism of the report as presented to you is that there is an attempt to provide too much information to the engineman. We feel that the practice of to-day does not require that so much detail information be furnished, and that it is a decided mistake to attempt to furnish it. We feel that unless we can say something to the engineman that is absolutely reliable, we would better not say anything.

The report, as it is presented to you, provides that the distant signal shall be a repeater of the home signal, regardless of how you connect it up. It often is in the "clear" position and the home signal is found against the runner. It is often in the "caution" position and the home signal is found "clear," due to various causes. The distant or caution signal should not say what the position of the next signal is, but it should say to the runner only "caution" or "proceed," either one or the other. Any attempt to make a distant signal a repeater of a home will encourage laxity on the part of the engineman, because he will be in a measure relieved of the responsibility of looking for the home signal. There have been to my knowledge three or four disastrous wrecks on railroads during the past two months, which are very illuminating in this connection; they are very interesting because they show just that weakness referred to.

The chairman has ridiculed the position of the minority, that the clear block signal should not mean to the engineman a clear block section. A clear block signal is one thing and a clear block section is another. The art of signaling has not reached a point up to the present date when we can say to an engineman with reliability that a clear block signal means a clear block section. We have not reached that point in railroad operation at the present time, and unless we can say to the runner that a clear block signal means a clear block section and can guarantee it, we do not want to say it. We want to say to him that a clear block signal means "proceed" and only "proceed." It does not mean that he is going to find the block clear; it means that he can go, provided he is not otherwise restricted. The chairman has ridiculed our stand in regard to this question, and asks what block signals are for. I will answer and say the conception of the minority in regard to the block signals is that they are introduced to space trains; they mean "stop" in one position and "proceed" in another, or if to be used in "caution" position, you have a third indication, which says "caution."

Without taking up too much of the time of the Association, I wish to say that the main differences between the minority and the majority revolve around the question of the meaning of a distant signal to an engineer, and the meaning of a clear signal to an engineer.

Before closing I wish to, if possible, remove an impression which you may have gained from the remarks of the chairman, with regard to the American Railway Association Code, and the report submitted by the majority. He probably left with you an impression that the majority report is in accordance with present practice and that it complies in every respect with the American Railway Association Code. I must dispute his statements. In the American Railway Association Code you will find but four indications, "stop," "caution," "proceed," and under the head "automatic block," you will find the fourth one, "approach next signal prepared to stop." How the majority can expand those four indications into fourteen as in the present report, is beyond my understanding.

In view of the arguments which we have presented in our reports; in view of the Committee's action in annually changing their reports; in view of the substantial minority on the Committee, which is against the report, and in view of the action of the Railway Signal Association in declining to accept the same report by an overwhelming vote, I believe that this report should be returned to the Committee for further consideration.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I move, in lieu of the pending motion, that subject 2 be referred back to the Committee for further consideration.

The President:—Amended, moved and seconded, that conclusion 2 be referred back to the Committee for further consideration. Any discussion on the amendment?

Mr. L. C. Fritch:—Mr. Chairman, I hope that motion will not carry.

The President:—Are you referring to the first motion, or to the amendment?

Mr. L. C. Fritch:—The amendment. The Committee has done very valuable and intelligent work on this report, and as this matter goes to the American Railway Association anyway for adoption or rejection, I can see no harm in having it passed upon at this meeting. If the minority of the Committee have something better to offer in lieu of this report, they should have given it to us so that we could choose between the two. Many of us are putting in new automatic block signals, and we want the most modern practice. We do not want to make an installation that is expensive now and in a year or two change it. I hope the Committee's report will be adopted.

Mr. Rudd:—Mr. Chairman, I should not care to withdraw my motion, that the conclusions be adopted. I believe I would have to withdraw that before the other motion could prevail.

Mr. McDonald:—Mr. Chairman, I rise to a point of order, and want to say that the motion should proceed on the amendment in lieu of the pending motion.

The President:—The understanding of the chair is that the gentleman is speaking in explanation. Mr. McDonald's amendment will come before your motion.

Mr. Rudd:—The conclusions endorse the report of the Committee as a good system, and refer them to the American Railway Association for its consideration. You can leave this a year or two or three years before sending it to that Association. Perhaps that Association will do something without your sending it anyway. It is a subject on which this Association ought to take some action, some day. But we cannot settle it. The American Railway Association is the Association that has to settle the indications and the aspects, but this Association, on account of its knowledge of signaling, what can be performed by signaling, and what cannot be performed by signaling, is in a position to make recommendations to the American Railway Association for a uniform system. It simply devolves on the point of whether or not you are ready to do that.

Mr. B. H. Mann (Missouri Pacific):—Mr. Chairman, I hope that the report will be referred back to the Committee for further action, for the reason that we have here a strong majority report and a strong minority report. The point is made as well that each year has seen a change in the form of the majority report, even though a slight one. There are two questions. One is the question of engineering, in which there seems to be but very little divergence. The second question is that of the transportation matter, the handling of the engineman on the train; the entire variance in opinion seems to be a question as to how the railroad shall handle the trainman after the train is in motion on the road. The Committee seems to have overlooked the fact that the indication is a sudden instruction to depart from the usual where the usual is the schedule, and is a parallel case to a "31" order. Ever since the train order has been in practice, one vital law has been that there shall be no written or printed or other instructions that will qualify the train order. The train order as delivered to the man on the engine and the conductor means exactly what it says. Some of the aspects of the majority report require that the engineman, when taking a signal on a high-speed train, must think back to his printed or written instructions to ascertain whether the yellow (caution) signal, for example, means proceed at normal speed—he may three miles in advance find a signal against him, but must maintain his schedule in the interim—or else it means an earlier or even immediate restriction.

In referring questions on operation to the American Railway Association, this Engineering Association ought to have a unanimous report. I think the President is right in his first suggestion that as we have these two reports, the Committee should be given one more opportunity, at least, to harmonize.

Mr. Thos. S. Stevens:—I would like to tell Mr. Fritch one thing. The chairman's report to the Association shows that I did one day's work more than any other member of the Committee on this subject. That did not take into account the large amount of work I did in my office. I held monthly meetings in Chicago for something like five months, which entailed an expenditure of nearly a week's time of part of my office force getting out reports and blueprints, so that the minority has been working on this matter, Mr. President, earnestly and sincerely, and this report is made after the earnest consideration they have given it, because they feel that this Association cannot afford to send the report to the American Railway Association in its present condition.

The President:—It has been moved and seconded that subject 2 be adopted. An amendment has been moved, duly seconded, that subject 2 be referred back to the Committee for further consideration, presumably on account of the divergence of opinion among the Committee itself.

Mr. Howard G. Kelley (Grand Trunk):—Before the motion is put, I wish to ask for some information. The difference of opinion in this Committee is basic. They agree on methods, mechanical and engineering. Their difference is, therefore, on the theoretical side, or the train-movement side. The members composing the minority, who have submitted a minority report, are men of long experience, representing many thousands of miles of railroad, and I believe that while we may agree with the majority, that we owe an obligation to the minority to allow them an ample opportunity for discussion in a manner that will enable them to settle the controversy. Well, how can they settle it? I believe by referring the matter back to this Committee, that it will not approach a settlement, that it will not help the situation. The only way that occurs to my mind is, can a settlement be reached by requesting the Committee on Signaling of the American Railway Association to discuss these basic principles with our Committee and ask them for information. It seems to me that is the only way we can arrive at a unanimous opinion. The gentlemen on this Committee are represented on the American Railway Association by their companies. I feel that the gentlemen composing the minority have their railroad operating officials behind them in their report, the same as the majority have their operating officials behind them. It is one of our hardest-working Committees, I believe one of our most conscientious Committees, and they have reached a point where they cannot as expert signalmen come together. We as an Association must not recommend to the American Railway Association anything that does not bear the unanimous stamp of the Committee that reported it to this Association. We must send it before the American Railway Association without a dissenting vote. I ask the members of this Committee if by referring the matter to a committee of the American Railway Association, and having a joint discussion between the two committees, whether they can come before us next year with an agreement and settlement of some of these divergences of opinion. Some men will have to give way, some men will gain their point, but if that can be done I believe that is the way we should proceed. I should certainly hestitate to support Mr. McDonald's motion to refer the matter back to the Committee for another year. If we do that, when the matter comes before us next year we will most certainly have another dissenting report.

The President:—The point raised by Mr. Kelley is well taken and reasonable, and I ask the chairman of the Committee to give his views whether such a thing is feasible or not.

Mr. Rudd:—Mr. President, three years ago, I think it was, the

Railway Signal Association adopted a report very much on these lines as a progress report, and referred it to the Joint Committee of the American Railway Association for its opinion, and that Joint Committee is now dead. I do not know whether that report killed it or not, but it went out of office, and I presume that the report went out with the Joint Committee. Now, whether we will get any better action by having this Committee try to take the matter up with the Transportation Committee of the American Railway Association, I do not know. It would seem to me that probably the way out might be for this Association to refer these reports, both majority and minority, to the committee of the American Railway Association, and ask them to give a ruling on the points at issue first. It seems to me such reference is one of three ways to settle it. There are two other ways; one is to remove the minority members from the Committee, and the other is to remove the majority members from the Committee; but I do not think, with the views which we hold on the basic principles, that we will ever get together on a recommendation otherwise. I would like to ask Mr. Stevens and Mr. Clausen, whether they believe there is any chance of our getting together on the question of the distant signal. Personally, I do not think we can.

Mr. Clausen:—I think if this Committee had an opportunity to discuss the entire question of signaling with a proper committee from the American Railway Association that the minority and majority could get together. It would all depend on the manner in which the matter was discussed and how much weight the Committee gave to the opinions of the gentlemen of the American Railway Association, but I think there is no question but what we could get together on the matter and bring in a report which we could all sign.

Mr. L. C. Fritch:—I want to make an amendment to the amendment, that this report be referred back to the Committee with instructions that the Committee confer with the proper Committee of the American Railway Association, with a view to bringing in an harmonious report at the next meeting.

Mr. Rudd:—Would you embody the suggestion that the American Railway Association Committee shall confer with us?

Mr. Fritch:—I have no objection to that.

Mr. McDonald:—I accept the amendment to the amendment.

The President:—The amendment as it now stands is that this subject No. 2 be referred back to the Committee with instructions to that Committee to confer with a similar committee of the American Railway Association, with a view of harmonizing, if possible, the differences between the majority and the minority reports of this Committee.

Mr. Mann:—I hope that that amendment will not go to the American Railway Association in that way. It would seem as though the dignity of this Association calls for rather an arbitration on questions that perhaps are not pertinent to the work of our Association, and this body in a dignified manner could ask for that arbitration, and the Committee on Transportation of the American Railway Association could refer back to this Association the settlement of the engineering questions when the latter require the previous decision as to transportation requirements.

Mr. Rudd:—I have asked the members of the Committee concerning this, and they feel that that method of disposing of the matter will not cast any reflections on the Committee.

I move that subject 3 on page 65, and subjects 4 and 5 on page 65, and subjects 6 and 7 on pages 66, 67 and 68, all be adopted as progress reports.

(The President put the motion to vote, and it was adopted.)

The President:—The Committee is relieved with the thanks of the Association.

REPORT OF COMMITTEE XVIII—ON ELECTRICITY.

(Bulletin 117.)

To the Members of the American Railway Engineering and Maintenance of Way Association:

Your Committee on Electricity is of the opinion that on account of the short length of time that its work has been in progress it will not be feasible to submit any definite recommendations to the Association this year.

As a progress report, however, your Committee would advise that two meetings of the Committee have been held in New York, the first on July 6 and the second on October 7. At the first meeting the following Sub-Committees were appointed:

A—Clearances: L. C. Fritch, Chairman; W. W. Drinker, G. A. Harwood.

B—Transmission Lines and Crossings: R. D. Coombs, Chairman; A. S. Baldwin, G. A. Harwood.

C—Insulation: H. R. Talcott, Chairman; R. D. Coombs, L. C. Fritch.

D—Maintenance Organization: J. B. Austin, Jr., Chairman; E. P. Dawley, C. E. Lindsay.

E—Electrolysis: A. S. Baldwin, Chairman; W. W. Drinker, H. R. Talcott.

F—Relation to Track Structures: C. E. Lindsay, Chairman; J. B. Austin, Jr., E. P. Dawley.

These Sub-Committees were directed to prepare a history and bibliography of the subject being considered, but, with the exception of these instructions, each Sub-Committee will be permitted to conduct its investigations in the manner that the subject and conditions seem to make most desirable. At this meeting it was decided that the Committee would meet bi-monthly.

At the second meeting of the Committee, progress reports from the Sub-Committees were made, as follows:

Sub-Committee A—Clearances:

A meeting of the Sub-Committee was held at Detroit, Mich., on July 26, at which reports of the Committee on Standard Location of Third Rail Working Conductors of the American Railway Association were discussed, and while no conclusion as to the amount of clearance which it would be advisable to recommend was agreed upon, it was the sense of the Sub-Committee that the clearances between the limiting lines of equipment and the limiting lines of third rail structures, which are shown as $1\frac{1}{2}$-in. in the report referred to, are insufficient and that a greater clearance should be established. In order to determine the limiting clearance that could be established it was decided to secure data showing limiting lines of clearances of third rail conductor structures, the limiting lines of rolling equipment and the limiting lines of third rail structures with respect to maintenance of way structures from various railways. The Sub-Committee is also collecting data from various railways electrified or partly electrified and also interurban lines with heavy traffic which may possibly interchange with steam lines electrified or not electrified. This Sub-Committee is communicating direct with the representatives of the various railways, and a circular has also been issued by the Secretary of the Association requesting data pertinent to the subjects outlined.

Sub-Committee B—Transmission Lines and Crossings:

No meetings of this Sub-Committee have been held, but the members have corresponded with one another. Communications have been sent to the Committee on Power Distribution of the American Street and Interurban Railway Engineering Association, Sub-Committee on Overhead Construction of the National Electric Lighting Association, and Committee No. 1 of the American Railway Bridge and Building Association, suggesting the advisability of the various associations cooperating and requesting copies of their previous reports; copies of crossing specifications have also been requested from various companies. It is the intention to make report of comparison of the various specifications referred to. The Secretary of the Association has issued a circular requesting data pertinent to the subject.

Sub-Committee D—Maintenance Organization, and Sub-Committee F—Relation to Track Structures:

A meeting of the above-mentioned Sub-Committees was held on July 20, at which was discussed the best methods of procedure relative to obtaining data in connection with the subjects referred to, and as a result a circular letter of inquiry has been sent out to representatives of various railways that have substituted electricity for steam, wholly or in part, as a means of motive power.

Sub-Committee C—Insulation, and Sub-Committee E—Electrolysis have made progress and their first report is expected soon.

The Committee will continue along the lines indicated with the idea of submitting recommendations to the Association next year.

Respectfully submitted,

George W. Kittredge (Past-President), Chief Engineer, New York Central & Hudson River Railroad, New York, *Chairman.*

J. B. Austin, Jr., Engineer Maintenance of Way, Long Island Railroad, Jamaica, N. Y., *Vice-Chairman.*

A. S. Baldwin, Chief Engineer, Illinois Central Railroad, Chicago.

R. D. Coombs, Structural Engineer, Pennsylvania Tunnel & Terminal Railroad, New York.

E. P. Dawley, Consulting Engineer, Providence, R. I.

W. W. Drinker, Assistant Engineer, Erie Railroad, New York.

L. C. Fritch (First Vice-President), Chief Engineer, Chicago Great Western Railroad, Chicago.

G. A. Harwood, Chief Engineer, Electric Zone Improvements, New York Central & Hudson River Railroad, New York.

C. E. Lindsay, Division Engineer, New York Central & Hudson River Railroad, Albany, N. Y.

H. R. Talcott, Engineer of Surveys, Baltimore & Ohio Railroad, Baltimore, Md.

Committee.

DISCUSSION.

The President:—In the absence of the chairman of the Committee on "Electricity," Mr. George W. Kittredge, Mr. J. B. Austin, Jr., vice-chairman of the Committee, will present the report.

Mr. J. B. Austin, Jr. (Long Island):—In explanation of the report in the form in which it is presented, I will say this is a new Committee on a new subject, and in gathering information we find it takes rather more time, possibly, than in the case of a subject that has been under discussion for some years. We have had four meetings of the general committee and about ten or eleven meetings of the various sub-committees, but we feel that our foundation work has not progressed far enough yet to enable us to draw any definite conclusions, or present any recommendations to the Association for adoption. I move the adoption of the report of the Committee.

(The President put the motion, which was carried.)

REPORT OF SPECIAL COMMITTEE CO-OPERATING WITH THE NATIONAL CONSERVATION COMMISSION.

(Bulletin 118.)

To the Members of the American Railway Engineering and Maintenance of Way Association:

The following report of the Special Committee Co-operating with the National Conservation Commission is submitted as a report of progress.

No meetings of the Committee have been held since the two held at the time of the meeting of the American Railway Engineering and Maintenance of Way Association in March, 1909.

The Committee has been in correspondence with Mr. Gifford Pinchot, Chairman of the Joint Committee on Conservation, and with his former and present Assistants, Mr. Shipp and Mr. Gipe, and we have been kept posted by the members of the Joint Committee on Conservation of the work that is being done and the meetings that were held.

The Committee was invited to meet with members of the National Conservation Commission in Seattle during the year, but on account of the great distance there was no attendance.

On May 13, 1909, the Secretary of the Joint Committee on Conservation submitted a report containing suggestions as to the method by which railroad companies could assist in the conservation of natural resources. These suggestions, with some slight modifications, are submitted herewith by this Committee without comment.

The Committee will continue to keep in touch with the Joint Committee on Conservation, and will hold itself in readiness to co-operate with that Committee when called upon to do so, and will keep the Association posted as to any steps that are taken by the Joint Committee on Conservation relating to railroads.

Respectfully submitted,

A. S. Baldwin, Chief Engineer, Illinois Central Railroad, Chicago, *Chairman.*

Moses Burpee, Chief Engineer, Bangor & Aroostook Railroad, Houlton, Me.

W. A. Bostwick, Metallurgical Engineer, Carnegie Steel Company, Pittsburg, Pa.

E. B. Cushing, Engineer of Construction, Sunset Central Lines, Houston, Texas.

E. O. Faulkner, Manager, Tie and Timber Department, Atchison, Topeka & Santa Fe Railway, Topeka, Kan.

A. L. Kuehn, General Superintendent, American Creosoting Works, Chicago.

D. W. Lum, Chief Engineer Maintenance of Way and Structures, Southern Railway, Washington, D. C.

C. L. Ransom, Resident Engineer, Chicago & Northwestern Railway, Omaha, Neb.

Committee.

SUGGESTIONS FOR RAILROAD WORK IN FOREST CONSERVATION.

CONTROL OF FOREST FIRES.

No accurate data have ever been compiled upon the total forest fire losses in the United States. More than 1,200,000 acres of forest were burned over last year in Wisconsin, and standing timber valued at nearly three million dollars was destroyed. In West Virginia, 1,700,000 acres were burned over, with about the same loss as in Wisconsin, while in Michigan, it is estimated, that seven million acres were burned over, and that ten million dollars' worth of timber was destroyed. These estimates do not include damage to young growth nor to the forest soil, which is often more serious than the damage to mature timber.

The railroads may well consider the advisability of co-operating with local and State authorities in preventing or suppressing forest fires in the regions which they traverse. Fires affect the public welfare most disastrously, as has been proved time and again.

The railroads of the country may materially assist in the work of forest preservation on the following general lines:

(a) Keeping the right-of-way cleared of all inflammable material;

(b) The exercise of great care to prevent the escape of fire while this clearing is being done;

(c) Having it thoroughly understood by all section foremen that they and their crews must immediately go to and put out fires set by the railroad about which information reaches them. Most roads have standing orders of this sort, but they are sometimes disregarded by the section foremen;

(d) By holding each train crew responsible for reporting to the section foreman, both by whistle signals and by personal report, any fires passed.

It is recommended that this Association do all in its power:

(1) To obtain systematic co-operation of railroads with Federal and State authorities in the abatement of forest fires, whether originating from railroad locomotives or from other causes.

(2) To devise efficient spark arresters.

(3) To enforce proper stoking.

(4) To place on the operatives, especially section foremen, responsibility for keeping rights-of-way clear and combating fires which do start.

THE GROWING OF TIMBER FOR RAILROAD PURPOSES.

One of the best methods by which the railroads can insure themselves against a shortage of ties and timber in the future is for them to own and manage their own forests. A number of railroads have already adopted this policy. Some have withdrawn from the market the remainder of their forested land-grant areas; others have purchased forest land outright. The management of existing forests is more economical, and in the long run will probably be more satisfactory, than the establishment of plantations. To be successful, however, such lands should be in charge of trained foresters, who should manage the lands more with a view to producing ties and timber needed by the railroads in the future, when it will be impossible to purchase from outside sources, than to meeting all the immediate demands of the roads from the present stand at a sacrifice of future productiveness.

Some railroads operate in regions where lands already forested cannot be purchased. Almost every railroad, however, can utilize waste lands, such as often become the property of the railroad through the purchase of rights-of-way, for forest plantations. These plantations, again, should be installed and managed by trained men, since each locality has differences of soil, climate, and fire danger, which render general instructions and rules of doubtful value. The following general rules for plantations may be of assistance, however:

Rapid-growing species should be planted as a rule, and the ties and timbers therefrom given preservative treatment. The harder and more durable woods are, as a rule, very slow growing, and plantations of these species would be less profitable. Loblolly pine in the South Atlantic and Gulf States; red oak, Scotch pine, and European larch for the Central and Northeastern States; red or Norway pine for the Northern Lake States; Douglas fir for the Northern Pacific Coast; eucalyptus for Southern California and other regions where there is no frost, are recommended. Black locust, which reaches fence-post and tie size quickly, is also desirable wherever the locust borer is not dangerous. The planting of chestnut is not recommended anywhere until means of combating the chestnut bark diseases have been found. The species to be planted must always be suitable for the immediate locality. This should be determined through examination on the ground by a trained expert.

RECOMMENDATIONS.

(1) That railroads own and manage timber lands for the production of ties and other wood needed by them.

(2) That these forests be managed, and extended by artificial means where necessary, by trained foresters.

USE OF SAWED INSTEAD OF HEWED TIES.

About 70 per cent. of the tree is wasted in making hewed ties. The waste is due to excess of material contained in most ties as hewed, loss of wood due to hewing large logs, the failure of tie cutters to use the butts of trees, on account of extra work involved, and to their failure to cut as far into the tops as could be done, through fear of manufacturing cull ties.

The saving in lumber by sawing instead of hewing ties varies from 20 to 190 per cent. of the volume of wood actually going into the hewed ties, depending mainly upon the size of the log. From a 16-ft. log of loblolly pine with a diameter at the small end inside the bark of 15 in., two hewed ties can be obtained which need not contain more than 64 board feet under the usual specifications. By sawing the same log, four ties can be obtained and also 57 board feet of lumber, or a total of 185 board feet. The gain in the form of ties and boards in this instance is nearly 190 per cent. This case is extreme, but it is safe to put the average gain from sawing at 80 per cent.

In 1907, 118,384,000 hewed ties were made—77 per cent. of the total number used. Assuming that they contained on the average three cubic feet, and that the waste due to hewing was 80 per cent., the loss was 284,100,000 cubic feet, which is equivalent to the annual growth of merchantable wood on 9,470,000 acres of well-stocked timber land. In hewing ties, trees 12 to 15 in. in diameter are preferred. This is the size when the most rapid growth is being made, and when the trees should be left in the forest to accumulate wood. When ties are sawed, the larger the tree, the better the quality of the tie and the less the cost of manufacture.

The chief objections to the sawed tie are that it is weaker and less durable than the hewed tie. On these points it may be said that few ties break that do not first partially decay, and preservative treatment will largely prevent decay.

Over 40 per cent. of the ties used in 1907 were of oak. In the past this has been largely white oak. The large proportion of white oak is not being maintained, because of the reduced supply of that wood and its increasing price. The use of other more abundant woods, such as inferior kinds of oak, pine, fir, hemlock, gum, and tamarack, is increasing, and must continue to do so. The durability of such woods will be insured by preservative treatment.*

RECOMMENDATIONS.

(1) The general introduction of sawed instead of hewed ties.
(2) The general use of other woods than white oak.

USE OF TREATED TIMBER.

The total number of cross-ties purchased by the steam railroads in 1907 was about 144,000,000, of which approximately 24,000,000 were used in the construction of new lines. The annual replacement, therefore, due to destruction, amounted to about 120,000,000 ties. The average cost of these ties was 51 cents. Hence, the total expenditure for renewal of ties alone amounted to $61,200,000. This does not include the cost of removing the old ties from the track and inserting new ones. Assuming this to amount to 15 cents per tie, the grand total in expenditure for renewals then equals $79,200,000.

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*A memorandum showing in detail the saving resulting from the use of sawed ties from trees of given diameters is appended.

Decay is responsible for the destruction of about 87 per cent. and abrasion 13 per cent. of ties in the track. There is greater need to protect the ties from decay than from mechanical wear, although a system that will do both is the best. Such a system is especially necessary when a road uses ties of soft woods. Since the cheaper grades of wood are being used more largely each year on account of the growing scarcity of the more durable and valuable varieties, preservative treatment is becoming more and more essential in order to keep maintenance charges as low as possible.

About 19,000,000 treated ties were used by the steam railroads in 1907. The number is rapidly increasing.

The average life of untreated ties used in steam roads is about seven years. If properly treated, this can be increased to at least seventeen years. In the report of the International Railway Congress, in 1895, it was stated that the life of creosoted ties in France is twenty years for pine, twenty-five years for oak, and thirty years for beech, while their lives untreated are, respectively, seven to eight, thirteen and one-half, and two and one-half to eight years.

The financial saving that would result to steam railroad companies if only treated ties were used, is estimated in the following table:

Initial Cost.		Total.	Cost of Treatment.	Years' Life.		Annual Charge. Interest 4%.		Annual Saving.	Total Saving if all Ties were Treated.
Tie.	Placement.			Untr.	Tr.	Untr.	Tr.		
51c	15c	66c	40c	7	17	$0.110	$0.087	$0.023	$19,320,000

If all ties used for renewal were treated, the annual consumption would fall to about 50,000,000, or a saving of about 58 per cent. in consumption on the basis of present mileage. This reduction represents the growth on about 7,000,000 acres of well-stocked forest land. In other words, the forest areas of the United States could be reduced by 7,000,000 acres, and the same conditions of supply and demand as now exist would prevail.

The treatment of construction timbers and piling, which are used so largely by railroads, is as practicable as the treatment of ties.

RECOMMENDATION.

That the railroads adopt the policy of treating with preservatives all ties, piles, construction, and other timbers which are subject to destruction by decay or marine borers.

NECESSITY OF EXTENDING THE SUPPLY OF CREOSOTE.

The greatest obstacle confronting the rapid advancement of preservative treatment is the lack of an adequate supply of a suitable preservative material to be obtained at a reasonable cost. The preservatives chiefly used in the United States are creosote, or the dead oil of coal tar, and zinc chloride. Considerable difficulty has been experienced in securing a sufficient quantity of good grades of creosote. The consumption of domestic creosote in 1908 was over 17 million gallons, and that of foreign creosote nearly 39 million gallons.

The production and composition of domestic creosote are regulated to a large extent by the demand for pitch, which is the primary product for which coal tar is distilled. Creosote is a by-product of insufficient value in itself to pay the cost of manufacture. The pitch takes out a large proportion of the heavier constituents of the tar and leaves a proportionately increased amount of light oils.

In Europe, the conditions are quite the reverse. There is little demand for pitch, but a large demand for the lighter constituents of the tar, which are used in the manufacture of the aniline dyes. Hence, the lighter constituents are removed and the heavier left in the creosote. In the United States, these heavier constituents are considered the most valuable components of the preservative, and consequently at the same price the foreign oils are preferred.

Coal tar is obtained chiefly from the distillation of coal in by-product ovens. Among the advantages of the by-product over the more common beehive oven are the possibility of using coals of greater range of volatility, larger capacity of oven, shorter time of operation, larger product of coke, and, what is especially important here, the using of the by-products.

The by-product oven has, however, several distinct disadvantages which have prevented its rapid adoption. It costs over four times as much as the beehive oven, and requires skilled labor to operate. Moreover, in the past the market for the by-products has been uncertain.

Coal tar is also obtained as a by-product in the manufacture of illuminating gas. According to the report of the United States Geological Survey, in 1902, there were 1,663 by-product retort ovens, in 1907 there were 3,892. Much gas is now made from petroleum instead of coal. In 1907 the production of oil and water gas was practically twice that of coal gas.

It is well known that it is common practice in this country to mix the tars derived from oil and coal. Inasmuch as the efficiency of oil tar creosote has never been thoroughly tested as a wood preservative, this practice has caused a strong prejudice against the domestic article. It cannot be stated with certainty at this time whether this prejudice is wholly warranted, but indications are that it is.

RECOMMENDATIONS.

(1) That efforts be made to secure such improvements and economies in the construction and operation of by-product coke ovens as will lead to their general substitution for the beehive type.

(2) That tests be made to determine the relative efficiency of oil tar creosote and coal tar creosote as preservatives of wood.

(3) That tests be made to determine the minimum quantity of oil of a specified grade necessary to preserve wood under given conditions.

(4) That tests be made to find satisfactory substitutes for creosote in the treatment of timber.

FOREST PRODUCTS LABORATORY.

The Forest Service, in co-operation with the University of Wisconsin, is establishing at Madison, Wis., a Laboratory which will be thoroughly equipped to work on problems connected with the utilization of wood. Its work and results will be of much interest to all wood-using industries, especially those whose use of wood is attended with a large amount of waste. The Laboratory should be of assistance to the several committees of the American Railway Engineering and Maintenance of Way Association, which have to do with the use of wood. It is the desire of the Government that the Association make as full use of the personnel and facilities of the Laboratory as is found practicable. Several of the problems suggested above can probably be worked out advantageously by committees of the Association in co-operation with the Laboratory.

SAWING VS. HEWING TIES.

The economy of sawing ties as compared with hewing them lies in the fact that in any sized log a tie may be sawed out where one is hewed out and, except in the very smallest, the saw will show additional product in the shape of boards. As the size of the log increases, the wood hewed away in the form of chips increases, while in sawing this hewing loss largely goes into boards. For example, in Texas, actual practice shows the following results:

16-FOOT LOBLOLLY PINE LOGS.

Diameter Inside Bark at Small End.	Actual Product in Hewed Ties (6″x8″x8′).		CALCULATED PRODUCT IN SAWED TIES AND BOARDS.			Gain in Sawed Product over Hewed.	16-Foot Long Leaf Pine Logs. Actual Hand Saw Cut in 1 inch Boards.
	Ties.	B. M. at 32 ft. Each.	Ties.	Boards.	Total.		
Inches.	No.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Per cent.	Bd. ft.
10	2	64	64	15	79	23	61
11	2	64	64	27	91	42	89
12	2	64	64	52	116	81	102
13	2	64	64	71	134	109	128
14	2	64	64	97	161	152	158
15	2	64	128	57	186	191	192

It is seen that the calculated saw product in ties and lumber exceeds the hewed-tie product by from 23 per cent. in 10-in. logs to 191 per cent. in 15-in. logs. An actual saw test in inch lumber given in the last column for longleaf pine logs upholds the calculated sawed product given in the sixth column in all directions, except the 10-in., where it falls even a little lower than the hewed-tie product. Of course, the saw kerf waste when the entire log is sawed into inch boards is greater than when sawing ties and boards, and in the form of ties and boards the saw test would have shown even a larger product.

Again, sawing ties will enable the economical utilization of larger timber for the production of ties. The heart portion of the tree, with the small knots and poor lumber qualities (this is especially true of some of the hardwoods), would go into ties, while the clear portion outside would go into lumber. Thus a considerable part of the tie supply would come from larger trees, and the young pole trees, which are usually at their most rapid growth, will be saved.

On the other hand, several factors encourage the timber owner to sell his stumpage for the production of hewed ties. The principal one is the unfairness of the existing log rules toward small trees, so that the product in hewed ties often gives a higher return than do the log rules which do not nearly show the actual cut. Thus, loblolly pine trees in Texas show the following comparison of stumpage returns from hewed trees with that from logs sold by the Doyle-Scribner and Herring rules:

CONTENTS OF TREE.

Diameter of Tree at 4.5 Feet.	From Hewed Ties.		Scale of Logs by Doyle-Scribner Rule.	Scale of Logs by Herring Rule.
	Ties 6"x8"x8'.	Scale at 32 ft. Each.		
Inches.	Number.	Bd. ft.	Bd. ft.	Bd. ft.
11	2.5	80	35	62
12	3.3	106	53	82
13	4.1	131	70	106
14	5.0	160	90	130
15	5.5	176	108	158
16	6.0	192	125	188
17	6.0	192	145	220

This shows that the loblolly pine stumpage owner would receive more from selling hewed ties (if scaled at 32 board feet each) than from selling the logs to a mill by the Doyle-Scribner rule for trees up to 17 in. at least, if the same price per M. ft. were paid in both cases. With the Herring rule, the ties would be more profitable in trees up to a 16-in. diameter.

The Forest Service found that the sale of lodgepole pine brought greater returns for trees under 15 in. when sold for hewed ties (scaling each ties 5 in. x 8 in. x 8 ft. at 33⅓ board feet) than when sold in the log by the Scribner decimal scale.

This does not show that hewing gives a greater product than sawing, but that the method of scaling saw logs in wide use robs the owner of small timber to such an extent that he gets larger returns by selling hewed ties, even though waste is greater.

Again, for 9, 10, and 11-in. trees, hewing ties is about as economical as sawing, and when it is desirable to cut such trees, as in thinning dense stands, or for species like lodgepole and Jack pines whose rate of growth falls off beyond that point, tie hewing can well be employed.

In small timber tracts or woodlots, where it will not pay to erect a mill, tie hewing may be desirable.

To summarize, then, tie hewing cannot be condemned without exception.

(1) Hewing is economical for very small trees when these are desirable to cut from the point of growth.

(2) Hewing ties from trees under 15 to 18 in. and getting full scale is more desirable for the stumpage owner than being robbed by the scale of most existing log rules, if the price per thousand feet is the same.

(3) Hewing ties is desirable in small woodlots where a mill would be impracticable.

(4) Sawing ties is more economical by 20 to 200 per cent., and preferable for trees over 11 in. when the mill man owns the stumpage, or for the independent stumpage owner when he is paid for the full saw output of his logs.

REPORT OF COMMITTEE XV—ON IRON AND STEEL STRUCTURES.

(Bulletin 117.)

To the Members of the American Railway Engineering and Maintenance of Way Association:

Your Committee on Iron and Steel Structures held a meeting at Chicago during the last convention and a meeting at Buffalo, N. Y., on October 15 and 16, the following members being present: J. E. Greiner, Chairman; C. F. Loweth, Vice-Chairman; C. L. Crandall, A. J. Himes, Chas. M. Mills, A. F. Robinson, C. C. Schneider, F. E. Turneaure, J. R. Worcester.

The following report is respectfully submitted:

REVISION OF MANUAL.

Your Committee recommends that the following revisions be made in the Manual of Recommended Practice (1907) and that the General Specifications for Steel Railroad Bridges (1906), printed in pamphlet form, be revised so as to correspond therewith.

In order to present clearly those modifications which affect to a greater or less extent the substance of the requirements and separate them from those which are of minor character and do not affect the substance, we have arranged the proposed modifications into two groups, as follows:

Group I.

Minor changes in punctuation, words and construction of sentences, which do not affect the substance.

Group II.

Important changes, additions to or revisions which affect the substance.

These additions or modifications are shown in boldface type, while those parts which have not been changed are shown in lightface type.

GROUP I—MINOR CHANGES.

Page 255. Revise so as to read as follows:

Contracting for Steel Railroad Bridges.

It is recommended that railroad companies

(1) **Furnish** general details, etc.

(2) **Invite** bids on the pound price basis, etc.

(3) **Invite** bids for as large groups of bridges, etc.

(4) **Erect bridges with their own forces on lines where traffic is to be maintained,** but on small roads, etc.

(5) **Furnish and lay the floor timber in all cases.**

Page 257. Change heading from I—GENERAL FEATURES to I—GENERAL.

Change the word "strain" to **stress** throughout the specifications.

1. Marginal heading **Materials.**

5. Marginal heading **Floors.**

7. Marginal heading **Live Load,** and insert **Train Load** immediately above the "4,000 lbs. per ft." which follows the engine.

10. Marginal heading **Lateral Forces.**

11. Marginal heading **Wind Force.** Change "load" in the fifth line to **force.**

12. Reconstruct so as to read "Viaduct towers and similar structures shall be designed for a longitudinal force of twenty per cent. of the live load applied at **the top of** the rail."

14. Revise so as to read "All parts of structures shall be so proportioned that the sum of the maximum **stresses produced by the foregoing loads** shall not exceed the following amounts in pounds per sq. in., except as modified in paragraphs 20 to 23."

22. Marginal heading **Combined Stresses.**

23. Omit marginal heading. Change "load" in the second line to **loads** and "forces" to **force.** Omit the expression in the last two lines "if the longitudinal and lateral or wind forces be neglected" and substitute **for live and dead loads and centrifugal force.**

27. Marginal heading **Plate Girders.**

32. Marginal heading **Pockets.**

46, 47 and 48. Omit marginal headings.

53. Omit marginal heading.

58. Add **"These expansion bearings shall be designed to permit motion in one direction only."**

59. Omit first sentence.

67. In third line change "girder" to **girders** and "shoe" to **shoes.** Make marginal heading **Stringer Frames.**

72. Marginal heading **Laterals.**

73. Omit marginal heading.

83. Marginal heading **Steel.**

86. Change "allowed" to **permitted** in the last line.

87. Marginal heading **Specimens.** Reconstruct so as to read **"Plate, shape and bar** specimens for tensile and bending tests shall be made by cutting coupons, etc."

88. Omit first word "Rivets."

89. Omit marginal heading. Reconstruct so as to read **"Pin and roller** specimens shall be cut, etc."

90. Reconstruct so as to read **"For steel castings the number** of tests will depend, etc."

99. Marginal heading **Melt Numbers.**

101. Marginal heading **Variation in Weight.** Change colon at the end of this paragraph to comma and add **when ordered to weight**

102 and 103. Omit marginal heading.

104. Omit marginal heading, and make addition so that paragraph will read "Plates **when ordered to gage** will be accepted, etc."

VI.—Subject heading "VI—SPECIAL METALS" should be omitted.

107. Marginal heading **Wrought-Iron.**

VII.—Change the number of this section to **VI.**

108. Marginal heading **Mill Orders.**

VIII.—Change this section to **VII.**

112. Marginal heading **Straightening.**

113. Make additions so as to read "Shearing **and chipping** shall be neatly and accurately done, etc."

116. Omit the first word "All."

127. Marginal heading **Riveting.**

128. Omit marginal heading.

130. Marginal heading **Members to be Straight.**

136. Omit marginal heading.

IX.—Change this section to **VIII.**

150. In the last line change "a good" coat to **an additional** coat.

X.—Change this section to **IX.**

154. Marginal heading **Starting Work.**

156. Marginal heading **Accepting Material.**

XI.—Change this section to **X.**

159. Marginal heading **Eye-Bar Tests.**

GROUP II—IMPORTANT CHANGES.

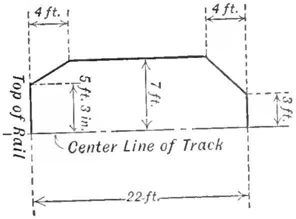
Clearanc

2. On a straight line, the clear height of through bridges shall not be less than 21 ft. above top of rails for a width of 6 ft. over a single track, and the clear width shall be not less than 7 ft. from the center line of the track between the heights of 4 and 17 ft. above the rails. The width shall be increased to provide the same minimum clearance on curves, for a car 80 ft. long, 14 ft. high, and 60 ft. center to center of trucks, allowance being made for curvature and superelevation of rails.

Substitute:

Clearanc

2. When alinement is on tangent, clearances shall not be less than shown on the diagram. The width shall be increased so as to provide the same minimum clearances on curves for a car 80 ft. long, 14 ft. high, and 60 ft. center to center of trucks, allowance being made for curvature and superelevation of rails.



6. Make addition so that the paragraph will read, "The dead load shall consist of the estimated weight of the entire suspended

structure. Timber shall be assumed to weigh 4½ lbs. per ft. B. M., ballast 100 lbs. per cu. ft., **reinforced concrete 150 lbs. per cu. ft.,** and rails and fastenings 150 lbs. per linear ft. of track."

Centrifugal Force.

*13. Structures located on curves shall be designed for the centrifugal force of the live load acting at a height of 6 ft. above the rail, proper account being taken of the superelevation; the speed and superelevation to be determined by the engineer for each case.

13. Omit marginal reference and substitute "Structures located on curves shall be designed for the centrifugal force of the live load **applied at the top of the high rail. The centrifugal force shall be considered as live load and be derived from the speed in miles per hour given by the expression 60 — 2½ D, where "D" = degree of curve.**

Compression.

16. Axial compression on gross section............ $16{,}000 - 70\frac{l}{r}$

where "l" is the length of the member in inches and "r" is the least radius of gyration in inches.

Substitute:

Compression.

16. Axial compression on gross section **of columns**. $16{,}000 - 70\frac{l}{r}$

with a maximum of.................................. **14,000**

where "l" is the length of the member in inches, and "r" is the least radius of gyration in inches.

Direct compression on steel castings.................. 16,000

17. Add **and steel castings** after "girders."

Paragraph will then read:

Bending.

17. Bending: on extreme fibers of rolled shapes, built sections, girders **and steel castings**; net section................ 16,000

on extreme fibers of pins.................................. 24,000

Bearing.

19. Bearing: shop driven rivets and pins	24,000
field driven rivets and turned bolts	20,000
granite masonry and Portland cement concrete	600
sandstone and limestone	400
expansion rollers; per linear inch	600d

where "d" is the diameter of the roller in inches.

Substitute the following:

Bearing.

19. Bearing: shop driven rivets and pins	24,000
field driven rivets and turned bolts	20,000
expansion rollers per linear inch	600d

where "d" is the diameter of the roller in inches.

On masonry	**600**

Insert the following new paragraphs after paragraph 19:

Limiting Length of Members.

19-a. **The lengths of main compression members shall not exceed 100 times their least radius of gyration, and those for wind and sway bracing 120 times their least radius of gyration.**

19-b. **The lengths of riveted tension members in horizontal or inclined positions shall not exceed 200 times their radius of gyration about the horizontal axis. The horizontal projection of the unsupported portion of the member is to be considered as the effective length.**

21. Omit marginal heading. Change "70 per cent." in the second line to **two-thirds.** Revised paragraph will then read:

21. Wherever the live and dead load stresses are of opposite character, only **two-thirds** of the dead load stresses shall be considered as effective in counteracting the live load stress.

27. Add to this paragraph: **"The thickness of web plates shall be not less than 1-160 of the unsupported distance between flange angles** (see 36).

Compression Flange.

28. Make additions shown so that the paragraph will read: "The gross section of the compression flanges of plate girders shall be not less than the gross section of the tension flanges; nor shall the stress per sq. in. in the compression flange of any beam or girder exceed 16,000 — 200 $\frac{l}{b}$, when flange consists of angles only **or if cover consists of flat plates, or 16,000 — 150 $\frac{l}{b}$, if cover consists** and second, as a marker to show the location of the signal if the other **of a channel section,** where l = unsupported distance and b = width of flange."

Lattice.

*45. Add the following prefix and the paragraph will then read: **"The latticing of compression members shall be proportioned to resist the shearing stresses corresponding to the allowance for flexure provided in the column formula in paragraph 16 by the term 70 $\frac{l}{r}$.** The minimum width of lattice bars shall be," etc.

Rivets in Flanges.

46. Five-eighths-inch rivets shall be used for latticing flanges less than 2½ in. wide, and ¾-in. for flanges from 2½ to 3½ in. wide; ⅞-in. rivets shall be used in flanges 3½ in. and over, and lattice bars with two rivets shall be used for flanges over 5 in. wide.

Omit marginal heading. Revise so as to read:

46. **Three-fourths**-inch rivets shall be used for latticing flanges **from 2½ to 3½ in. wide;** ⅞-in. rivets shall be used in flanges 3½ in. and over, and lattice bars with **at least** two rivets shall be used for flanges over 5 in. wide.

51. Change last sentence so as to read: "At least one of these plates shall extend to the far edge of the farthest tie-plate, and the balance **to the far edge of the nearest tie-plate, but** not less than 6 in. beyond the near edge of the **farthest** plate."

60. Add **"Segmental rollers shall be geared to the upper and lower plates."**

61. Omit brackets and the footnote referring thereto.

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*Amend by inserting after the word "flexure" the following: "For uniform load."

66. Change "connection angles not less than 7-16-in." to **connection angles not less than ½-in. in thickness.**

75. Omit brackets and footnote referring thereto.

Web Stiffeners. 77. There shall be web stiffeners, generally in pairs, over bearings, at points of concentrated loading and at points required by the formula: $d = \frac{t}{40}(12{,}000 - s)$,

Where d = clear distance, between stiffeners or flange angles.
t = thickness of web.
s = shear per sq. in.

The stiffeners at ends and at points of concentrated loads shall be proportioned by the formula of paragraph 16, the effective length being assumed as one-half the depth of girders. End stiffeners and those under concentrated loads shall be on fillers and have their outstanding legs as wide as the flange angles will allow and shall fit tightly against them. Intermediate stiffeners may be offset or on fillers and their outstanding legs shall be not less than one-thirtieth of the depth of girder plus 2 in.

Substitute the following:

Web Stiffeners. 77. **There shall be web stiffeners, generally in pairs, over bearings, at points of concentrated loading, and at other points where the thickness of the web is less than 1-60 of the unsupported distance between flange angles. The distance between stiffeners shall not exceed that given by the following formula, with a maximum limit of six feet (and not greater than the clear depth of the web).**

$$d = \frac{t}{40}(12{,}000 - s),$$

Where d = clear distance, between stiffeners of flange angles.
t = thickness of web.
s = shear per sq. in.

The stiffeners at ends and at points of concentrated loads shall be, etc.

Camber. 79. Truss spans shall be given a camber by making the panel lengths of the top chords, or their horizontal projections, longer than the corresponding panels of the bottom chord in the proportion of ⅛-in. in 10 ft.

Substitute the following:

Camber. *79. Truss spans shall be given a camber by **so proportioning the length of the members that the stringers will be level when the bridge is fully loaded.**

80. Omit the footnote, also omit the expression "up to 300 ft. spans" and reconstruct so as to read: "Hip verticals and similar members, and the **two end panels** of the bottom chords of single-track pin-connected trusses shall be rigid."

84. Marginal heading **Properties.**

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*Amend by substituting the word "straight" for "level" in the second line.

Phosphorus limit for acid structural steel should be 0.06 instead of "0.08."

Insert the following paragraph after paragraph 84:

84-a. **In order that the ultimate strength of full-sized annealed eye-bars may meet the requirements of paragraph 160, the ultimate strength in test specimens may be determined by the manufacturers; all other tests than those for ultimate strength shall conform to the above requirements.**

Annealed Specimens.

91. Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed, or otherwise treated before use, the specimens for tensile tests representing such material shall be cut from properly annealed or similarly treated short lengths of the full section of the bar.

Substitute the following:

Specimens of Rolled Steel.

91. **Rolled steel shall be tested in the condition in which it comes from the rolls.**

Modification in Elongation.

93. For material less than 5-16-in. and more than ¾-in. in thickness the following modifications will be allowed in the requirements for elongation:

(a) For each 1-16-in. in thickness below 5-16-in., a deduction of 2½ will be allowed from the specified percentage.

(b) For each ⅛-in. in thickness above ¾-in., a deduction of 1 will be allowed from the specified percentage.

Substitute the following paragraph:

Modification in Elongation.

93. **A deduction of 1 per cent. will be allowed from the specified percentage for elongation, for each ⅛-in. in thickness above ¾-in.**

111. Add: **Material arriving from the mills shall be protected from the weather and shall have clean surfaces before being worked in the shops.**

117. Marginal heading **Reaming.**

Omit last sentence, "All reaming shall be done with twist drills," and make additions so that the paragraph will read: "Where **sub-punching and** reaming are required, the punch used shall have a diameter not less than 3-16-in. smaller than the nominal diameter of the rivet. Holes shall then be reamed to a diameter not more than 1-16-in. larger than the nominal diameter of the rivet."

118. Omit the marginal heading, change footnote to correspond with revised addendum and alter so as to read: "When general reaming is required it shall be done after the pieces forming one built member are assembled, and so firmly bolted together **that the surfaces shall be in close contact.** If necessary to take the pieces apart for shipping and handling, the respective pieces reamed together shall be so marked that they can be reassembled in the same position in the final setting up. No interchange of reamed parts will **be permitted.**"

119. †[Sheared edges or ends shall, when required, be planed at least ⅛-in.]

Omit this paragraph, marginal heading and footnote, and substitute:

119. **"Reaming shall be done with twist drills and without using any lubricant."**

120. Omit marginal heading. Make addition so that the paragraph will read: "The outside burrs on reamed holes shall be removed **to the extent of making a 1-16-in. fillet."**

Connection Angles.

126. Connection angles for floor beams and stringers shall be flush with each other and correct as to position and length of girder. In case milling *[of all such angles] is needed or is required after riveting, the removal of more than 1-16-in. from their thickness will be cause for rejection.

Substitute the following and change marginal reference to correspond:

Floor Beams and Stringers.

*126. **The main sections of floor beams and stringers shall be milled to exact length after riveting and the connection angles accurately set flush and true to the milled ends *[or if required by the purchaser the milling shall be done after the connection angles are riveted in place, and milling to extend over the entire face of the member]. The removal of more than 3-32-in. from the thickness of the connection angles will be cause for rejection.**

127. Change marginal heading to **Riveting** and make additions so that the paragraph will read as follows: "Rivets shall be **uniformly heated to a light cherry red heat in a gas or oil furnace so constructed that it can be adjusted to the proper temperature. They shall be** driven by pressure tools wherever possible. Pneumatic hammers shall be used in preference to hand driving."

129. Change "turn to" in the second line to **shall make** and make additions so that the paragraph will read: "Wherever bolts **are used in place of rivets which transmit shear, the holes shall be** reamed parallel and the bolts **shall make** a driving fit, **with the threads entirely outside of the holes.** A washer not less than **¼-in.** thick shall be used under nut."

132. Interpolate **not less than** after "templet" in the second line, and the paragraph will then read, "Holes for floor beam and stringer connections shall be sub-punched and reamed according to paragraph 117, to a steel templet **not less than** one inch thick. †[If required, all other field connections," etc.]

Change marginal reference to correspond with revision in addendum.

140. Make additions so that the paragraph will read: "Steel castings **shall be free from large or injurious blow holes and shall be** annealed."

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*Omit the word "and" in the fifth line; bracket to be placed at end of paragraph, instead of after word "member."

142. Make additions so that the paragraph will read: "Expansion bed plates shall be planed true and smooth. Cast wall plates shall be planed top and bottom. The **finishing** cut of the planing tool shall **be fine and** correspond with the direction of expansion."

146. Interpolate the word **scale** before "weight." The paragraph will then read: "The **scale** weight of every piece," etc.

Eye-Bar Tests.

158. Make addition so that the paragraph will read: "Complete copies of shipping invoices shall be furnished to the purchaser with each shipment. **These shall show the scale weights of individual pieces."**

160. In eye-bar tests, the fracture shall be silky, the elongation in 10 ft., including the fracture, shall be not less than 15 per cent.; and the ultimate strength and true elastic limit shall be recorded (see 133).

Substitute the following:

160. **In eye-bar tests, the minimum ultimate strength shall be 55,000 lbs. per sq. in. The elongation in 10 ft., including fracture, shall be not less than 15 per cent. Bars shall break in the body and the fracture shall be silky or fine granular, and the elastic limit as indicated by the drop of the mercury shall be recorded. Should a bar break in the head and develop the specified elongation, ultimate strength and character of fracture, it shall not be cause for rejection, provided not more than one-third of the total number of bars break in the head** (see 133).

In order to conform to the recommended revisions in the body of the specifications the "Addendum" on page 276 should be changed to the following, and all footnote references given in the specifications should correspond therewith:

POINTS TO BE SPECIFICALLY DETERMINED BY BUYERS WHEN SOLICITING PROPOSALS FOR STEEL RAILROAD BRIDGES.

When general detail drawings are not furnished for the use of bidders specific answers should be given to questions a, b and c, below.

Specific answers should also be given to questions d, e and f if the class of work described in any of the paragraphs there referred to is desired. If these features are not specifically demanded, the unbracketed paragraphs will be construed to define the kind of work desired.

(a) What class of live load shall be used? (Par. 7 and 8.)

(b) Shall linseed oil or paint be used? If paint, what kind? (Par. 148.)

(c) Shall contractor furnish floor bolts?

(d) Shall general reaming be done? (Par. 118.)

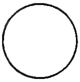
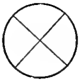
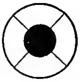
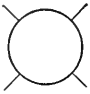
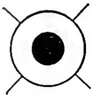
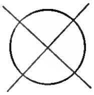
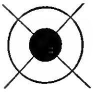
(e) Shall field connections be assembled at the shop? (Par. 132.)

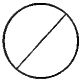
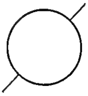
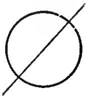
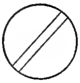
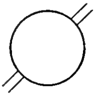
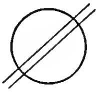
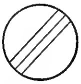
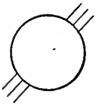
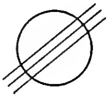
(f) Shall floor connection angles be milled after riveting? (Par. 126.)

Page 256. Omit Table of Standard Upsets and substitute the following:

RECOMMENDED CONVENTIONAL SIGNS.

A—BRIDGE RIVETS.

	Shop.	Field.
Two Full Heads.		
Countersunk and chipped, far side.		
Countersunk and Chipped, near side.		
Countersunk and Chipped, both sides.		

	Far Side.	Near Side.	Both Sides.
Countersunk and not Chipped.			
Flattened to ¼-in. high for ½-in. and ⅝-in. rivets.			
Flattened to ⅜-in. high for ¾-in., ⅞-in. and 1-in. rivets.			

B—STRESSES.

\+ Tension.
— Compression.

CONCLUSIONS.

Your committee recommends:

(1) That the recommendations under the heading "Revision of Manual" be adopted.

(2) That the report on "Care of Existing Bridges" be adopted and incorporated in the Manual.

(3) That the subect of "Specifications for Erection of Railroad Bridges" be referred back to the Committee for further consideration.

(4) That the Review of the Development of Bridge Building in America be accepted.

(5) That report on Reinforced Concrete vs. Steel be accepted.

Respectfully submitted,

J. E. Greiner, Consulting Engineer, Baltimore, Md., *Chairman.*

C. F. Loweth, Engineer and Superintendent of Bridges and Buildings, Chicago, Milwaukee & St. Paul Railway, Chicago, Ill., *Vice-Chairman.*

C. H. Cartlidge, Bridge Engineer, Chicago, Burlington & Quincy Railway, Chicago, Ill.

C. L. Crandall, Professor Railway Engineering, Cornell University, Ithaca, N. Y.

B. W. Guppy, Bridge Engineer, Boston & Maine Railroad, Boston, Mass.

A. J. Himes, Engineer Grade Elimination, New York, Chicago & St. Louis Railway, Cleveland, O.

Chas. M. Mills, Principal Assistant Engineer, Philadelphia Elevated Railroad & Subway, Philadelphia, Pa.

A. D. Page, Civil Engineer, Chicago, Ill.

C. D. Purdon, Consulting Engineer, St. Louis, Mo.

C. C. Schneider, Consulting Engineer, Philadelphia, Pa.

F. E. Turneaure, Dean, College of Engineering, University of Wisconsin, Madison, Wis.

J. R. Worcester, Consulting Engineer, Boston, Mass.

Committee.

Appendix A.

CARE OF EXISTING BRIDGES—METHODS OF FIELD WORK, INSPECTION AND RECORDS OF INSPECTION.

This compound subject has been under consideration for several years and progress reports for information and discussion have been submitted as follows:

Maintenance of Existing Metal Bridges, covering Inspection, Inspection Reports and Records, by B. W. Guppy, Bulletin 81, Vol. 8.

Inspection, Reports and Records of Inspection by majority of members of the Committee, Bulletin 97, Vol. 9.

Maintenance of Bridges, including Protection from Corrosion, submitted by the majority of the Committee, Bulletin 108, Vol. 10.

As stated above, these reports were submitted for the purpose of information and discussion only, and it was not the intention that they should be included in the Manual of Recommended Practice.

Your Committee, after a careful consideration of all that has been said on this subject, is of the opinion that the matter which pertains to Inspection and Records of Inspection, can be arranged so as to embody instructions of sufficient general application to justify publication in the Manual of Recommended Practice.

We therefore submit the following final report, with the recommendation that it be printed in the Manual.

INSPECTION OF BRIDGES AND RECORDS OF INSPECTION.

Inspections of bridges should be made with the object of discovering weakness or defects, of ascertaining the amount and rate of deterioration, the general physical condition, safety under traffic and the necessity for repairs, reinforcements and renewals.

The frequency of inspections should depend upon the character of the bridges, their location, strength and physical condition. A thorough annual inspection by a competent inspector may suffice for many cases where the bridges have been properly constructed and are not overloaded. On the other hand, a daily inspection may be necessary in order to observe with sufficient promptness damage which may be caused by an accidental blow.

Between these two extremes there are many reasons for making inspections of more or less thoroughness and frequency, but your Committee does not feel that a set of hard and fast rules, prescribing in detail the manner and frequency of making inspections, could be drawn up which would be alike efficient for the various conditions of traffic, the many types of structures to be inspected, and the widely differing forms of organization of the forces entrusted with the safety and maintenance of railway bridges.

A proper system of bridge inspection should therefore generally include the following:

(1) Inspection by the regular section forces, daily, or as often as they inspect the track under their supervision. The obect of this inspection is to discover any damage to the structure from fire, flood, derailments or other accidents from traffic, or any displacement in the structure in whole or in part. This inspection, due to the lack of skill on the part of the section forces, must necessarily be superficial, and will rarely, if ever, do more than call attention to unsafe conditions arising from causes other than those of natural depreciation. No reports of such inspections need be made unless adverse conditions are discovered.

(2) At periodic intervals of from one to six months there should be inspections by bridge foremen or others experienced in bridge repairs. These inspections should be more thorough than those of the section forces, and are intended to discover all the defects, arising from traffic, to which the bridge is subjected, and those due to natural depreciation or othr causs. Rports of such inspctions shuld be made to the one next in authority; preferably to the one mot directly or primarily responsible for the safety of the structure.

(3) Annual or semi-annual inspections are to be made by men experienced in the design and maintenance of bridges; preferably by those who are primarily responsible for their safe maintenance. The reports of these inspections should be filed, and in connection with an examination of office data will determine the safety of the structures, and be the basis for decisions as to repairs, reinforcements or renewals.

The inspections outlined in (1), (2) and (3) above must be considered as quite general. There will often be cases where much more frequent and thorough inspection than above outlined will be necessary, especially for structures which are carrying traffic much heavier than that for which they were designed, or which, by reason of poor design, age or injury of any kind, have a reduced margin of safety. Because of inability to renew some bridges in time for changed traffic conditions, or uncertainties as to revision work, lack of time for replacement after injury or for other reasons, it is occasionally necessary to keep in service structures which have not the usual margin of safety. The manner and frequency of the inspection necessary to safely maintain such structures must be determined separately for each individual case.

Railway bridges are of timber, masonry or metal, and occasionally of unusual design; men competent to inspect one kind are often incompetent to inspect other kinds, and it therefore may be necessary to limit an inspector to structures of a certain kind. It is sometimes desirable to have large and important or doubtful structures inspected by expert engineers.

Appendix B.

REINFORCED CONCRETE VS. STEEL FOR SHORT SPAN BRIDGES.

Your Committee was instructed to report "To What Extent Is Steel Construction, Carrying Heavy Loads at High Speed, Preferable to Reinforced Concrete for Main Girders of Bridges."

This inquiry is understood to mean a consideration of "The Relative Desirability of Reinforced Concrete vs. Steel Construction for Short Span Bridges," and your Committee submits the following as a progress report for information and discussion, with the recommendation that it be referred back for further consideration.

In any bridge the qualities to be desired are: adequate strength, freedom from vibration and excessive deflection, economy in first cost, economy in maintenance, and permanence.

The theory of flexure of reinforced concrete is sufficiently well understood to enable safe and economical designs to be made of this material, and experience with reinforced concrete structures carrying dead loads only has been abundant. Experience with such structures carrying heavy live loads and subjected to the shock and vibration of these loads, moving at high speed, has not been so extensive, but reinforced concrete girders can be designed and built in short spans of any strength required, or likely to be required, by railway loads. In the event of overloading or defective construction, reinforced concrete will give quite as much warning of probable failure as other materials.

While the art of bridge construction in steel has so far progressed that the safeguards surrounding the manufacture of steel and its fabrication into bridges have come to be matters of course, the equally careful supervision of the manufacture of reinforced concrete seems burdensome to the engineer, although it is just as necessary, but not more so. This necessity for careful inspection of methods and materials of manufacture needs to be emphasized, for, like steel, concrete may most easily be ruined by careless workmen, but when the same pains are taken to produce good concrete as are now taken to produce good steel, with the same rigid inspection and insistence on proper specifications, there will result a product which we believe will prove to be equally reliable.

One of the chief advantages of reinforced concrete over steel for short spans is that the form lends itself more readily to ballast floor construction, the superiority of which to open decks is evident to every operating officer, not only on the account of the absence of wood, which may rot or burn, or exposed steel, which requires protection from brine drippings or other corrosive influences, but also on account of the freedom from vibration and excessive deflection and the reduction of the cost of maintenance to a minimum.

The comparative economy of the two styles of construction is a matter which is not easily determined in general terms, depending as it does upon the market price of steel, concrete materials and labor. The character of the design is also a factor of first importance. Generally speaking, if it is not considered advisable to use ballasted floors in a particular case, for that case the short span of I-beams with ordinary floor of wooden ties is the cheaper construction in first cost. If, however, a large number of similar spans are to be built, so that concrete slabs can be constructed in a central and conveniently arranged plant, and if the erected price of steel work approximates three (3) cents per pound, the difference between concrete slab construction built with ballast floor and steel construction with open wooden floor, will be small, and in many cases will be favorable to the concrete.

If the designs contemplate the use of I-beams embedded in concrete, compared with reinforced concrete girders, economy will be all on the side of the latter.

Short spans of reinforced concrete also permit a substantial economy in the design of abutments carrying them.

It is the opinion of your Committee that reinforced concrete flat slabs or girders are not generally advisable for railway loads in spans exceeding 40 ft., but, as the great majority of structures carrying tracks over openings in the roadway are of spans less than 40 ft., the importance of these small structures is very great, and we believe the use of reinforced concrete for these small spans is desirable.

Appendix C.

SPECIFICATIONS FOR ERECTION OF RAILROAD BRIDGES.

BY J. E. GREINER.

There is not much uniformity in the practice of railroad companies concerning the manner in which they manage the erection of bridges. Some companies whose bridges are of ordinary character and dimensions erect them with their own forces, others contract for the erection, others again erect the small bridges with their own forces and contract for the larger bridges.

The erection of a bridge, whether done by the railroad company's forces or by a contractor or by a combination of the two, embraces the use of erection plant, materials and labor required for performing a number of items of work. When done by the company's forces, the company furnishes all materials and plant and the separate items are distributed among the gangs properly equipped for the different characters of work, and no question arises as to what is included in the erection. When done by contract, the railroad companies in some instances construct spur tracks, unload and store materials, furnish free transportation and engine or work train service, flagmen and falsework, maintain traffic, frame and place ties; other companies furnish none of these items.

It is necessary to construct spur tracks for the convenient handling of materials only when the structure is of some magnitude and is at a considerable distance from the nearest siding; or when the traffic is so heavy as to require erection with the least possible interference, in which case it is usually erected on the outside and pulled into position. While the construction of spur tracks is at times a necessary part of the erection, the railroad company's forces are better equipped for such work than are the contractor's, and it is therefore advisable, in all cases where such spur tracks are necessary, for the company to construct them with its own forces.

Cars cannot always be permitted to remain for any considerable length of time on sidings. They should therefore be promptly unloaded and, if the material for the superstructure has been delivered in advance of the completion of the masonry, or when it is not expedient to start the erection immediately after the delivery of the material, the material should be unloaded and the cars released by the company's forces. It cannot be expected that the contractors will ship plant and men to unload the cars and then either wait until the masonry is finished or else move their forces away.

The materials used in the erection of a bridge are usually shipped to the nearest siding, unless a spur track has been constructed at the site. This siding may be quite a distance from the bridge site and will in that case require engine and work train service in order to get materials within handling distance of the erector's outfit. It is properly up to the railroad company, therefore, to furnish such service when required. It is optional with them whether they furnish all such service free of charge to the contractor, free for a limited number of days, or charge for every day's service furnished. Whether the work is done by the railroad company's forces or by contract, there will be expense to the railroad company, and it should be charged to the bridge.

When all such service is furnished free of cost, there is a possibility of abuse and calling for engines and work trains more than is necessary for the work. When each day's service is charged against the work, such service will be called for only when absolutely necessary, but in all cases of work train service there is involved more or less delay in furnishing the service on account of keeping the main tracks open for regular traffic service, and it frequently happens that but one or two hours' actual service is obtained during the day. A contractor cannot well include the cost of such interrupted service in his estimate, and thinks he has good cause for complaint when he is delayed and charged fully.

In order to avoid the abuse of engine service by contractors, a number of railroads furnish such service free of cost for a limited number of days, according to the judgment of the engineer, and charge the contractors regular service rate for all time in excess of that named. The writer thinks this will meet the conditions better than furnishing unlimited service free, or charging for all service, as it will have a tendency to make the contractor not call for service except when necessary, and when rendered will cause him to use it to the best advantage.

Practice also varies as to the transportation furnished by railroad companies to contractors. Some companies furnish no transportation whatever for men or materials, others will transport free over their lines the contractor's equipment, materials and men. This is therefore optional with the railroad, but as it involves a question of considerable expense, the contractor doing the work should know in advance whether or not he is to have free transportation. When such transportation is furnished by the railroad company, it is usually with certain restrictions as to trains and time.

While erection is in progress, flagmen must be stationed each way from the bridge in order to protect the trains and the work. These men should be familiar with train movements and should preferably be employés of the railroad company and under the company's complete control. Some roads furnish such flagmen and charge their wages to the contractors. The contractors understand this in advance, and add the cost of such labor to their contract price. Therefore, it makes no difference so far as the cost of the work is concerned whether the railroad company furnishes these flagmen free of cost or charges their time to the contractors, provided the contractors know in advance who is to pay the bill.

It is not necessary for a structure intended for temporary use to be designed with the same degree of strength and excellence that would be required should the structure be intended for permanent use. It, of course, must be of ample strength for the purpose and sufficiently substantial to prevent excessive motion. In designing such structures, therefore, it is proper to take into consideration their temporary use, that traffic, if any, will be operated at slow speed and that the structures are under constant supervision until finally removed. Materials must be suitable for the purpose, although they need not necessarily be new nor inspected with such refinement as would be applied to a structure that was to remain in service eight or ten years. It is well to properly proportion all parts for the maximum loads which will come upon them while in service, but it is not necessary to apply in these designs the unit stresses recommended for permanent regular service conditions. We all know that the unit stresses recommended by committees of this Association for timber trestles are safely exceeded time and again in regular practice. It would, therefore, be an unnecessary expense to use these low unit stresses in purely temporary structures used during the erection of a bridge.

Specifications for erection do not usually specify the permissible unit stresses, this matter being left either to the judgment of the erector or to the engineer who plans the work. It is advisable to fix a limit to these stresses and with suitable materials this limit could reasonably be placed 50 per cent. in excess of limits recommended by Committee VII, as given in the Manual of Recommended Practice (1907).

In the construction of such falsework, there can be no reasonable objection to the use of round timbers instead of square timbers for the legs of bents, provided such timbers are of sufficient dimensions as not to exceed permissible stresses, and provided they are sawed off square to the axis of the stick.

When there is temporary falsework under an old bridge, placed by the railroad company for the purpose of supporting it until it can be renewed, the contractor who erects the new bridge should be permitted to use any part of this falsework during the construction of the new bridge, provided, of course, it is not wasted in cutting.

Some railroad engineers, even when they contract for the erection of a bridge, prefer to build the supporting structure for maintaining traffic, the contractor building only such additional temporary structures as may be necessary for the handling of the work. Frequently these temporary structures, whose only purpose is to maintain traffic, are constructed without any consideration whatever as to the requirements during erection, with the result that they have to be altered, cut down, or lengthened out before erection can proceed. If the railroad companies insist upon doing this work with their own forces, the contractor's men will work at a disadvantage or lounge about waiting for the railroad companies' forces to finish. From the writer's observation, he is not at all convinced that the railroad companies' forces are able to maintain traffic on falsework any safer or better than is done by the contractors' forces under efficient supervision, and, aside from this, when the two forces work on the same job at the same time, there is bound to be more or less interference and friction.

If the railroad companies build the temporary structure for carrying the traffic, the contractor is relieved of that responsibility, which means that the railroad company should always keep a force of men there to make the changes as the work progresses. In case the erection of a bridge is contracted for, it is evidently better to have the erector build the temporary structure for maintaining the traffic as well as that for erection purposes solely, in which case he is the responsible party, and on proper supervision by the railroad company the work will be just as well done and interference of forces will be avoided.

When, however, railroads insist upon maintaining the traffic with their own forces, the falsework should be placed so that it can be used for erection purposes as well as for maintenance purposes, and in such a manner as to interfere as little as possible with the work of the contractor.

Committee XV has recommended that the floor decks in all cases be placed by the railroad companies' forces. The work should be well and accurately done in accordance with well-developed plans. Many ties have been spoiled by improper dapping on account of uncertainty of the requirements shown on undeveloped plans. The railroad companies' forces are just as liable to make such errors as are contractors' forces. If the contractors' forces are required to maintain traffic, it would appear better that they should also be required to frame and place the ties, as placing of these ties is necessarily a part of the maintenance of traffic, and if in any change of the old structure to the new structure, the railroad companies' forces are not available or are not on the ground, there will be delay in the execution of the work, or the contractor will have to put all ties in for his own protection.

In the case of solid floors where ballast is used, traffic must be carried on temporary stringers during the erection of the work. When the ballasting is done by the company's forces, as is customary, these stringers should be furnished and removed by them in order not to hold the contractor at the site after all his work has been finished.

Many railroads require that a special paint be used on their structures. As the paint applied after erection is a part of the material which enters into the permanent construction, it should be furnished either by the manufacturer of the steel work or by the railroad company, and the application alone left to the erector. Bridge erectors usually do not make a very good job of painting; for this reason a number of roads prefer to paint with their own forces, but, if the erection is done by contract, it is necessary for the contractors to know whether or not they are to do this work.

The question of responsibility during the construction of a piece of work could perhaps be more properly covered in the contract, but as the specifications form a part of the contract and are the governing rules for the execution of the work in the hands of the erector, it is well to define the contractor's responsibility in order that the man doing the work may know where he stands.

When erection work is done by the company's forces alone the question of responsibility does not arise. When done by the manufacturer or by an independent contractor, there is in all justice a division of the responsibility between the railroad company and the contractor. The contractor should undoubtedly be held responsible for all accidents, loss or damage to *his own* work, *his* materials or *his* plant, due to any cause whatever. As the company's materials are in his hands, he should also be responsible for it in case of accidents, due to causes within his reasonable control. It is proper for him to carry insurance against injury to workman, and protect the company in case suit is entered. It is, however, not fair to make him responsible for damage to the company's property or materials when such damage is due to causes beyond his reasonable control, as this is a matter against which he could not protect himself. The mere fact that he had charge of the company's property at the time of such accident is no reason why he should pay such costs.

There should be no material difference in the requirements of specifications, whether the work is done by the company's forces. by contractors or by a combination of the two, since rules governing the proper execution of work are just as necessary for the company's forces as for the contractor's forces, and the work should be of ample strength and of workmanship suitable for the purpose, no matter who does it.

The following specifications are submitted for the purpose of discussion:

SPECIFICATIONS FOR ERECTION OF RAILROAD BRIDGES.

1. The work of erection shall include the furnishing of all labor, tools, equipment and materials, other than those which enter into the permanent structure, the removal of the old bridge, if any, and the construction of the new superstructure ready for the rails, all in accordance with the plans and specifications. Work Included.

2. The railroad company when inviting proposals for erection will state where the materials will be delivered and whether on cars or stored, what materials, spur tracks for convenient handling of materials, transportation, engine or work train service and flagmen they will provide, and whether they or the contractor shall construct all falsework or protection work, remove old bridge, maintain traffic, construct solid floors, frame and place the ties, waterproof and paint the steel work. The contractor shall furnish the erection equipment and do all work specified in the inquiry and according to the requirements of the plans and specifications. Proposals.

3. The method of erection, except where local conditions justify a special scheme, will generally be at the discretion of the erector, subject to the approval of the engineer. Erection Methods.

Where conditions justify a special scheme, the requirements will be clearly stated or shown on plans.

4. Bridges shall be erected in accordance with approved plans of the falsework and permanent structure. Approval of contractor's plans shall not be considered as relieving the contractor of any responsibility. Plans.

5. Erection shall not be started until sufficient material has been delivered to enable the work to proceed continuously, nor until the erector has been authorized to proceed. It shall be conducted with a force of men and plant sufficient for speedy completion and in such manner as to be at all times subordinate to the unobstructed use of the tracks of the company, and so as not to interfere with other work in progress, or close any thoroughfare by land or water, except under proper authority. Conducting the Work.

Traffic and work must be protected by flagmen whenever necessary, and competent watchmen shall guard the work and materials against injury. All laws and ordinances applying to the work shall be complied with, the necessary permits obtained, and lights provided to protect work at night.

6. When engine or work train service is desired by the contractor, he shall give the proper railroad officials at least 24 hours' advance notice, and the company will furnish the service according to conditions stated as promptly as possible, consistent with railroad operations. When derrick cars are used on main tracks, their movements shall be in charge of a regular train crew. Engine Service.

7. When transportation of equipment, materials and men is furnished free over the company's lines, it shall be subject to such conditions as may be stated. Transportation.

Masonry Finish.

8. The railroad company will finish all masonry to correct lines and elevations, and unless otherwise stated will make all changes in old masonry without unnecessarily impeding the operations of erection. The company's engineers will establish lines and elevations, but the erector shall compare the elevations, distances, etc., shown on plans, with the masonry as actually constructed, so far as practicable with spirit levels and steel tapes, before he assembles the steel. In case of discrepancy he shall immediately notify the engineer.

Handling and Storing Materials.

9. Cars containing materials or plant shall be promptly released upon delivery. Material shall be placed on skids above the ground, laid so as not to hold water and stored and handled in such a manner as not to be injured and not interfere with railroad operations. The expense of repairing or replacing material injured in handling by contractors shall be charged to the contractors. Material when being unloaded and stored shall be compared with the shipping list and any shortage or injury discovered shall be promptly reported.

Temporary Structures.

10. The temporary structures for use during erection and for maintaining the traffic shall be properly designed and substantially constructed for the loads which will come upon them. All bents shall be thoroughly braced transversely, and held against longitudinal movement by diagonal bracing or lines of struts extending from face to face of piers or other approved anchorages. The bents shall be well secured against settling, and piles driven wherever firm bottom cannot be obtained by wedging down the bents.

The maximum permissible unit stresses in any member shall not exceed the unit stresses recommended in the Manual of 1907, page 85, for wooden bridges and trestles, by more than 50 per cent.

Temporary falsework placed by the railroad company under an old structure or for carrying traffic over a new opening may be used by the erector during erection, provided it is not unnecessarily cut and wasted.

Maintenance of Traffic.

11. When traffic is maintained by the company's forces, any changes in structures carrying the traffic, required for the purpose of facilitating erection by contract, shall be made by the contractor, under the supervision of the company's representative.

Old Structures.

12. Metal work in old structures shall be dismantled without any unnecessary damage and loaded on cars or neatly stored at the site, immediately adjacent to the tracks and at a convenient grade for future handling, as may be directed. When a structure is to be used elsewhere, all parts shall be match marked, in accordance with diagram to be furnished by the engineer, and when the old bridge is composed of several spans, the parts of each shall be kept separate. All trestle work placed under the old bridge for support shall be considered part of the old structure.

Steel Work.

13. All steel work shall be adjusted to correct position and true to lines before being permanently connected, threads of pins protected by pilot and driving nuts, and, wherever permanent bolts are used, the nuts effectively locked by checking the threads. Moderate drifting will be permitted in order to draw parts together, but not for the purpose of matching unfair holes. Such holes shall be reamed or drilled.

All splices and field connections shall be securely bolted before riveting, and important connections, such as tension splices and attachment of stringers and floor beams, shall have at least 75 per cent. of the holes filled with bolts, when the parts are required to carry the traffic. When not carrying any traffic at least 50 per cent. of the holes shall have bolts. Rivets in splices of members shall not be driven until the members have been subjected to the full dead load stresses.

Rivets shall be uniformly heated to a light cherry red color, and when driven shall completely fill the holes and be tight. The heads shall be full and uniform in size, concentric, free of fins, in full contact with metal and be painted immediately after inspection and acceptance. Rivets shall be inspected immediately after being driven and those rejected shall be cut out and replaced without delay.

Shop Errors.

14. Minor misfits which require a reasonable amount of reaming, cutting and chipping in order to permit accurate assembling shall be considered a legitimate part of erection. Errors in general dimensions and misfits or holes so badly matched as to require drilling or cutting apart of metal work cause extra work properly chargeable to the manufacturer. Such errors shall be reported to the engineer as soon as discovered and corrections made during the presence of the inspector who shall check the time required. All extra work ordered will be paid for at actual cost to the contractor for labor and materials, plus 15 per cent. for use of tools and supervision.

Anchor Bolts.

15. Holes for anchor bolts, except where bolts are built into the masonry, shall be drilled by the erector and set in Portland cement grout or lead after the span is in place.

Bed Plates.

16. Bed plates shall be set level in exact position and have a full and even bearing over their entire surface, a thin layer of Portland or rust cement or lead being used for this purpose.

Floor Decks.

17. Floor decks shall be constructed strictly in accordance with the approved plans. In case of wooden floor decks, the ties shall be framed so as to give a full and even bearing on the girders and under the rails. The outer edges shall be sawed off to correct lengths and be in true line. Guard rails shall be dapped and framed to a tight fit over the ties and secured as shown on the plans.

When structures have a camber of more than one-half inch, ties shall be framed so as to take out all camber over this amount, except when the bridge is composed of one span only, in which case the camber may be neglected.

Painting. 18. The paint used shall be of such color, quality and manufacture as may be specified. The metal shall be thoroughly cleaned of dirt, rust, loose scale, blistered paint or paint which has been damaged in handling. Surfaces inaccessible after erection, such as bottoms of base plates, tops of stringers, etc., shall receive two coats before assembling in place and the balance of the metal work shall receive two coats after erection. There shall be sufficient time allowed between the coats to allow the first to dry before the second is applied, and no painting shall be done in wet or freezing weather nor when the surface of the metal is damp. Painting shall be done in good and workmanlike manner, subject to strict inspection during progress and after completion.

Clearing the Site. 19. Upon completion of the steel work all surplus material, debris and temporary structures shall be removed and the premises left in a neat condition. The material from temporary structures, if the property of the company, shall be neatly stored near the site or loaded on cars as may be directed.

Workmanship. 20. All work done and materials furnished shall be of good quality.

Inspection. 21. The work of erection shall at all times be subject to the inspoction and acceptance of the engineer or his representative on the ground.

Responsibility. 22. When work is done under contract, the contractor shall assume all responsibility for loss or damage to his own work, materials or plant, due to any cause whatsoever; also for all loss or damage to the railroad company's materials or property and to other property adjacent to the railroad, due to causes within his reasonable control.

He shall assume all responsibility for injury to the workmen, or the public or to any individual, and in case of accident or suit, he shall defend the suit in person, and relieve the company from all costs and expenses, and pay any judgments that may be recovered thereon.

He shall comply with the local or Government laws or ordinances controlling or limiting the manner of doing the work and shall take such precautions as may be necessary to protect life and property.

Appendix D.

A REVIEW OF THE DEVELOPMENT OF METAL BRIDGE BUILDING IN AMERICA.

BY C. L. CRANDALL.

The rapidity of the development of the metal truss bridge can be appreciated by noting that it has occurred since 1840, or within the lifetime of many of the older engineers. The suspension bridge dates back to an earlier period, or to the close of the eighteenth century.

The following on early American suspension bridges is condensed from the Engineering News (Vol. 53, p. 269):

"The first man to apply scientific design to a suspension bridge was the American engineer, James Finley, of Fayette County, Pa. In 1796 Finley built one of his iron chain bridges across Jacob's Creek in the State of Pennsylvania, on the turnpike connecting Uniontown and Greenburg. Finley proposed for his bridges substantial masonry towers; the use of two main suspending members built up of iron links, each as long as one of the panels; a deflection in the cables equal to one-seventh of the span; the floor suspended by rods and stirrups located at the panel points; and, to overcome any tendency to overturn the main towers, he would give the same deflection to the shore half span as to the main span. He also insisted upon longitudinal stiffness in his floor system."

Up to 1801, when Finley patented his design, eight bridges had been built on his plan in the United States. Between 1800 and 1808 forty more were constructed, the largest over the Schuylkill, near Philadelphia, with a span of 306 ft., and the one of greatest interest at the time, over the Merrimac, near Newburyport, Mass., with a span of 244 ft. The masonry towers for the latter were 47 ft. wide and 37 ft. high above the bridge floor. The two roadways, each 15 ft. wide, were supposed to be safe for horses and carriages at any speed. Ten chains were used, three on each side and four in the middle of the bridge; they were designed to be safe for a load of 500 tons. The railing contributed to the stiffness of the floor, and there was little perceptible motion, whatever the speed or kind of traffic.

It is stated by Theodore Cooper that on February 6, 1827, one of the chains broke under a heavily loaded wagon drawn by four oxen and one horse. It was rebuilt, still using chain cables, and it was in use in 1889 (Trans. Am. Soc. C. E., Vol. 21, p. 3).

The one built over the Lehigh River in 1811, near Northampton, Pa., and consisting of two whole and two half spans, was the first suspension bridge on record having more than one span.

The first wire suspension bridge was also of American origin. It was a foot bridge, with a floor 18 in. wide and a span of 804 ft.; it was built by White and Hazard over the Schuylkill near Philadelphia in 1816, and the entire cost is said to have been but $125.00.

The review of the development of the metal truss bridge is abstracted largely from the following excellent articles:

Bridge Superstructure (Trans. Am. Soc. C. E., Vol. 7, p. 339), by G. S. Morison, E. P. North and J. Bogart, tracing the development and characteristics of American practice in connection with the Society's exhibit at the Paris Exposition of 1878.

American Railroad Bridges (Trans. Am. Soc. C. E., Vol. 21, p. 1), by Theodore Cooper, tracing the development from Thomas Paine's model of 1787 up to 1889.

The American Railroad Viaduct (Trans. Am. Soc. C. E., Vol. 25, p. 349), by J. E. Greiner, containing, besides the development of the viaduct, some interesting letters from Squire Whipple and J. H. Linville concerning the construction of some of the first metal bridges.

Historical Sketch of the Development of American Bridge Specifications (Proc. Am. Ry. E. & M. of W. Assn., Vol. 6, p. 199), by Committee XV, reviewing the development of bridge construction to its expansion about 1870, and then taking up quite fully the growth of bridge specifications, with the modifications in general types, and in details, which have resulted from increased knowledge and experience and from changed requirements.

In 1787 Thomas Paine took a model for a cast-iron arch to Paris and presented it as a model for an arch bridge of 400 ft. span to the Academy of Sciences for its opinion. It was referred to a committee and the report was favorable. He then had two arch ribs of 90 ft. span and 5 ft. rise cast at Yorkshire, England, and tested with double their own weight. On the success of this experiment, Paine had a complete bridge of five arch ribs of 110 ft. span and 5 ft. rise made by the same founders and sent to London "as a specimen for establishing the manufacture of bridges to be sent to any part of the world."

The French Revolution soon took up Mr. Paine's attention and no further consideration seems to have been given to the use of iron for bridges until about 1830, when Itheil Long and Colonel Town, patentees of the Long and Town bridge trusses, respectively, both suggested that their bridges could be made in iron or wood.

In 1833 August Canfield took out the first patent for an iron truss bridge.

The first one built is believed to be the one erected over the Erie Canal at Frankfort, N. Y., in 1840, by Earl Trumbull. "The truss was a combination of truss and suspension principles, and was formed of—first, seven cast-iron sections or panels, of about 11 ft. in length and 7 ft. in depth, cast solid, each segment consisting of an upper chord, a pair of diagonal braces and half of a hollow cylindrical post at each end (of the segment), except that the end segments had full cylindrical posts at the abutments. These semi-cylinders being bolted or clamped together in series, formed full cylindrical posts, which were flanged at the bottom, and through which were passed vertical bolts securing them to wooden transverse floor beams. Second, two wrought-iron suspension rods (1½ ins. diameter) attached to the top of the end posts, and sagging in a parabolic curve, so as to pass under and support the two centermost floor beams, and under lugs cast at proper elevations upon the posts intermediate between the centermost and the end posts, whereby such intermediates were supported. Cross-sections of chords and diagonal braces of the + formed the section."

In the same year (1840) Squire Whipple built his first iron bridge, a bow string truss in which the compression members were of cast-iron and the tension members of wrought-iron. A large number of bridges of this type, with spans of 50 to 100 ft., have been built, and some with spans up to 180 ft.

In 1846-47 James Millholland built a boiler plate tubular girder 55 ft. long for the Baltimore & Ohio Railroad at Bolton depot.

In 1846 Frederic Harbach patented an iron Howe truss with cast-iron tubes in pairs for the upper chords and main diagonals and boiler iron riveted together as continuous tubes for the lower chords. The vertical rods were wrought-iron, with cast-iron saddles at the panel points. A bridge of this type with a span of 30 ft. was built on the Boston & Albany Railroad near Pittsfield, Mass., in 1846-47.

About 1847-50 Nathaniel Rider built a number of bridges for the New York & Harlem, Erie, and other railroads. The chords were parallel with a multiple system of vertical posts and diagonal ties. The members were bolted together, while a wedge at the top of each post was used to key up the systems. The failure of one of these bridges on the Erie in 1850, soon after the failure of the iron bridge over the River Dee in England, led to an order for the replacement of all iron bridges on the road with wooden ones.

"The first impulse to the general adoption of iron for railroad bridges was given by Benjamin H. Latrobe, Chief Engineer of the Baltimore & Ohio Railroad. When the extension of this road from Cumberland to Wheeling was begun he decided to use this material in all the new bridges. Mr. Latrobe had previously much experience in the construction of wooden bridges in which iron was extensively used; he had also designed and used the fish-bellied girder constructed of cast and wrought-iron; he had adopted on the older portion of that road the Bollman plan of bridge for short spans. For the bridges west of Cumberland he adopted the plans submitted by Albert Fink, his assistant."

In 1851-52 a Bollman truss with a span of 124 ft. at Harper's Ferry and three Fink trusses of 205 ft. each over the Monongahela were completed. Both types were called suspension trusses, as all parts were suspended from the upper chord by diagonals attached to the parts in pairs, no lower chord being required. These wrought-iron diagonals had screw ends for adjustment at the chord and eyes passing over pins at the posts. The compression members were of cast-iron.

In 1852-53 a double intersection Pratt (or Whipple) truss railroad bridge with inclined end posts was built by Squire Whipple near Troy, N. Y. Links were used for the lower chords and round rods for the diagonals; the latter with eyes connected to pins at the upper chords and screw end connections to the posts at the lower chords.

From 1851-61 many iron bridges with spans of 65 to 110 ft. were built on the Western and Mountain divisions of the Pennsylvania Railroad. They were Pratt trusses stiffened with arches, the top chords, posts and arches being of cast-iron.

In 1858-59 John W. Murphy built a Whipple-Murphy railroad bridge with a span of 165 ft. over the canal at Phillipsburg, N. J., which was probably the first pin-connected truss ever erected. Wrought-iron unturned pins were substituted for the Whipple cast trunnions at the bottoms of the posts; the Whipple lower chord links were retained, while the lower eyes of the counters were elongated and fitted with gib castings and keys for adjustment.

In 1861 J. H. Linville built a bridge over the Schuylkill in which wide forged eyebars were used for the first time.

In 1863 John W. Murphy built a bridge at Mauch Chunk for the Lehigh Valley Railroad in which, probably for the first time in America, wrought-iron tension and compression members were used. The joint blocks and pedestals were of cast-iron.

Between 1865 and 1880 a large number of Post bridges were built. These usually have a double web system, the posts having an inclination across half a panel, the main ties across a panel and a half, and the counter ties the same inclination as the posts reversed. This connection of the two systems renders the stresses indeterminate.

In 1859 Howard Carroll commenced building riveted latticed bridges for the New York Central Railroad and its connections. They were mostly spans of from 40 to 90 ft. and they gave excellent satisfaction. Later engineers used spans up to 180 ft.

In 1860 a double-track deck plate girder was designed by E. S. Philbrick for the Boston & Albany Railroad. The girders were 96 ft. 9 in. long, 90 in. deep, with ½-inch web, 4-inch angles and 24-inch flange plates. There were three girders, and one was still in use at the site a few years ago.

The first iron trestles were designed by Albert Fink and built by the Baltimore & Ohio Railroad Company over ravines on the Cheat River in 1852-53. They were known as the Buckeye and Tray

Run viaducts. All parts of the trestles were of cast-iron except the tie rods, and they rested on continuous walls of masonry. They were not removed until 1884 and 1887, respectively.

The Bullock Pen viaduct, designed by Smith, Latrobe & Co., and erected on the Cincinnati & Louisville Short Line in 1867, marked about the first improvement in general design, while the Verrugas viaduct, on the Lima & Oroya Railroad in Peru, built in 1871 by the Baltimore Bridge Company, was the first wrought-iron structure embodying the principle of independent braced piers, as set forth by C. Shaler Smith in a general design for a viaduct in 1870.

The era of long-span truss bridges may be considered as dating from the building of the first bridge over the Ohio River at Steubenville, by J. H. Linville, in 1863-64. The channel span was 320 ft. long and 28 ft. deep, and the assumed live load was 3,000 lbs. per foot; the posts and top chords were of cast-iron. This was followed by the Louisville bridge, built by Albert Fink in 1868-70, with two main spans, one of 360 and the other of 390 ft.; by the bridges at Parkersburg and Bellaire by J. H. Linville, with channel spans of 340 ft., and the Newport and Cincinnati bridge, with a channel span of 420 ft., 1870-72.

The Eads bridge over the Mississippi at St. Louis, consisting of two arches of 502 and one of 520 ft. clear span, was built in 1868-74.

The Cincinnati Southern bridge over the Ohio, built by the Keystone Bridge Company in 1876, with a channel span of 519 ft., was the longest truss span in existence at that time.

The first iron cantilever bridge of importance was the Kentucky River bridge, designed and built by C. Shaler Smith in 1876-77, with three equal spans of 375 ft. The second, also by Mr. Smith, was built over the Mississippi near St. Paul during the winter of 1879-80. It consists of one center span of 324 ft. and two shore spans of 270 ft. each. The third and fourth were the Niagara and Frazier River bridges, designed by C. C. Schneider and completed in 1883 and 1885, respectively. The St. John cantilever was built in 1885.

Squire Whipple's book on Bridge Building, published at Utica, N. Y., in 1847, appears to have been the first in which an attempt was made to analyze the stresses in skeleton bridge trusses; this was followed by Hermann Haupt's treatise on Bridge Construction in 1851, written apparently without knowledge of Mr. Whipple's book.

The use of a uniform load of one ton per foot of track for designing all parts of a railroad bridge was the custom for some years after 1860, and it was not until about 1870 that a heavier uniform load was used for the floor than for the trusses.

Whipple advocated the use of unit stresses of 10,000 lbs. per sq. in. for wrought-iron in tension and 10,000 to 12,000 lbs. compression on hollow cast-iron cylinders of not over 18 diameters in length. For highway bridges he added about 50 per cent. to these values.

Up to about 1874 the design and construction of bridges were mainly in the hands of the several bridge companies, each with its own peculiar type of bridge. At this time the bridge engineer acting in the interest of the railroad company began to exert a salutary influence. The investigations made during the construction of the Eads bridge, and especially the testing of full-sized members and their connections, gave an impetus to the work which has been very helpful, while the erection of two balanced cantilevers, each over 250 ft. long, called attention to the advantages of the cantilever system for situations where falseworks were expensive or dangerous.

The bridges of the Cincinnati Southern Railroad, including the large span over the Ohio at Cincinnati and the crossing of the Kentucky River gorge, were the first of importance that were offered for competition upon specifications drawn by an engineer acting exclusively in the interest of the railroad company. These specifications by Mr. Bouscaren were important in two particulars; the use of an engine and train diagram for the live load and in the requirement that full-sized compression members be submitted for test for the determination of ultimate strength and elastic limit.

After the failure of the Ashtabula bridge in December, 1876, a general examination of the character and condition of the bridges was made on most of the roads by competent engineers, and many defective structures were found and strengthened or replaced. Floor systems and counterbracing were found inadequate for the concentrated engine loads in use, and the details in many cases showed a lack of appreciation of the stresses which were to be carried. Broken castings showed the unreliability of cast-iron for bridge work.

The Erie specifications, drawn up by Theodore Cooper in 1878, were the first general specifications, "covering the designing, proportioning and detail of construction with that completeness necessary to give the railroad company the full advantage of the competitive method, with a certainty that the resulting structure would in all ways be up to the advanced state of the art."

It gave definite unit stresses for the different parts of the structure rather than factors of safety and left the contractor free to select the type of truss and details within the limits which gave protection to the railroad company. The Phœnix Iron Company and the Keystone Bridge Company had testing machines in their shops previous to 1870 which were used for testing eyebars and wrought-iron columns. Many tests were made in connection with the construction of the St. Louis bridge on account of its great importance and the use of steel and new forms of members, but no marked progress was made in the forms of compression members until after the tests of Mr. Bouscaren on the forms then in use, referred to in connection with the bridges of the Cincinnati Southern Railroad.

The use of steel for the arch tubes of the St. Louis bridge, 1868-74, was followed by the use of steel members for the Plattsmouth bridge, designed by G. S. Morison and built in 1879-80. The staves of the arch were of chrome steel, having an ultimate strength of 100,000 lbs. and a compressive strength of 60,000 without permanent set, while the steel used by Mr. Morison averaged about 80,000 and 50,000 lbs. for the specimen tests and 70,000 and 40,000 for the eyebar tests for ultimate strength and elastic limit, respectively.

For the Plattsmouth bridge, the steel was confined to the top chords, end posts, bolsters, rollers and pins, and to all the tension members except the vertical suspenders in the end panels and the transverse wind ties, for the two 400-ft. channel spans. The other posts of these spans and the 200-ft. spans were of wrought-iron.

The first bridge of importance in the world to be made entirely of steel was the Glasgow, on the Chicago & Alton Railroad, built in 1880. There were two 138-ft. and two 311-ft. deck spans and three 311-ft. through spans. The steel had an elastic limit of 48,000 lbs. and the working stress adopted was 16,000. The general prediction on the part of the bridge engineers was that the structure would fail.

From this time to 1890 many steel or part steel bridges were built, but they were usually exceptional and the material of high ultimate strength, demanding special workmanship. At about the latter date, however, some engineers were specifying what was later known as medium steel for all parts of bridges, and nearly all were using it for eyebars.

F. H. Lewis' paper on Soft Steel in Bridges, read in 1892, did much to convince engineers that soft steel was as reliable as wrought-iron.

About 1894 structural wrought-iron passed out of the market and those who preferred it changed to soft steel, while those who had been using the higher grade of steel changed to medium steel, the division line between them being about 60,000 lbs. ultimate.

In 1903, a single grade with 60,000 ultimate was adopted by the American Railway Engineering and Maintenance of Way Association in its specifications for steel structures.

The present tendency is toward uniformity in types and details for given spans.

Plate girders are in general use for spans up to 65 ft. and to quite an extent for spans up to 100 ft.

With the increasing use of ballast floors, there is a tendency to the use of reinforced concrete for spans up to about 20 ft.

The riveted lattice girder for spans above the limit for the plate girder is giving way to the single intersection truss. This truss has riveted joints up to spans of 150 to 200 ft. and pin-connected joints in whole or in part for greater spans. As the span increases, the tendency is to use longer or subdivided panels rather than a double web system.

In the effort to eliminate the defects due to the loose joints and flexible tension members of the early pin-connected truss, the secondary stresses due to stiff joints and stiff members do not seem to be given sufficient consideration.

The experimental study of primary and secondary stresses which is being made on the Beaver bridge of the Bessemer & Lake Erie Railroad, the series of tests of the impact upon bridges due to trains at different velocities, and the investigations and tests of the strength of built-up compression members due to the failure of the Quebec bridge, will all tend to still further improve the practice in bridge design.

Appendix E.

REPORT OF THE SUB-COMMITTEE ON ALLOWABLE LENGTH OF FLAT SPOTS ON CAR WHEELS.

To the Members of the American Railway Engineering and Maintenance of Way Association:

In submitting its report to the last annual convention, the Sub-Committee felt that without an appropriation of funds sufficient to carry on some experimental investigation nothing further of interest or value concerning the effect of flat wheels on the roadway structures could be learned. It was expected, however, that the work of the Sub-Committee on Impact would develop some information of value, and we are now able to present a statement by that Sub-Committee concerning the impact of flat wheels on bridges. The Sub-Committee on Impact gave particular attention to this matter while carrying on some of its impact measurements and has now had sufficient time to review its data. The result of its study is embodied in the "Observations of the Effect of Flat Spots on Car Wheels on Bridge Stresses, made by Sub-Committee on Impact Tests," submitted herewith. These observations indicate a jarring or vibratory effect rather than a material increase in the unit stresses of the several bridge members. Such a result was to be expected, but the possession of tangible evidence of this effect is a material addition to our knowledge of the behavior of bridges.

In the general discussion concerning the effect of flat wheels, which has been carried on during the past year or two in the technical journals and various meetings, it has been asserted that under a rapidly moving train the fall of a car wheel due to a flat spot is so trifling that no serious blow could be delivered. For this reason the Sub-Committee has sought to procure some evidence of the magnitude of the blow from a flat wheel, and through the courtesy of Mr. A. W. Johnston, Past-President of the Association, and General Manager of the New York, Chicago & St. Louis Railroad, an attempt has been made to measure the force of the blow under working conditions.

For this purpose an 80,000-lb. capacity car was equipped with registering devices to measure the compression of the car springs and a pair of wheels with flat spots was placed in one of the trucks. A diagram showing the position of the flat wheels, the springs and the recording devices is shown in Fig. 1. The trucks were of the arch bar type and in the center of each nest of springs there was placed a small tube in which was inserted a steel pin fitted sufficiently tight to hold it in place, but capable of being forced upward when, through the deflection of the springs, it came in contact with a

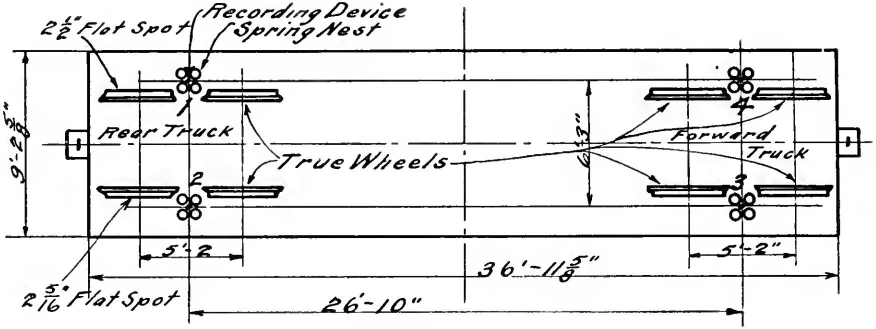


FIG. 1.

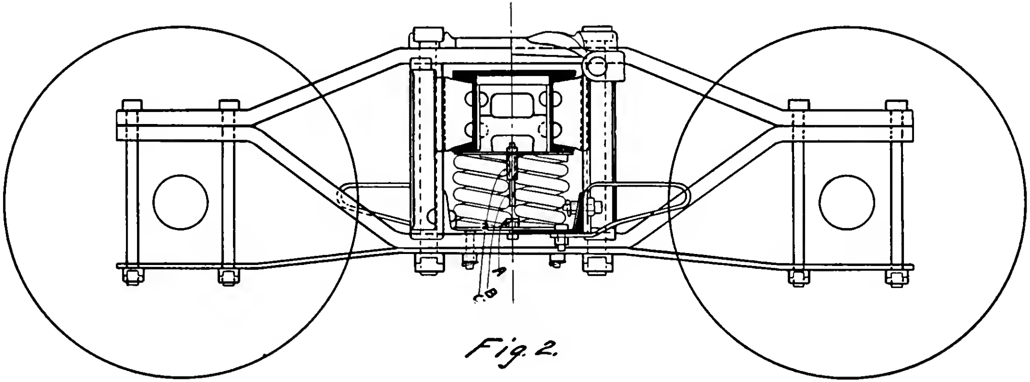


Fig. 2.

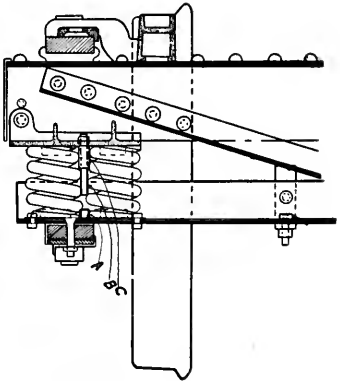


Fig. 3.

projection arranged at the bottom of the nest. This device is shown in Figs. 2 and 3.

Messrs. Blaser and Pallister, of the instructing force of the Case School of Applied Science, volunteered to calibrate the springs both before and after the test, and for this assistance the Sub-Committee expresses its hearty thanks. We are also indebted to President Howe of the above School for the use of the equipment of the testing laboratory. The report of the calibration of the springs is attached hereto. The observations of the test were made by Mr. G. H. Tinker, Bridge Engineer of the New York, Chicago & St. Louis Railroad, assisted by Messrs. Blaser and Pallister. The notes of the test are also attached hereto.

The car was carefully loaded with splice bars to its full capacity, the load being uniformly distributed throughout the car. The trucks were fitted with registering devices and the flat wheels placed in position, at the Conneaut shops. The car was then run to Cleveland and the test made on a piece of straight track in excellent condition between Cleveland and Lorain. At the beginning of the test the steel pins were driven down in the tubes until they came in contact with the aforementioned projection, which is lettered "A" on Figs. 2 and 3. The train was then run for a short distance, brought to a stop, and the displacement of the steel pin carefully measured with calipers. After this measurement, the pin was again driven down and the process repeated. In this manner seven different tests were made.

In the following discussion it is assumed that inasmuch as the springs and recording devices are located midway between the two pairs of wheels belonging to a single truck, if the wheels of one pair have flat spots, only half of the influence of those spots is recorded. This may not be precisely correct, but it seems the most reasonable assumption that can be made.

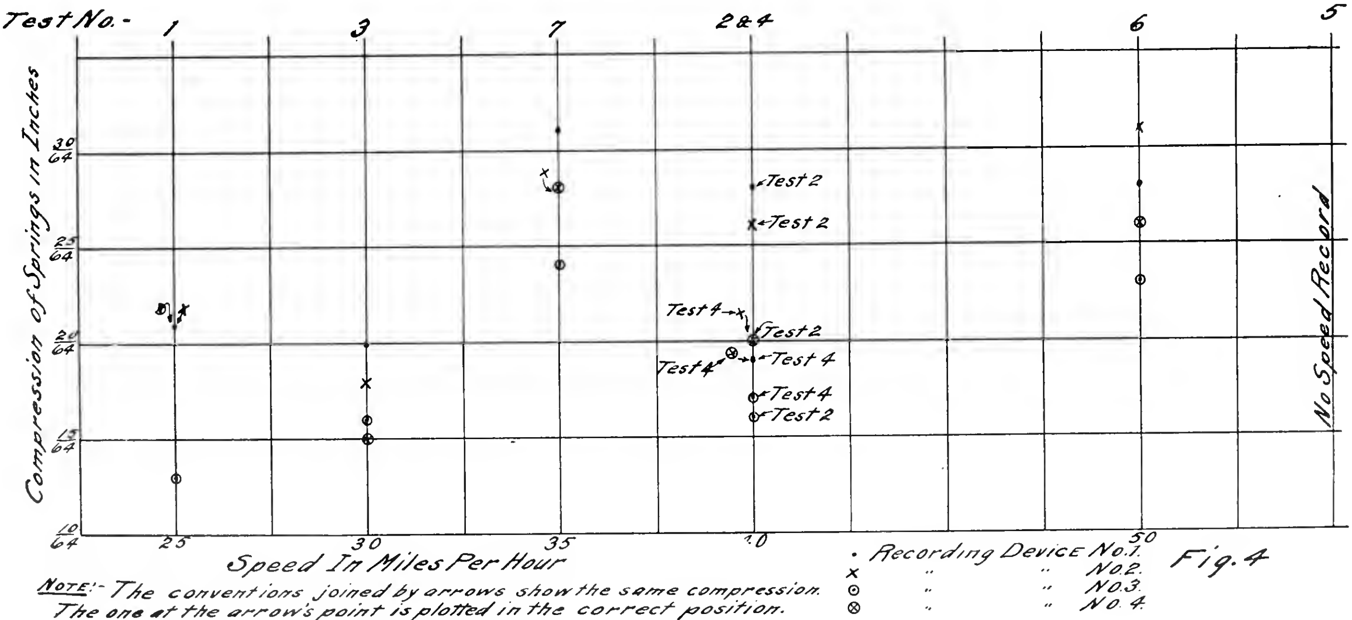
The deflection of the car springs is occasioned by many causes. First in importance is, of course, the load of the car. In addition to this every inequality of the track produces a swaying or lurching movement of the car body, which causes the springs to oscillate back and forth. Bad rails, particles of earth and stone on the rails, the starting and stopping of the locomotive, the change of speed of the locomotive, and the application of brakes all cause variations in the deflection of the springs. In order to avoid these effects as far as possible, the recording device was arranged so that it could be set at any given time and indications secured at any time thereafter, and a very smooth and straight piece of track was selected on which to make the tests. The speed record was secured by counting the joints as the train passed over them. The wheels having flat spots were placed in a lathe and found to be elsewhere perfectly circular and truly centered on the axles.

The readings taken in the calibration of the springs were plotted and connected by continuous lines, which proved to be parallel within the limits of the test. This means that a given change of deflection indicates a certain number of pounds, regardless of which nest of springs is considered and regardless of whether the calibration was made before or after the test. This is important, since we have to consider the differences of deflection rather than the total load. From these curves it was found that a load of 32,500 lbs. applied to a nest of four springs produced a compression of one inch. The loads shown in the following tables were read from the curves and if verified by calculation will be found slightly different from the calculated results.

In Table 6 is shown the values of all of the observed deflections in pounds. These are platted in Fig. 4 with speeds as abscissas and deflections in inches as ordinates. It should be carefully remembered that these are not total deflections but deflections caused by the motion of the car between the points of starting and stopping. The deflections shown for the truck with true wheels are therefore due entirely to the ordinary causes producing an oscillation of the springs. In the truck where the flat wheels were located the flat spots were an additional cause of oscillation. It is assumed that whatever difference may have occurred between the deflections in the truck with true wheels and in the truck in which the flat wheels were placed, was due to the flat spots.

In Table 7 the pressures indicated by the records of recording devices No. 1 and No. 2 are averaged and the pressures indicated by the records of recording devices No. 3 and No. 4 are averaged, and the differences of these averages shown in the fifth column. These differences show one-half of the influence of the flat wheels in the truck carrying recording devices No. 1 and No. 2. They were multiplied by two and shown in the sixth column as "Increase of Pressure on the Rail Due to Flat Spot."

There is some reason to doubt the accuracy of the record from device No. 4. The notes show that in this device the pin moved very easily and after a study of the results a suspicion arises that it may have moved far enough to indicate too great a deflection. By looking at Table No. 1 it will be seen that the excess of pressure indicated by device No. 2 over that indicated by device No. 3 generally exceeds the excess of pressure indicated by device No. 1 over the pressure indicated by device No. 4. By referring to Fig. 1 it will be seen that devices No. 1 and No. 4 were on the same side of the car and devices No. 2 and No. 3 were on the same side of the car. It is quite evident that there was some specific cause for the differences in pressure indicated on the two sides of the car. It may be wrong to assume that this cause was the comparatively loose pin, but we have no evidence of any other cause.



NOTE:- The conventions joined by arrows show the same compression. The one at the arrow's point is plotted in the correct position.

Fig. 4

Test No. 5 is not to be considered in the discussion because it was made, as stated in the notes, over several miles of track which included many curves and switches.

Considering that devices Nos. 2 and 3 were on the same side of the car and their pins had about the same degree of tightness, it is reasonable to suppose that the influences, other than flat spots, causing the springs to deflect, would be the same at each, and the comparison showing most truly the increased pressure due to flat spots is that made in Table 8. The pressure recorded by device No. 2 compared with that recorded by device No. 3 and arranged as in Table 2 shows an increase of pressure on the rail due to the flat spot as given in the sixth column, and is much greater than the similar values given in the sixth column of Table 7.

From a study of these tables it is apparent that the springs in the truck having flat wheels show a greater deflection than the springs in the other truck where the wheels had no flat spots; also that the increase of pressure on the rail due to a flat spot under the conditions of the test may amount to as much as 10,600 lbs.

The pressure shown in the table is of course the number of pounds pressure required to compress the spring the amounts mentioned in the tests. But it should be remembered that the impacts producing these deflections were made almost instantaneously and the effect is that of a blow and not a gradually applied load. This difference is very important since the steel of which rails are made is injuriously affected by blows.

The tests appear to be a sufficient demonstration that a flat wheel does actually deliver a very serious blow on the rail, and in conclusion we would say that while these tests may not be sufficient to change the opinions of those who hold that the present M. C. B. limit for flat spots of 2½ in. is sufficient for 100,000-lb. capacity cars, they certainly indicate an abuse of the track structure which is hard to excuse and which is of such serious moment as to demand the attention of this Association.

OBSERVATIONS ON EFFECT OF FLAT CAR WHEELS ON BRIDGE STRESSES MADE BY SUB-COMMITTEE ON IMPACT TESTS.

During the progress of the special impact tests the Sub-Committee on Impact made such observations as it could relative to the effect of flat spots on car wheels on the stresses in bridges. In one series of tests a car having a wheel with a very decided flat spot was purposely used, and in other tests wheels with flat spots were occasionally noted in the test trains. In one case the tires of the locomotive were badly worn and quite rough.

From these observations the Committee is unable to report any quantitative results. A distinct effect was noticeable on such members as stringers and floor beams. Where the track was smooth, and the wheels also, the record from the instruments attached to such members were generally clear and readable, even though the stresses under high speed might be largely in excess of those at low speed. In the case, however, of a rough track, caused by an open rail joint, or a flat or rough wheel, the passing train would produce such a "jarring" action on the stringer or beam that the measuring apparatus would be so shaken as to cause the parts to vibrate excessively, producing large and rapid vibrations in the record, thus rendering the diagram unreliable and, in many cases, quite worthless. Such diagrams would also commonly result where, for any reason, there was little or no elasticity between the rail and the beam. In one case where the rails were placed in steel troughs riveted directly to small cross-beams, the hip verticals were affected in this way. This effect would, however, seldom reach beyond the floor beams, and in the case of widely spaced stringers, would not always show up in the stringers. It would seem, therefore, that the "jarring" effect might not imply a very great increase in stress, but that there is some increase is undoubtedly true.

The effect of flat spots on main truss members of a bridge was not definitely noticed in any case, but there were several cases where a train of three or four heavily loaded freight cars in a test train caused vibrations of the whole structure quite as large, relatively to the static deflection, as those caused by the locomotive. This ffect was not noted in connection with any decided flat spots in the wheels, but in some cases, at least, it seemed to be caused by a vibratory motion of a car body due to some other cause. This vibratory motion appeared to be due rather to some eccentricity of the bearing or of the wheel than to any flat spots, although our observations were not extensive enough to enable us to make a definite statement on this point. The speed at which such truss vibrations occurred under the loaded freight cars was generally high, such as 50 to 60 miles per hour. No such vibrations were ever noticed under the cars of a passenger train. The difference in equipment was very evident in the character of the diagrams produced.

CALIBRATION OF CAR SPRINGS.

(Testing Laboratory, Case School of Applied Science, November 12, 1909.)

The helical springs to be calibrated were of 1⅛ in. round bars, inside diameter 3⅛ in., outside diameter 5⅜ in., approximate height 6⅝ in.

The sixteen springs were grouped into four sets of four each. The four springs of the first set have one punch mark on top and for convenience one on the bottom of each spring at the end of the flattened coil; the second set two punch marks each, similarly located, the third set three each, and the fourth set four each. The four individual springs in each set are numbered one, two, three, four. These numbers are punch marks on the side of the coil immediately opposite the set or group mark.

The springs were calibrated in a 200,000-lb. Olsen testing machine. The four springs of the first set were first calibrated individually and then as a nest of four. For individual springs readings were taken every 1,000 lbs. for the nests at intervals of 4,000 lbs. The individual springs were placed directly on the platen of the machine, were carefully centered, then received a large (10 in. x 10 in.) 2-in. thick cast-iron plate on top, a ball and a socket above this and another cast-iron plate over this. The nests had the same arrangement except that the top and the bottom nest plates were used to keep the springs properly spaced. The two cast-iron plates and ball and socket were used as above.

The deflections were read on the two deflectometers 180 degrees apart to take care of any tilting in the plate. The deflectometers were read to the nearest hundredths of an inch. They multiplied the actual deflections by 10, thus giving deflections to the nearest thousandths of an inch. Since the deflections were quite large, it was necessary after several readings to set the deflectometers back to zero and run up again. This had to be repeated several times in the course of one spring or of one nest. We believe, however, that the results are far better than any attempt at reading from a scale directly.

The tables herewith give the readings for the individual springs and for the nests.

TABLE NO. 1—INDIVIDUAL SPRINGS OF SET 1.

	SET No. 1			SET No. 2		
Load 1,000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average	Defl. No. 1	Defl. No. 2	Defl. Average
1,000	.090	.097	.093	.126	.135	.130
2,000	.212	.210	.211	.252	.251	.252
3,000	.324	.317	.320	.373	.367	.370
4,000	.423	.431	.427	.495	.489	.491
5,000	.532	.540	.536	.617	.607	.612
6,000	.643	.647	.645	.743	.728	.735
7,000	.762	.763	.761	.868	.855	.861
8,000	.889	.890	.890	.999	.981	.990
9,000	1.009	1.013	1.011	1.130	1.112	1.121
10,000	1.127	1.132	1.130	1.265	1.247	1.256
11,000	1.252	1.257	1.253	1.394	1.377	1.386
12,000	1.372	1.378	1.375	1.536	1.519	1.527
13,000	1.486	1.495	1.490	1.667	1.650	1.658
14,000	1.606	1.611	1.609	1.752	1.738	1.745
15,000	1.718	1.722	1.720	1.776	1.761	1.768
16,000	1.786	1.794	1.790	1.783	1.767	1.775
17,000	1.790	1.797	1.796	1.788	1.771	1.778

	SET No. 3			SET No. 4		
Load 1,000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average	Defl. No. 1	Defl. No. 2	Defl. Average
1,000	.105	.120	.112	.127	.131	.129
2,000	.218	.227	.223	.247	.248	.247
3,000	.329	.334	.331	.371	.372	.372
4,000	.444	.452	.448	.486	.485	.486
5,000	.561	.564	.562	.616	.602	.610
6,000	.684	.690	.687	.733	.713	.723
7,000	.792	.802	.797	.851	.830	.840
8,000	.906	.912	.909	.973	.955	.964
9,000	1.034	1.035	1.034	1.088	1.074	1.081
10,000	1.162	1.164	1.163	1.219	1.200	1.209
11,000	1.295	1.294	1.294	1.351	1.326	1.338
12,000	1.428	1.434	1.431	1.490	1.467	1.479
13,000	1.581	1.583	1.582	1.626	1.600	1.613
14,000	1.698	1.710	1.704	1.772	1.740	1.756
15,000	1.748	1.751	1.750	1.882	1.848	1.865
16,000	1.764	1.770	1.767	1.938	1.907	1.923
				1.948	1.910	1.928

TABLE NO. 1—RETURN READINGS AS LOAD WAS RELEASED.

SET No. 1				SET No. 2			
Load 1,000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average	Load 1,000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average
14,470	1.653	1.738	1.696	13,500	1.754	1.740	1.747
11,300	1.380	1.477	1.428	10,800	1.552	1.540	1.546
10,250	1.277	1.374	1.355	8,500	1.324	1.323	1.324
8,400	1.075	1.176	1.126	7,000	1.149	1.162	1.155
6,900	.895	.983	.939	5,000	.897	.920	.908
4,630	.648	.713	.680	3,850	.756	.778	.767
3,750	.530	.595	.562	2,000	.496	.526	.511
1,050	.145	.202	.174	1,300	.371	.406	.388
150	.031	.062	.046	500	.237	.288	.262
				100	.173	.214	.194
					.139	.186	.162

SET No. 3				SET No. 4			
Load 1,000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average	Load 1000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average
14,200	1.760	1.755	1.758	15,000	1.917	1.895	1.906
12,800	1.676	1.674	1.675	14,600	1.897	1.873	1.885
10,400	1.451	1.450	1.450	12,000	1.671	1.649	1.660
8,150	1.232	1.236	1.234	10,500	1.510	1.493	1.501
6,700	1.058	1.050	1.054	9,000	1.335	1.322	1.328
4,800	.850	.841	.846	7,000	1.124	1.108	1.116
3,500	.668	.655	.661	5,050	.889	.880	.884
2,000	.462	.445	.453	4,000	.733	.723	.728
900	.300	.275	.288	2,400	.531	.538	.535
300	.200	.185	.192	1,250	.350	.354	.352
100	.172	.146	.159	400	.211	.230	.220
000		.115	.115	50	.154	.171	.162
					.154	.139	.146

TABLE NO. 2—RETURN READINGS AS LOAD WAS RELEASED.

SET No. 1				SET No. 2			
Load 1,000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average	Load 1,000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average
48,000	1.879	1.702	1.790	42,000	1.719	1.673	1.696
45,000	1.809	1.638	1.724	34,500	1.526	1.479	1.502
36,000	1.602	1.448	1.525	28,000	1.325	1.291	1.308
30,600	1.416	1.257	1.336	21,500	1.124	1.089	1.106
18,000	1.037	.883	.960	15,750	.922	.904	.913
7,400	.651	.530	.590	9,500	.712	.699	.705
800	.245	.190	.218	4,250	.499	.503	.501
000	.145	.086	.116	800	.315	.324	.319
				100	.198	.238	.218
				000	.187	.225	.196

SET No. 3				SET No. 4			
Load 1,000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average	Load 1,000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average
60,500	2.096	2.127	2.111	49,500	1.849	1.873	1.861
50,500	1.917	1.953	1.935	41,500	1.641	1.670	1.655
42,400	1.715	1.758	1.736	34,700	1.449	1.477	1.463
35,000	1.524	1.563	1.544	28,000	1.242	1.292	1.267
28,200	1.329	1.374	1.352	21,700	1.052	1.114	1.083
21,500	1.135	1.271	1.203	15,000	.837	.909	.873
15,500	.932	1.076	1.004	10,000	.656	.727	.692
10,000	.743	.873	.808	4,500	.441	.517	.479
4,850	.530	.667	.598	1,000	.259	.334	.296
1,600	.357	.492	.424	200	.171	.226	.198
300	.239	.371	.305	000	.153	.150	.152
000	.127	.302	.214				

TABLE NO. 2—NESTS OF FOUR SPRINGS EACH.

	SET No. 1			SET No. 2		
Load 1,000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average	Defl. No. 1	Defl. No. 2	Defl. Average
4,000	.329	.266	.298	.248	.219	.234
8,000	.471	.406	.438	.383	.353	.368
12,000	.609	.547	.578	.533	.470	.502
16,000	.731	.669	.700	.617	.593	.635
20,000	.856	.789	.822	.746	.723	.704
24,000	.972	.901	.936	.873	.850	.816
28,000	1.099	1.026	1.062	.998	.977	.987
32 000	1.215	1.153	1.184	1.127	1.107	1.117
36,000	1.331	1.253	1.292	1.273	1.255	1.264
40,,000	1.472	1.393	1.432	1.407	1.385	1.396

	SET NO. 1—Continued			SET NO. 2—Continued		
Load 1,000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average	Defl. No. 1	Defl. No. 2	Defl. Average
44,000	1.598	1.518	1.558	1.549	1.532	1.540
48,000	1.712	1.627	1.669	1.726	1.704	1.715
52,000	1.840	1.754	1.797	1.882	1.855	1.868
56,000	1.945	1.852	1.898	2.038	2.006	2.022
60,000	1.974	1.872	1.923	2.067	2.029	2.048
64,000	1.982	1.880	1.931	2.090	2.040	2.065
68,000	2.074	1.881	1.978	2.114	2.050	2.082
72,000	2.087	1.882	1.984	2.134	2.060	2.097
76,000	2.192	1.882	1.992			
80,000	2.112	1.883	1.997			

	SET No. 3			SET No. 4		
Load 1,000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average	Defl. No. 1	Defl. No. 2	Defl. Average
4,000	.260	.264	.262	.230	.249	.239
8,000	.390	.425	.408	.353	.373	.363
12,000	.524	.561	.542	.471	.498	.484
16,000	.645	.680	.662	.588	.614	.601
20,000	.770	.804	.787	.712	.736	.724
24,000	.885	.925	.905	.832	.859	.845
28,000	1.004	1.039	1.022	.960	.985	.972
32,000	1.125	1.159	1.142	1.110	1.134	1.122
36,000	1.241	1.282	1.262	1.249	1.272	1.260
40,000	1.366	1.402	1.384	1.394	1.413	1.403
44,000	1.496	1.533	1.514	1.547	1.574	1.560
48,000	1.621	1.663	1.642	1.694	1.723	1.708
52,000	1.758	1.796	1.777	1.850	1.872	1.861
56,000	1.896	1.935	1.916	1.894	1.917	1.905
60,000	2.010	2.048	2.029	1.019	1.939	1.927
64,000	2.096	2.128	2.112	1.933	1.952	1.942
68,000	2.114	2.149	2.132	1.957	1.964	1.960
72,000	2.125	2.157	2.141	1.973	1.975	1.974
76,000	2.133	2.162	2.148	1.987	1.986	1.986
80,000	2.138	2.167	2.153			

TABLE NO. 3—NESTS NO. 2 AND NO. 4 (REPEATED).

	No. 2			No. 4		
Load 1,000 lbs.	Defl. No. 1	Defl. No. 2	Defl. Average	Defl. No. 1	Defl. No. 2	Defl. Average
4,000	.260	.250	.255	.286	.273	.280
8,000	.393	.389	.391	.413	.406	.410
12,000	.509	.506	.508	.531	.541	.536
16,000	.625	.620	.622	.646	.661	.653
20,000	.746	.737	.742	.770	.786	.778
24,000	.867	.862	.864	.902	.921	.911
28,000	.981	.978	.980	1.032	1.048	1.040
32,000	1.109	1.102	1.106	1.178	1.194	1.186
36,000	1.235	1.229	1.232	1.338	1.354	1.346
40,000	1.364	1.356	1.360	1.485	1.502	1.494
44,000	1.515	1.492	1.503	1.621	1.648	1.634
48,000	1.643	1.623	1.633	1.759	1.793	1.776
52,000	1.778	1.754	1.766	1.810	1.846	1.828
56,000	1.915	1.887	1.901	1.826	1.863	1.844
60,000	1.965	1.935	1.950	1.851	1.881	1.866
64,000	1.983	1.949	1.966	1.881	1.895	1.888
68,000	slip	slip	slip	1.906	1.904	1.903
72,000	2.090	1.915	2.002	1.927	1.909	1.918

REMARKS.

The springs were calibrated by applying the load gradually. No attempt was made at sudden application of load.

When the curves were plotted for the four nests, curves two and four showed some irregularities, and for that reason these two were repeated. The curves from the second trial are almost identical with those of the first.

By taking account of the initial deflection (as shown by producing the curve back to zero) the readings of the first set or nest agree very closely with the readings of the individual springs composing the set. For this reason it did not seem necessary to test the others individually.

FLAT SPOT TESTS, DECEMBER 15, 1909. GEO. H. TINKER, OBSERVER.

Car 27847, loaded with scrap iron. A. F. Blaser, Recorder.
2½-in. flat spot under Nest 1.
2 5/16-in. flat spot under Nest 2.
No flat spot under Nests 3 and 4.
Pin in Nest 1 very tight. Top injured in driving down.
Difficult to drive.
Pin in Nest 4 moved very easily.

Pins in Nests 2 and 3 moved with about equal ease, intermediate between 1 and 4.

Train consisted of engine, empty gondola, test car and caboose.

Tests were made on straight track without switches or frogs, except test No. 5. Pins closed down at beginning of each test, except No. 5, train speeded up and brought to rest, and separation of pins measured with calipers.

Test 1	Pin 1=21-64	2=21-64	3=13-64	4=21-64	Maximum Speed about 25 Miles per hour.
2	28-64	26-64	16-64	20-64	40 “ “ “
3	20-64	18-64	16-64	15-64	30 “ “ “
4	19-64	20-64	17-64	19-64	40 . “ “
5	37-64	28-64	31-64	30-64	
6	28-64	31-64	23-64	26-64	50 “ “ “
7	31-64	28-64	24-64	28-64	35 “ “ “

Test No. 5 was a run of several miles over track with curves and switches.

RECALIBRATION OF CAR SPRINGS.

Testing Laboratory Case School of Applied Science, January 27, 1910.

The method of procedure was the same in this calibration as in the former one. The arrangement of plates, ball and socket joint, etc., was identical. Deflection readings were taken at intervals of 4,000 lbs. up to 76,000 lbs. No readings were taken on individual springs. In removing the load several readings were taken, as indicated in the table.

The springs were identified by the punch marks described in the former calibration. They were grouped precisely as before and were placed in the same position in the machine. The deflectometers occupied the same places, that is, between springs No. 1 and No. 4, and between No. 2 and No. 3.

The deflections for a given load are a little smaller in this calibration than in the former one. This is readily seen from the figures in the table, but appears also by plotting the two curves of a set. The curve from the second calibration is slightly steeper. This is probably due to a slight set in the springs themselves, caused by the jolting of the car with flat-spot wheels. The deflections would also be slightly smaller, due to the difference in the zero reading (first reading), which is seen by producing the curves backward. This, however, would not make the curves steeper. A slight set in the springs would also account in part for the smaller total deflections.

A small difference in the zero reading would not effect the results of the experiment, though a set in the springs would effect the results.

TABLE NO. 4.

RECALIBRATION OF CAR SPRINGS, JANUARY 27, 1910.

	SET No. 1			SET No. 2		
Load	No. 1	No. 2	Average	No. 1	No. 2	Average
000	.000	.000	.000	.000	.000	.000
4,000	.275	.323	.299	.225	.294	.260
8,000	.402	.446	.424	.350	.410	.385
12,000	.518	.562	.540	.461	.514	.487
16,000	.635	.680	.657	.574	.627	.601
20,000	.749	.800	.775	.682	.740	.711
24,000	.864	.914	.889	.794	.850	.822
28,000	.978	1.030	1.004	.905	.955	.935
32,000	1.091	1.150	1.120	1.021	1.082	1.051
36,000	1.208	1.260	1.234	1.139	1.201	1.170
40,000	1.325	1.390	1.358	1.258	1.322	1.290
44,000	1.447	1.520	1.483	1.376	1.445	1.410
48,000	1.558	1.632	1.594	1.499	1.570	1.535
52,000	1.671	1.749	1.710	1.629	1.700	1.665
56,000	1.730	1.812	1.770	1.732	1.808	1.770
60,000	1.750	1.825	1.788	1.778	1.855	1.816
64,000	1.762	1.835	1.798	1.794	1.872	1.832
68,000	1.775	1.845	1.810	1.804	1.880	1.842
72,000	1.836	1.855	1.846	1.811	1.891	1.851
76,000	1.870	1.857	1.863	1.815	1.894	1.855

	SET No. 3			SET No. 4		
Load	No. 1	No. 2	Average	No. 1	No. 2	Average
000	.000	.000	.000	.000	.000	.000
4,000	.263	.315	.289	.249	.266	.257
8,000	.383	.442	.413	.370	.394	.382
12,000	.496	.556	.526	.482	.507	.494
16,000	.607	.676	.648	.592	.626	.609
20,000	.717	.786	.757	.700	.735	.718
24,000	.827	.902	.864	.810	.844	.827
28,000	.937	1.020	.978	.920	.963	.941
32,000	1.047	1.117	1.082	1.032	1.088	1.060
36,000	1.161	1.241	1.200	1.152	1.211	1.181
40,000	1.379	1.361	1.320	1.274	1.337	1.306
44,000	1.396	1.483	1.439	1.402	1.472	1.437
48,000	1.509	1.592	1.549	1.523	1.597	1.560
52,000	1.628	1.720	1.674	1.651	1.720	1.686
56,000	1.747	1.842	1.792	1.711	1.788	1.750
60,000	1.792	1.890	1.841	1.727	1.801	1.764
64,000	1.812	1.915	1.863	1.738	1.815	1.775
68,000	1.825	1.925	1.875	1.748	1.825	1.785
72,000	1.832	1.940	1.886	1.755	1.830	1.792
76,000	1.829	1.990	1.910	1.761	1.835	1.798

TABLE NO. 5.

DEFLECTIONS ON REMOVING LOAD.

	SET No. 1				SET No. 2		
Load	No. 1	No. 2	Average	Load	No. 1	No. 2	Average
76,000	1.870	1.857	1.863	76,000	1.815	1.894	1.855
56,500	1.839	1.835	1.837	54,000	1.738	1.820	1.779
44,000	1.619	1.615	1.617	45,000	1.550	1.625	1.587
40,500	1.535	1.532	1.533	38,000	1.368	1.441	1.404
33,000	1.338	1.325	1.331	31,000	1.171	1.235	1.203
27,600	1.167	1.158	1.162	24,000	.970	1.060	1.015
20,000	.957	.936	.946	17,000	.761	.848	.804
14,500	.792	.781	.786	12,000	.580	.675	.627
9,000	.590	.606	.598	5,500	.372	.465	.418
4,800	.405	.451	.428	1,300	.189	.298	.243
1,500	.255	.304	.280		.001	.012	.006
100	.120	.150	.135				
	.055	.069	.062				

SET No. 3				SET No. 4			
Load	No. 1	No. 2	Average	Load	No. 1	No. 2	Average
76,000	1.829	1.990	1.910	76,000	1.761	1.835	1.798
55,000	1.752	1.910	1.831	47,000	1.608	1.682	1.645
46,500	1.573	1.722	1.648	39,000	1.408	1.482	1.445
39,000	1.391	1.533	1.462	32,000	1.214	1.283	1.249
31,300	1.192	1.325	1.258	26,000	1.040	1.108	1.074
25,500	1.026	1.158	1.092	19,200	.854	.908	.881
18,300	.822	.941	.882	13,500	.676	.726	.701
13,200	.655	.777	.717	7,200	.458	.487	.473
7,400	.472	.570	.521	4,000	.372	.358	.363
3,500	.330	.406	.368	200	.124	.135	.130
400	.110	.119	.115		.013	.011	.012
	.060	.035	.047				

Table shows calibration of four sets or nests marked Set No. 1, Set No. 2, etc. Columns headed No. 1 and No. 2 refer to two deflectometers 180 degrees apart.

TABLE NO. 6.

Test	Speed, Miles per Hour	Recording Device No. 1		Recording Device No. 2	
		Deflection	Load, Lbs.	Deflection	Load, Lbs.
1	25	21-64=.328	10,800	21-64=.328	10,800
2	40	28-64=.437	14,200	26-64=.407	13,300
3	30	20-64=.312	10,000	18-64=.282	9,000
4	40	19-64=.297	9,500	20-64=.312	10,000
5	..	37-64=.579	18,700	28-64=.4375	14,300
6	50	28-64=.4375	14,300	31-64=.485	15,800
7	35	31-64=.485	15,800	28-64=.438	14,300

TABLE NO. 6.

Test	Speed, Miles per Hour	Recording Device No. 3		Recording Device No. 4	
		Deflection	Load, Lbs.	Deflection	Load, Lbs.
1	25	13-64=.203	6,700	21-64=.328	10,800
2	40	16-64=.25	8,000	20-64=.312	10,000
3	30	16-64=.25	8,000	15-64=.234	7,700
4	40	17-64=.265	8,700	19-64=.296	9,500
5	..	31-64=.485	15,800	30-64=.468	15,200
6	50	23-64=.36	11,600	26-64=.407	13,300
7	35	24-64=.375	12,100	28-64=.4375	14,300

TABLE NO. 7.

Test	Speed, Miles per Hour	Average Compression Shown by Devices No. 1 and No. 2 Lbs.	Average Compression Shown by Devices No. 3 and No. 4 Lbs.	Difference of Averages	Increase of Pressure on Rail Due to Flat Spot
1	25	10,800	8,750	2,050	4,100
2	40	13,750	9,000	4,750	9,500
3	30	9,500	7,850	1,650	3,300
4	40	9,750	9,100	650	1,300
5	..	16,500	15,500	1,000	2,000
6	50	15,050	12,450	2,600	5,200
7	35	15,050	13,200	1,850	3,700

TABLE NO. 8.

Test	Speed, Miles per Hour	Compression Shown by Device No. 2 Lbs.	Compression Shown by Device No. 3 Lbs.	Difference	Increase of Pressure on Rail Due to Flat Spot
1	25	10,800	6,700	4,100	8,200
2	40	13,300	8,000	5,300	10,600
3	30	9,000	8,000	1,000	2,000
4	40	10,000	8,700	1,300	2,600
5	..	14,300	15,800	1,500	3,000
6	50	15,800	11,600	4,200	8,400
7	35	14,300	12,100	2,100	4,200

DISCUSSION.

The President:—The Committee on Iron and Steel Structures will please come to the platform. Mr. J. E. Greiner is chairman of the Committee. This is a very valuable report. I would ask Mr. Greiner, the chairman, to make a statement in reference to how he wishes to put it before the meeting in order to get the best results.

Mr. J. E. Greiner, Chairman (Baltimore & Ohio):—Mr. President and gentlemen, this report on Revision of the Manual refers to the revision of the specifications for bridges, divided up into two groups. The first group refers to minor changes which do not affect in any manner the sense or meaning of the original clauses in the specifications; they are simply minor changes in wording or punctuation, or reconstruction, in order to make the reading a little clearer. The second group are changes of more or less importance. There is nothing really radical. It merely means that we have brought these specifications up to the present time, the present standard of good practice, as any bridge specification necessarily must be revised every three or four years. These have been published now for three years, and we have brought them up to date. There are, of course, some changes here which will, perhaps, bring forth a little discussion, but I can say on behalf of the Committee that there has been no change made except after a very careful consideration and after a very thorough discussion, and perhaps with one exception every change that we have made has met with the full approval of the entire Committee. In regard to these minor changes I would suggest that they be accepted by the Association without any discussion, unless someone sees something which is incorrect or could be better expressed.

(Upon motion, duly seconded and carried, group 1 of the changes was adopted without discussion.)

The President:—The Secretary will read paragraph 2 as proposed to be changed. He will read first the present rendering and afterward the proposed change.

Mr. Greiner:—I move the adoption of revised clause No. 2.

(The motion carried.)

(The Secretary read the first two paragraphs on page 6 of Bulletin 117.)

Mr. Greiner:—In regard to the proposed change in the first two paragraphs on page 6 of Bulletin 117, the only practical difference is that we made the height one foot more than before. It was 21 ft. before, and we thought it advisable to make it 22 ft. We have illustrated the clearance by means of a diagram. The change is really of no great importance.

Mr. G. A. Mountain (Canadian Railway Commission):—According to the railway act, bridges built in Canada are required to be 22 ft. 6 in. from base of rail, the idea being to give 7 ft. over the running board of the highest car. I would like to ask the Committee how they get it 22 ft.; if they have any cars that would exceed that?

Mr. Greiner:—I think 22 ft. will conform with the laws in this country. Some of the laws here, I think, make it lower, requiring 21 ft. above the top of the rail. In order to be safe we made it 22 ft. This merely means the minimum clearance. If there are no other restrictions, you could make it as high as you want.

The President:—I think what Mr. Mountain wants to get at is that based on so many feet above the top of the running board of the highest freight car.

Mr. Mountain:—The highest freight car, or furniture car, for instance, from the running board. I figured it out and could not get it down more than 22 ft. 3 in. I do not know what road it was on.

The President:—According to the system in your country the 22 ft., as given by the Committee, would suit.

Mr. Mountain:—No; 22 ft. 6 in. from the base of rail. It was originally made 22 ft. 6 in. I think that was the top of rail. I changed that to base of rail.

The President:—What is the legal height now?

Mr. Mountain:—Twenty-two ft. 6 in. from base of rail.

The President:—Well, that is practically the same.

Mr. Mountain:—Yes; I beg pardon. It says top of rail.

Mr. Greiner:—I think the majority of the roads in this country have established 21 ft. from the top of the rail.

The President:—If there be no objection to these clauses we will take them up and regard them as passed without putting them in the form of a resolution. Paragraph 2 is accepted. The Secretary will read paragraph 6.

Mr. Greiner:—The only change in paragraph 6 is that we have added to the original the clause "Reinforced concrete 150 lbs. per cu. ft." The rest is just the same.

The President:—Paragraph 6 stands.

Mr. Greiner:—In explanation of the change in paragraph 13, we will say that the original clause was a little indefinite, and we thought that it would be better to fix the degree of curve for which centrifugal force should be calculated. That formula simply means that for a 10-degree curve the speed is 35 miles an hour, and on a tangent it is 60 miles an hour, which in our opinion is ample provision for the centrifugal force in connection with the other forces.

Mr. T. L. Condron (Consulting Engineer):—Is it intended that the impact formula shall be applied to this load, which is treated as live load?

Mr. Greiner:—No.

Mr. Condron:—It says, "shall be considered as live load." Live loads are subject to impact formula.

Mr. Greiner:—I think you will find in the specification we state that the impacts are not to be applied to centrifugal force. I think that is taken care of.

The change in paragraph 16 is limiting the original compression formula to 14,000 lbs. In the old specification we used a simple straight-line formula without any maximum, and we thought it advisable to fix that maximum at 14,000 lbs., pending the results of bending tests on full-size members which are now being undertaken. Then there is another addition to the paragraph which gives a unit stress of 16,000 lbs. for steel castings. These are not in the original specification.

Mr. Howard G. Kelley (Grand Trunk):—I wish to make an inquiry of the Committee. As to adopting a maximum of 14,000 lbs., is that based on any series of experiments? The reason I ask is, that for a number of years in using a similar formula, I have been limiting it so that it gave me 13,500 as the maximum. Before raising it, I would like to know on what basis the 14,000 was obtained. It may be better than the 13,500.

Mr. Greiner:—It was simply a compromise. There are not enough tests made on steel compression members at the present day to enable us to settle that with any degree of certainty. Our old formula would allow 16,000, or pretty near it, for short columns. We felt on the line of conservatism it would be better to reduce that 2,000 at any rate. Some members of the Committee thought we should go down to 12,500, but we compromised on 14,000, pending the results of the full-sized tests that are being undertaken.

As to paragraph 17, the old specification for bending did not provide any bending on steel castings. We made the addition of 16,000 lbs. for bending steel castings.

As to paragraph 19, the old specification gave a bearing value of 600 lbs. per sq. in. on granite masonry and Portland cement concrete, and 400 lbs. per sq. in. for sandstone and limestone. We have simplified that by making a uniform bearing value of 600 lbs. on masonry.

(Paragraphs 19-a and 19-b were approved as read.)

Mr. Greiner:—As to paragraph 21, the only change is from "70 per cent." in the old specification to "two-thirds" in the present specification. These specifications provide that 70 per cent. of the dead load will be considered as counteracting the live load in counter stresses. In order to take care of the 50 per cent. overload we have changed that to 66⅔ per cent., which is perhaps more consistent with our general practice.

(Paragraph 27 was adopted as read.)

Mr. Greiner:—As to paragraph 28, in the old specification we gave a formula of 16,000—200 l/b for the maximum length of the compression flange of the girder. That applies to girders when flanges are composed of angles and flat plates. We thought in this revision that we had better take care of other kinds of girders, such as crane girders which have channel flanges and which are rather long and without lateral support, and that is the object of this change here, to make it 16,000—150 l/b when the cover consists of a channel section.

The President:—It is natural to assume that the Committee is a unit in regard to these findings. Is there any discussion on paragraph 28? If not, we will pass it and go to the next section.

Mr. Greiner:—The Committee would like to make a slight change in paragraph 45, as there has been some question as to whether the shearing stresses should be determined from a uniform load, or from a concentrated load. In order to clear up that point we would like to add after the word "flexure" the words "uniform load," so that it shall read "shall be proportioned to resist the shearing stresses corresponding to the allowance for flexure for uniform load provided in the column formula," etc.

The President:—The question to be considered is paragraph 45 with that addition, "flexure for uniform load." If there is no discussion the clause will be approved.

Mr. Greiner:—The change in paragraph 46 is very slight, simply changing from 5/8-in. rivet shall not be less than 2½ in. wide, to make it read ¾-in. rivets. The interpolation of the words "at least" between the word "with" and the word "two" in the next to the last line of that paragraph is also a slight change which we propose.

The President:—If there is no objection paragraph 46 will be accepted as given in the report. Clause 51 is really a minor change and is adopted.

Mr. Greiner:—In paragraph 60, the change simply means that segmental rollers have to be attached to the bed plates in such manner that they cannot upset or topple over.

Paragraph 66 was changed on account of the gradual increased weight of our moving loads, so as to take care of that in the future; 7/16-in. has been perhaps safe enough and all right for the ordinary loads, perhaps the minimum loads, as called for under these specifications, but we are getting up to 60 and we had better increase that load.

(Paragraph 77 was adopted as read.)

Mr. Greiner:—As to paragraph 79, the old rule, one that has been in quite general use, was to increase the length of the top chord one-eighth of an inch for every 10 ft., in order to provide for camber, but it is a sort of rule of thumb that is not considered except in small spans. It is all right for a very small span, but when you get up to 400 or 500 ft. spans you must take care of the camber in the manner provided here.

Mr. C. E. Lindsay (New York Central & Hudson River):—Would not the word "straight" better express that than the word "level?"

The President:—The Committee accepts the suggestion.

Mr. Greiner:—There is a slight change in paragraph 80. We have simply added the words, "two end panels." In the old specification we said that the two end panels up to 300 ft. shall be rigid.

Paragraph 84 is merely the correction of a typographical error.

(Paragraphs 84-a, 91, 93, 111, 118, 119 and 120 were adopted.)

Mr. Greiner:—The reason for the change in paragraph 120 is to avoid small pieces of drillings adhering to the metal on account of the oils and lubricants used in the drilling process, and it makes a better job.

Paragraph 126 gives two methods of making ends of stringers and floor beams, and it is really not radical in any way, simply good practice. There is a small change in there the Committee would like to make. In the fifth line after "riveted in place," the word "and" ought to be omitted in the sub-title, and the brackets should be placed at the end of the paragraph instead of at the end of the sentence before.

(Paragraph 126, with the changes recommended, was adopted. Paragraphs 127 and 129 were adopted as read.)

The President:—The chairman will please explain paragraph 132.

Mr. Greiner:—This is simply limiting the thickness of the templet. In the old paragraph it said, "holes for floor beams and stringer connections shall be punched and reamed to a steel templet one inch thick." We say, "not less than one inch thick."

The President:—Paragraph 132 is adopted.

(Paragraphs 140, 142, 146 and 158 were adopted as read.)

The President:—Mr. Schneider will please explain paragraph 160.

Mr. C. C. Schneider (Consulting Engineer):—This change was made in order to have a uniform grade of steel for all members of a bridge. The process of annealing reduces the ultimate strength of the eye-bars and, therefore, the material as it is rolled requires a higher ultimate strength in order to fill the requirements of the specifications in the full-sized annealed eye-bars. As the manufacturer has to guarantee the strength of the finished eye-bars, it was thought advisable to let him determine the ultimate strength of the test specimen.

(Paragraph 160 was adopted as read.)

Mr. Greiner:—There is a small change in paragraph 133 that the Committee would like to make in addition to those which have already been suggested. The last part of that paragraph, in order to make it consistent with 160, we want to change so as to read, "the manufacturer shall guarantee the bars to meet the requirements of paragraph 160."

In paragraph 160 we want to interpolate the word "generally" in the third sentence, which reads now "bars shall break in the body." We want to say "bars shall generally break in the body." Because we make provision later on that unless more than one-third of them break in the head it will not be cause for rejection.

(The Secretary read the "Points to be specifically determined by buyers when soliciting proposals for steel railroad bridges."

The President:—In the absence of objection, the change will be made.

Mr. Kelley:—I want to refer to paragraph 127 and ask the Committee if there should not be a change in that paragraph. I think it is quite specific, but I want to know if that is what it means, whether this is limited. I will, of course, defer to the Committee on that, because they have given it special attention. My own idea is that it may not be necessary to limit to such a narrow limit as this would give; in a girder five feet deep it will cut out a ⅜ths web, and as worded it applies alike to deck and through girders.

Mr. Schneider:—The present specification limits the thickness of web-plates for plate girders to ⅜-in., regardless of the size of the girders. The change made in the new version of limiting the minimum thickness of web-plates to 1/60 of the unsupported distance between flange angles is in line with the tendency of the present time to increase the thickness of web-plates and provide for a future increase of live loads. Some railroad companies already limit the minimum thickness of web-plates for all plate girders to ½-in., which I think is a move in the right direction to produce more substantial work.

Mr. Greiner:—You should also take into consideration the fact that while we have many plate girders now with ⅜ths and 5/16ths web, a number of them were built for much lighter loads. Three-eighths webs are undoubtedly giving good service now for the lighter loads; but as we have increased the loads and nearly everything else it is no more than consistent to increase the webs also.

Mr. Chas. S. Churchill (Norfolk & Western):—I want to refer back to paragraph 119, increase of load on masonry. It occurs to me that may be a step backward, due to the fact that loads are increasing; I mean the jars from impact. It is not strictly correct to say that sandstone and limestone bases are equal to granite.

Mr. Schneider:—The present specification gives the permissible pressure on concrete masonry and Portland cement concrete as 600 lbs. per sq. in., and for sandstone and limestone 400 lbs. per sq. in. At the time when the steel work of a bridge is designed and the dimensions of the bed-plates are determined it frequently happens that the kind of material for the coping upon which the bed-plates rest has not yet been determined. It was therefore deemed advisable to specify only one pressure, more particularly as it is the opinion of the Committee that 600 lbs. per sq. in. is low enough for all classes of masonry.

Mr. Greiner:—There was another reason; we wanted to be consistent with the Masonry Committee's recommendation.

Mr. J. P. Snow (Boston & Maine):—I assume that when this specification is finally printed by the Secretary, the sub-letters will be dropped out and the paragraphs numbered consecutively.

Mr. Greiner:—That will be a good thing, if we are going to begin all over, new; but there are hundreds of these specifications all over the country, and if we renumber these paragraphs, the people using the old specifications will have to do considerable work to find out where the changes are, but if we number them as they are in this pamphlet they can see changes at a glance. I do not think, however, that the Committee has any objections to renumbering them.

Mr. Snow:—I think it will be necessary for anyone using the specifications to refer to the year of issue. The old addition was of the year 1906, and this will be 1910, and it will be absolutely necessary, if it is referred to in a request for a price on a bridge, to refer to the edition. In fact we have had to do that in the past, because there are one or two preliminary editions previous to 1906. It is very little trouble, and it would seem to me it would make much better specifications to number them consecutively and let the thing work itself out.

Mr. Greiner:—The Committee will accept that suggestion.

The President:—We will now take up the conclusions.

(The Secretary read conclusion 1.)

Mr. L. C. Fritch (Chicago Great Western):—I would like to know if the Committee would be willing to change the signs for tension and compression, using minus for tension and plus for compression.

Mr. Greiner:—I will say some of the Committee have used minus for compression and plus for tension, and others reverse them. But the professors have beaten us out. They use plus for tension and minus for compression in all the textbooks, and it has become the general practice now and I think we shall have to fall into line.

Mr. L. C. Fritch:—I think that every reason points to using the minus sign for tension.

(Conclusion 1 was adopted. The Secretary read conclusion 2.)

Mr. Greiner:—This section has been under consideration for several years. The Committee felt that rules for governing the inspection of bridges in the field should be very carefully considered and expressed, and so far as possible in such a manner as not to commit either this Association or the individual railroads which would use this rule to any great extent. Inspection of bridges must necessarily, of course, depend on the character of the bridges and the organization of the roads which control the inspection, and while our first report, the one that was submitted last year, was much more complete and went considerably more into detail than this report, the Committee felt it said too much and we thought we had better be a little more conservative, and the result was the adoption of this report, which is the report of the full Committee without any dissension.

(The Secretary read the clauses relating to Inspection of Bridges.)

Mr. Greiner:—I move that conclusion No. 2 on Care of Existing Bridges be adopted.

(The motion carried. The Secretary read conclusion 3.)

Mr. Greiner:—Conclusion 3 states that the matter relative to the erection of railroad bridges has merely been submitted for purposes of information and discussion from the members of the Asssociation. It is expected that the final report on this subject will be made at our next convention, and as it is one wherein the practices of the different roads vary to a considerable extent, the Committee would like to hear of any criticisms that may be offered. I move that it be referred back to the Committee for further consideration.

The President:—The Committee would appreciate an expression of opinion on some of the points brought out in this section, if anyone is prepared to discuss it.

Mr. Snow:—I think that a specification for this purpose should be pretty much in outline, concise and short, something similar to what the Committee has given us in the way of directions for the care and inspection of existing bridges. I think that is most excellent, and I am really proud of my old comrades in arms that they have reached such a conclusion on this very difficult subject. I think the subject of erection should. be treated in the same way.

(The motion to refer this section back to the Committee was adopted.)

Mr. Greiner:—Conclusion 4 is: "That the review of the development of bridge building in America be accepted." I move its acceptance.

(The motion carried.)

Mr. Greiner:—Conclusion 5 is: "That the report on reinforced concrete vs. steel be accepted." This report has not been presented without considerable discussion on the part of the Committee. We have in our Committee, as I suppose is the case with all other committees, men who are almost daffy on certain subjects, and it is pretty hard to keep them within limits at all times, but I think this report is fairly conservative and is really worth discussion by some of the members.

I would like to ask some of the reinforced concrete men present what kind of a railroad bridge they could construct of reinforced concrete in the shape of a slab for a span of 40 or 50 ft. Has anyone every designed one? Perhaps Mr. Condron has. Mr. Condron, have you designed one up to 40 ft.?

Mr. Condron:—I have designed up to 30 ft.

Mr. Greiner:—The Committee feel that 40 ft. is about the limit.

The President:—Some of you gentlemen may, after the meeting is over, wish you had said something, and you will have lost the opportunity.

(On motion, the conclusion was accepted as information.)

The President:—The subject of impact will now be taken up, and I ask the chairman if he has any statement to make.

Mr. Greiner:—Of all subjects that have been given this Committee for investigation and report, that on impact is the most important, not only from the scientific results which were expected, but which have been actually obtained.

The Committee has been very fortunate in having among its members investigators who have given attention to this subject, and when you hear of some of the results which have been accomplished by Professors Turneaure and Crandall, and their associates on the sub-committee, Messrs. Schneider and Cartlidge, you will just begin to realize the immense amount of work which has been done and the scientific value of that work. I will ask Professor Turneaure to outline to the Association what has been accomplished.

Prof. F. E. Turneaure (University of Wisconsin):—It would be impossible to read the report here, of course, but a brief statement of the scope of the work may be in order. The report is prefaced by the following statement:

The Sub-Committee on Impact presents herewith a report covering the work of the past three years. This report is not to be considered a final one upon the subject, but the experiments which have been conducted have been fairly comprehensive except for long spans, and it is the intent of the Committee to present a report which shall include a full account of the tests, the detailed results and such a discussion of the same as appears to be warranted at this time. Results of other tests have been briefly noted, but are not discussed. The subject of secondary stresses has not been touched upon farther than to present a few typical results obtained as incidental to the main experiments.

The Sub-Committee is not prepared at this time to recommend an impact formula for general use in specifications. It has seemed proper, however, in presenting the results of the tests which have been made, to express the law of maximum impact, as thereby developed, by a formula, and this has been done. It should be noted that the impact percentages, herein discussed, relate to the variations in the axial stresses in the members, and do not include the element of secondary stress. The few results on secondary stresses noted herein, as well as measurements of such stresses by other experimenters, indicate that they are very important and require careful consideration in the selection of working stresses used in design. The element of secondary stress may or may not be included in a single formula with that of impact. This is a question which must be considered in making recommendations of an impact formula.

The report is divided into seven sections, as follows:

Section 1. Account of the work of the Sub-Committee; (a) organization and history of the work; (b) instruments employed; (c) structures tested and railroads assisting in the work; (d) test trains; (e) general method of conducting the tests.

Section 2. Detailed results of tests.
Section 3. Discussion of results.
Section 4. Summary of results.
Section 5. Results of other experiments.
Section 6. Secondary stresses obtained during the tests.
Section 7. Theoretical analysis.

There are some ten main tables, each of which consists of several sheets; also some twelve plates. I might state briefly some facts relative to the railroads which have assisted in the work.

In determining upon a program of work it was assumed at the outset that the desired results could be secured only by the use of special test trains which could be available for several hours at any particular structure. To depend upon trains in regular traffic would, for several reasons, have been impracticable. This requirement involved large contributions in the way of track and train service on the part of the railways assisting directly in the work. However, the Committee takes much pleasure in recording the fact that during the three years over which the experiments have been extended the facilities offered by various railroad companies have been much greater than could be utilized, and desires to extend its thanks to the many officials who have shown so large an interest in this work. Limitations of time, convenience of location, and the nature of the structures available led finally to the carrying out of tests on the following roads: Illinois Central; Chicago, Burlington & Quincy; Chicago, Milwaukee & St. Paul; Chicago, Rock Island & Pacific; New York, Chicago & St. Louis; Atchison, Topeka & Santa Fe; Pennsylvania Lines; Norfolk & Western, and New York Central. In all cases these roads furnished, free of charge, a special test train and all needed assistance in the way of laborers and mechanics. Every effort was made to facilitate the task, and the thanks of the Committee are due the several managements for the valuable courtesies extended.

The number and kind of structures tested included 21 plate girder spans and 24 truss spans, classified as to length as follows:

Plate Girders.	No. Tested.
Under 50 feet	7
From 50 to 75 feet	8
From 75 to 100 feet	6
Truss Spans.	
Under 100 feet	1
From 100 to 150 feet	12
From 150 to 200 feet	6
From 200 to 250 feet	3
Over 250 feet	2

The following summary of results relates only to the series of tests which have been made by the Sub-Committee:

(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 structure 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 percentage determined from measurements of deflection, but both values follow the same general law.

(6) 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 maximum impact percentage as determined by these tests is closely given by the formula

$$I = \frac{100}{1 + \frac{l^2}{20000}}$$

in which $I =$ impact percentage and $l =$ span length in feet.

(9) The effect of difference 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 indicate 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.

(10) 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.

(11) 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.

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

(13) 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 report includes a number of photographs of typical curves, illustrating various points of the report, diagrams of the impact percentages on all of the trusses, diagrams of maximum impact with the curves plotted thereon, and sheets of data. The original diagrams are now filed in the Secretary's office, where they can be inspected by anyone interested.

The future work of the Committee, so far as it has been planned, includes some additional work on spans exceeding 300 feet in length, and, if practicable, on very short spans. It has been found very difficult to devise an instrument which will be entirely satisfactory for spans 20 or 30 feet in length, but if that can be done it is very desirable to continue experiments on such spans.

The President:—I am sure you will agree with me that we have some very valuable information before us in this particular form; it will be in print as early as possible and you will receive a copy of it.

Mr. Greiner:—I move that this report on impact be accepted at the present time, merely as a progress report, although it is almost complete, and that the Committee be continued with instructions to make further investigations on impacts on long spans and very short spans and also on the investigation of secondary stresses.

Mr. L. C. Fritch:—I second the motion of Mr. Greiner.

Mr. McDonald:—I would suggest that slabs be included.

Mr. Greiner:—That was our intention.

Mr. Kelley:—I feel that the Association should express its appreciation of the work done by Prof. Turneaure and his associates in the conduct of these experiments in a manner more emphatic than is done by the ordinary vote of thanks. I move that a vote of thanks be given Prof. Turneaure and his associates for the valuable work which they have offered free for the use of this Association and the railroads of this country.

The President:—Gentlemen, you have heard Mr. Kelley's motion, duly seconded, expressive of the deep thanks of this Association to Prof. Turneaure and his associates for the work they have done on this subject of impact.

(The motion was put to a vote and unanimously carried.)

The President:—Prof. Turneaure, I have much pleasure in tendering you, in behalf of the Association, its thanks for the work you and your associates have done in connection with this subject of impact.

Mr. Greiner:—The last subject that this Committee was instructed to investigate during the past year was the allowable length of flat spots on car wheels, and the effect of flat spots on car wheels on bridge structures, which is reported on in Bulletin 121 by Mr. A. J. Himes, of the New York, Chicago & St. Louis Railroad, chairman of the Sub-Committee on this subject, and it is found on reading the report that there has been considerable investigation made and there is no question as to the effect of flat spots 2½ in. in length being rather severe on bridge structures. This, of course, is not conclusive, as the tests have not been completed. The Committee expects during the next year to make further tests on that question, and hopes to get more definite conclusions by the time of the next annual convention.

I, therefore, move that this report be accepted as a progress report, with instructions to the Committee that they continue their investigation.

(The motion was put and carried.)

The President:—The Committee is relieved with the thanks of the Association, and I wish personally to congratulate the Committee on the excellent report which it has presented.

REPORT OF COMMITTEE VII—ON WOODEN BRIDGES AND TRESTLES.

(Bulletin 118.)

To the Members of the American Railway Engineering and Maintenance of Way Association:

BRIEF REVIEW OF THE REPORT OF 1909.

Standard specifications for Bridge and Trestle Timbers were submitted, and after further amendment in accordance with the recommendation of the Committee, were adopted. (See Proceedings, Vol. 10, pp. 539-541.) The amendment included the elimination of Douglas fir and Western hemlock, for which separate specifications were to be prepared. In connection with the specifications the following conclusion was adopted: "That it is preferable to make the inspection of bridge and trestle timbers at the mills." The revised specifications for Timber Piles were adopted (see Proceedings, Vol. 10, pp. 541-542), as well as the standard names for Structural Timbers as printed in Proceedings, Vol. 9, page 358 (see Proceedings, Vol. 10, page 609).

The concluding portion of the results of studies on timber tests extending over a period of years was presented in the report. It contained six diagrams showing the variation in the strength of structural timbers based on the U. S. Forest Service tests, eleven diagrams comparing the average values of tests on large sticks, according to various authorities, an abstract of Talbot's tests on full-size stringers, and some tests on redwood, made at the University of California. The object of these studies was to prepare a list of working unit stresses, and the table giving recommended unit stresses for 12 species of structural timber was adopted (see Proceedings, Vol. 10, pp. 543-564).

There was also submitted as a report of information the first installment of a study on Piles and Pile Driving, which included a series of definitions; historical notes; illustrations of various types of wooden and steel sheet piles; a summary of replies to two circular letters relating to the use of different drivers, weights of hammers, and the use of water jet, caps, shoes, and followers; an essay on over-driving piles; and a classified bibliography on the subject, covering 14 pages of text (see Proceedings, Vol. 10, pp. 565-578).

REVISION OF THE MANUAL.

The contents of the Manual of Recommended Practice, relating to Wooden Bridges and Trestles, as well as other definitions and specifications adopted by the Association, but not yet printed in the Manual, were examined and as a result some amendments of recommended standard definitions are offered as well as amendments of two paragraphs in the specifications for metal details used in wooden bridges and trestles (see Appendix A).

The specifications for Bridge and Trestle Timber and Piling in the Manual, 1907, pp. 80-83, are superseded by others adopted later. The safe unit-stresses, on page 85, are also superceded by those adopted in 1909. Some other amendments relating to specifications to be inserted in the Manual are given under subsequent topics.

STANDARD SPECIFICATIONS FOR BRIDGE AND TRESTLE TIMBERS.

The designations adopted for the two grades of Southern yellow pine at the last convention (see Proceedings, Vol. 10, p. 614) proved to be unacceptable to the Yellow Pine Manufacturers' Association, and at a joint conference of committees the designations "Standard Heart Grade" and "Standard Grade" were agreed upon. It was also agreed to substitute "corner" for "edge," since the latter is employed as a technical term in the lumber trade, having a different meaning from that in ordinary usage; and to insert the requirement of having the timber sawed to full length. With these modifications the specifications were adopted August 4, 1909, by the Yellow Pine Manufacturers' Association, printed in pamphlet form, and issued to the trade with the request to put them into effect. It is to be remembered that the American Society for Testing Materials, through its Committee Q, on standard specifications for the Grading of Structural Timbers, has actively co-operated to secure this result. On account of the minor changes mentioned above, which the Association is asked to approve, and the numerous amendments printed as footnotes in the Proceedings, Vol. 10, pp. 539, 540, the specifications are again reprinted to show their final form (see Appendix B).

The Committee desires to call special attention to the importance of careful inspection in order to make the specifications of real significance, and to insure fair dealing with all the manufacturers who may be requested to submit bids. It is unfair to any honest manufacturer, who submits a bid on the basis of the face value of the specifications, if the purchaser finally accepts material which is inferior in quality to that demanded by a reasonable interpretation of the specifications.

At the last convention the Committee withdrew all references to Douglas fir and Western hemlock, believing it to be impracticable to frame satisfactory specifications to apply in common to these species and to Southern yellow pine. Separate specifications, relating to Douglas fir and Western hemlock, are now presented for approval (see Appendix C). They are the result of a critical examination of a number of specifications in use by different railroads, including the Chicago & Northwestern, Colorado & Southern, Chicago, Milwaukee & St. Paul, Northern Pacific, and Chicago, Burlington & Quincy. The grading rules of the Associated Bureau of Grades were consulted and the proposed specifications were discussed by individual members of Sub-Committee B with the timber inspectors of their own roads.

In the opinion of the Sub-Committee some of the existing specifications are too strict in certain particulars, and timber conforming to their requirements cannot be purchased except at excessive prices. It has been the purpose to frame a specification which will secure a good grade of timber and which is thoroughly practicable from a manufacturer's standpoint.

The Chairman of the Sub-Committee is endeavoring to arrange for a meeting with representatives of the Oregon and Washington Lumber Manufacturers' Association and the Pacific Coast Lumber Manufacturers' Association, and of the American Society for Testing Materials, to secure, if possible, a uniform standard specification.

It was decided that the specifications shall cover only two grades of timber. The standard heart grade is intended for general use in bridges and trestles, while the standard grade is intended for falsework, trestles for filling, and for other temporary construction. White Douglas fir is excluded in the standard heart grade and accepted in the standard grade since it is not regarded as sufficiently durable for use in other than temporary structures. The limiting sizes given for pitch pockets and knots are believed to be readily met by the manufacturer, and that the quality specified will be satisfactory to the user. The general form of the specifications is similar to that adopted last year by the Association.

Whether the percentage of heart for different members of a structure should be specified was discussed. The Committee concluded that while this may not be necessary at present, the specifications to be adopted by the Association will probably stand for a number of years, and since the time may come soon when heart wood cannot be so easily secured, that the percentage of heart should be designated.

DEFINITIONS RELATING TO STRUCTURAL TIMBER.

On account of the numerous technical terms employed in specifications for timber, including some words in common use to which new meanings are given, it is desirable to secure the adoption of a fairly comprehensive series of definitions. Those heretofore adopted relate chiefly to standard defects (see Manual, 1907, pp. 72-79). Most of the definitions now submitted were prepared last year, a few having been revised this year and several others added (see Appendix D).

PILES AND PILE DRIVING.

A circular, No. 123, was prepared by Sub-Committee C and sent in July to members of the Association and to a selected list of other engineers and contractors. The report submitted in Appendix E is a continuation of that of last year, as a further compilation of the practice of the art. The data furnished is presented as information, and it is hoped that definite expressions of opinion on the relative merits of the devices shown may be received by the Committee for its assistance in making recommendations next year. The paper on "The Supporting Power of Piles," given in Appendix F, was prepared by E. P. Goodrich, at the request of the Committee.

STRENGTH OF REDWOOD TIMBER.

In Appendix G is given an abstract of an unpublished progress report by the U. S. Forest Service, dated March 31, 1909. This abstract is published for the information of members of the Association as a valuable addition to the relatively meager results heretofore available upon the subject. However, since the number of tests is somewhat limited and the timber is taken from only one district, it is not deemed advisable to recommend any revision at present of the working unit-stresses for redwood.

CONCLUSIONS.

Your Committee recommends the adoption of the following conclusions:

(1) That the proposed amendments relating to specifications, etc., in the Manual of Recommended Practice, be adopted.

(2) That the Standard Specifications for Douglas Fir and Western Hemlock Bridge and Trestle Timbers be adopted and published in the Manual of Recommended Practice.

(3) That the Definitions for Structural Timber be referred to the Board of Direction, with the recommendation to publish them in the Manual of Recommended Practice.

(4) That the report on Piles and Pile Driving be received as information.

Respectfully submitted,

Henry S. Jacoby, Professor of Bridge Engineering, Cornell University, Ithaca, N. Y., *Chairman.*

James Keys, Assistant Engineer, Union Pacific Railroad, Omaha, Neb., *Vice-Chairman.*

F. H. Bainbridge, Resident Engineer, Chicago & Northwestern Railway, Clinton, Iowa.

F. E. Bissell, Consulting Engineer, Cleveland, Ohio.

W. S. Bouton, Engineer of Bridges, Baltimore & Ohio Railroad, Baltimore, Md.

R. D. Coombs, Structural Engineer, Pennsylvania Tunnel & Terminal Railroad, New York, N. Y.

L. J. Hotchkiss, Assistant Bridge Engineer, Chicago, Burlington & Quincy Railroad, Chicago, Ill.

Hans Ibsen, Bridge Engineer, Michigan Central Railroad, Detroit, Mich.

J. A. Lahmer, Principal Assistant Engineer, Kansas City Southern Railway, Kansas City, Mo.

F. B. Scheetz, Assistant Engineer, Missouri Pacific Railway, St. Louis, Mo.

W. F. Steffens, Engineer of Structures, Boston & Albany Railroad, Boston, Mass.

G. R. Talcott, Maintenance of Way Department, Baltimore & Ohio Railroad, Wheeling, W. Va.

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

P. H. Wilson, Civil Engineer, Devon, Pa.

Committee.

Appendix A.

PROPOSED AMENDMENTS OF RECOMMENDED STANDARD DEFINITIONS.

PROPOSED DEFINITIONS.

WOODEN BRIDGES AND TRESTLES.

Post.—One of the vertical or battered members of the bent of a framed trestle.

Pile.—(See definition under subject of Piles and Pile Driving.)

Sub-Sill.—A timber bedded in the ground to support a framed bent.

Jack Stringer.—A stringer placed outside of the line of main stringers.

Guard Rail.—A longitudinal member, usually a metal rail, secured on top of the ties inside of the track rail, to guide derailed car wheels.

Guard Timber.—A longitudinal timber framed over the ties outside of the track rail, to maintain the spacing of the ties.

Fish-Plate.—A short piece lapping a joint, secured to the side of two members, to connect them end to end.

Bulkhead.—A wall of timber placed against the side of an end bent to retain the embankment.

PILES AND PILE DRIVING.

Batter Pile.—One driven at an inclination to resist forces which are not vertical.

Leads.—The upright parallel members of a pile driver which support the sheaves used to hoist the hammer and piles, and which guide the hammer in its movement.

Cap.—A block used to protect the head of a pile and to hold it in the leads during driving.

Follower.—A member interposed between the hammer and a pile to transmit blows to the latter when below the foot of the leads.

STANDARD DEFECTS OF STRUCTURAL TIMBER.

Wane.—See definition under subject of Structural Timber.

Note.—See additional definitions of defects under Structural Timber.

SPECIFICATIONS FOR METAL DETAILS USED IN WOODEN BRIDGES AND TRESTLES.

In the Manual of 1907, pp. 83 and 84, amend paragraphs 2 and 3 on steel and cast-iron, respectively, to conform to the specifications for iron and steel structures in paragraphs 83-85, and 106, on pp. 267 and 270 of the Manual.

The paragraphs now read as follows:

"2. Steel shall be made by the open-hearth process. It shall contain not over 0.04 per cent. phosphorus and not over 0.04 per cent. sulphur, when tested in specimens of the form Fig. 1, or full-sized pieces of the same length. It shall have a desired ultimate strength of 50,000 lbs. per sq. in.; tensile tests of steel, showing an ultimate strength within 5000 lbs. per sq. in. of that desired, will be considered satisfactory, except that, if the ultimate strength varies more than 4000 lbs. from that desired, a retest shall be made on the same, which, to be acceptable, shall be within 5000 lbs. of the desired ultimate; it shall have an elongation of $\frac{1500000}{\text{ult. tens. strength}}$ in 8 in.; it shall bend cold without fracture 180 degrees flat. The fracture of tensile test shall be silky.

"3. Cast-iron shall be made of tough gray iron, with sulphur not over 0.10 per cent. If tested on the "Arbitration Bar" of the American Society for Testing Materials, which is a round bar 1¼ in. in diameter and 15 in. in length, the transverse test shall be made on a supported length of 12 in. with load at the middle. The minimum breaking load so applied shall be 2900 lbs. with a deflection of at least ·$\frac{1}{10}$-in. before rupture."

Their amended form is to read as follows:

2. Steel shall be made by the open-hearth process and shall be of uniform quality. It shall contain not more than 0.05 per cent. sulphur; if made by the acid process it shall contain not more than 0.08 per cent. phosphorus, and if made by the basic process not more than 0.04 per cent. phosphorus. When tested in specimens of the form of Fig. 1, or full-sized pieces of the same length, it shall have a desired ultimate tensile strength of 60,000 lbs. per sq. in. If the ultimate strength varies more than 4000 lbs. from that desired, a retest shall be made on the same gage, which, to be acceptable, shall be within 5000 lbs. of the desired ultimate. It shall have a minimum percentage of elongation in 8 in. of $\frac{1500000}{\text{ult. tens. strength}}$; and shall bend cold without fracture 180 degrees flat. The fracture for tensile tests shall be silky.

3. Except where chilled iron is specified, castings shall be made of tough gray iron, with sulphur not over 0.10 per cent. They shall be true to pattern, out of wind and free from flaws and excessive shrinkage. If tests are demanded, they shall be made on the "Arbitration Bar" of the American Society for Testing Materials, which is a round bar 1¼ in. in diameter and 15 in. long. The transverse test shall be made on a supported length of 12 in., with load at middle. The minimum breaking load so applied shall be 2900 lbs., with a deflection of at least 1-10 in. before rupture.

Appendix B.

STANDARD SPECIFICATIONS FOR SOUTHERN YELLOW PINE BRIDGE AND TRESTLE TIMBERS.

(To be applied to single sticks and not to composite members.)

General Requirements. 1. General Requirements. Except as noted, all timber shall be sound, sawed to standard size, full length, square cornered and straight; shall be 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 one-fourth (¼) in. scant from the actual size specified. For instance, a 12 by 12 in. timber shall measure not less than 11¾ by 11¾ in.

Standard Dressing. 3. Standard dressing means that not more than one-fourth (¼) in. shall be allowed for dressing each surface. For instance, a 12 by 12 in. timber, after being dressed on four sides, shall measure not less than 11½ by 11½ in.

Standard Heart Grade, Longleaf Yellow Pine.

Stringers. 4. Stringers shall show not less than eighty-five (85) per cent. heart on the girth anywhere in the length of the piece; provided, however, that if the maximum amount of sap is shown on either narrow face of the stringer the average depth of sap shall not exceed one-half (½) in. Knots greater than one and one-half (1½) in. in diameter will not be permitted at any section within four (4) in. of the edge of the piece, but knots shall in no case exceed four (4) in. in their largest diameter.

Caps and Sills. 5. Caps and Sills shall show not less than eighty-five (85) per cent. heart on each of the four sides, measured across the sides anywhere in the length of the piece; to be free from knots over two and one-half (2½) in. in diameter.

Posts. 6. Posts shall show not less than seventy-five (75) per cent. heart on each of the four sides, measured across the sides anywhere in the length of the piece, and to be free from knots over two and one-half (2½) in. in diameter.

Longitudinal Struts and Girts. 7. Longitudinal Struts and Girts. One side shall show all heart; the other side shall show not less than eighty-five (85) per cent. heart, measured across the side anywhere in the length of the piece, and shall be free from any large knots or other defects that will materially injure its strength.

Longitudinal X Braces, Sash and Sway Braces. 8. Longitudinal × Braces, Sash Braces and Sway Braces shall show four square corners and not less than eighty (80) per cent. heart on each of two sides, and shall be free from any large knots or other defects that will materially injure their strength.

9. Ties and Guard Rails shall show one side all heart; the other side and two edges shall show not less than seventy-five (75) per cent. heart, measured across the surface anywhere in the length of the piece; shall be free from any large knots or other defects that will materially injure its strength; and where surfaced the remaining rough face shall show all heart. **Ties and Guard Rails.**

Standard Grade, Longleaf and Shortleaf Yellow Pine.

10. Stringers shall be square cornered, with the exception of one (1) wane on one corner. Knots shall not exceed in their largest diameter one-fourth (¼) of the width of the surface of the stick in which they occur, and shall in no case exceed four (4) in. Ring shakes shall not extend over one-eighth (⅛) of the length of the piece. **Stringers.**

11. Caps and Sills shall be square cornered, with the exception of one (1) wane on one corner, or one-half (½) in. wane on two corners. Knots shall not exceed in their largest diameter one-fourth (¼) of the width of the surface of the stick in which they occur, and in no case shall exceed four (4) in. Ring shakes shall not extend over one-eighth (⅛) of the length of the piece. **Caps and Sills.**

12. Posts shall be square cornered, with the exception of one (1) in. wane on one corner, or one-half (½) in. wane on two corners. Knots shall not exceed, in their largest diameter, one-fourth (¼) of the width of the surface of the stick in which they occur, and shall in no case exceed four (4) in. Ring shakes shall not extend over one-eighth (⅛) of the length of the piece. **Posts.**

13. Longitudinal Struts and Girts shall be square cornered and sound, and shall be free from any large knots or other defects that will materially injure their strength. **Longitudinal Struts or Girts.**

14. Longitudinal × Braces, Sash Braces and Sway Braces shall be square cornered and sound, and shall be free from any large knots or other defects that will materially injure their strength. **Longitudinal X Braces, Sash and Sway Braces.**

Explanatory Note for Standard Heart Grades.
(See Proceedings, Vol. 10, p. 541.)

Appendix C.

STANDARD SPECIFICATIONS FOR DOUGLAS FIR AND WESTERN HEMLOCK BRIDGE AND TRESTLE TIMBERS.

(To be applied to single sticks and not to composite members.)

Standard Heart Grade.

1. Standard Heart Grade shall include yellow and red Douglas fir and Western hemlock. White Douglas fir will not be accepted.

General Requirements.

2. General Requirements. All timber shall be live, sound, straight and close grained, cut square cornered, full length, not more than one-fourth (¼) in. scant in any dimension for rough timber or one-half (½) in. for dressed timber; free from large, loose or unsound knots, knots in groups, or other defects that will materially impair its strength for the purpose for which it is intended. Subject to inspection before loading.

Stringers.

3. Stringers shall show not less than ninety (90) per cent. heart on each side and edge, measured across the surface anywhere in the length of the piece. Shall be out of wind and free from shakes, splits, or pitch pockets over three-eighths (⅜) in. wide or five (5) in. long. Knots greater than two (2) in. in diameter will not be permitted within one-fourth (¼) of the depth of the stringer from any corner nor upon the edge of any piece; knots shall in no case exceed three (3) in. in diameter.

Caps, Sills and Posts.

4. Caps, Sills and Posts shall show not less than eighty-five (85) per cent. heart on each of the four sides, measured across the surface anywhere in the length of the piece. Shall be out of wind and free from shakes, splits, or pitch pockets over one-half (½) in. wide or five (5) in. long. Knots shall not exceed one-fourth (¼) of the width of the surface of the piece in which they occur and shall in no case exceed three (3) in. in diameter.

Longitudinal Struts or Girts, X Braces, Sash and Sway Braces.

5. Longitudinal Struts or Girts, X Braces, Sash and Sway Braces shall show one side all heart, the other side and two edges shall show not less than eighty-five (85) per cent. heart, measured across the surface anywhere in the length of the piece.

Ties and Guard Timbers.

6. Ties and Guard Timbers shall show one side and one edge all heart, the other side and edge shall show not less than eighty-five (85) per cent. heart, measured across the surface anywhere in the length of the piece.

Howe Truss Chords.

7. Timbers for Howe Truss Chords shall show not less than ninety (90) per cent. heart on each side and edge, measured anywhere in the length of the piece. Shall be out of wind and free from shakes, splits, or pitch pockets over one-eighth (⅛) in. wide or three (3) in. long. Knots shall not be over one and one-half (1½) in. in diameter

nor be closer together on each surface than one in any four linear feet, but if knots are one (1) in. or less in diameter, one in any three linear feet will be allowed.

Standard Grade.

8. Standard Grade shall include yellow, red and white Douglas fir and Western hemlock.

General Requirements.

9. General Requirements. All timbers shall be sound and cut square cornered, except that timbers ten by ten (10x10) in. in size may have a two (2) in. wane on one corner or its equivalent on two or more corners. Other sizes may have proportionate defects. Must be free from defects which will impair its utility for temporary work. Knots shall not exceed one-fourth (¼) the width of the surface of the piece in which they occur. Subject to inspection before loading.

Stringers, Caps, Sills and Posts.

10. Stringers, Caps, Sills and Posts shall be out of wind, free from shakes or splits extending over more than one-eighth (⅛) of the length of the piece, or knots more than four (4) in. in diameter. Knots greater than three (3) in. in diameter will not be permitted on the edge of any stringer.

Appendix D.

STRUCTURAL TIMBER.

DEFINITIONS.

1. TIMBER.—A single stick of wood of regular cross-section.
2. CROSS-SECTION.—A section of a stick at right angles to the axis.
3. TRUE.—Of uniform cross-section. Defects are caused by wavy or jagged sawing or consist of trapezoidal instead of rectangular cross-sections.
4. AXIS.—The line connecting the centers of successive cross-sections of a stick.
5. STRAIGHT.—Having a straight line for an axis.
6. OUT OF WIND.—Having the longitudinal surfaces plane.
7. CORNER.—The line of intersection of the planes of two adjacent longitudinal surfaces.
8. GIRTH.—The perimeter of a cross-section.
9. SIDE.—Either of the two wider longitudinal surfaces of a stick.
10. EDGE.—Either of the two narrower longitudinal surfaces of a stick.
11. FACE.—The surface of a stick which is exposed to view in the finished structure.
12. SAPWOOD.—A cylinder of wood next to the bark and of lighter color than the wood within. It may be of uneven thickness.
13. HEARTWOOD.—The older and central part of a log, usually darker in color than sapwood. It appears in strong contrast to the sapwood in some species, while in others it is but slightly different in color.
14. SPRINGWOOD.—The inner part of the annual ring formed in the earlier part of the season, not necessarily in the spring, and often containing vessels or pores.
15. SUMMERWOOD.—The outer part of the annual ring formed later in the season, not necessarily in the summer, being usually dense in structure and without conspicuous pores.
16. DECAY.—Complete or partial disintegration of the cell walls, due to the growth of fungi.
17. SOUND.—Free from decay.
18. SOLID.—Without cavities; free from loose heart, wind shakes, bad checks, splits or breaks, loose slivers and worm or insect holes.
19. WANE.—A deficient corner due to curvature or to taper of the log.
20. SQUARE CORNERED.—Free from wane.
21. KNOT.—The hard mass of wood formed in a trunk at a branch, with the grain distinct and separate from the grain of the trunk.
22. CROSS-GRAIN.—The gnarly mass of wood surrounding a knot, or grain injuriously out of parallel with the axis.
23. WIND-SHAKE.—A crack or fissure, or a series of them, caused during growth.

Appendix E.

PILES AND PILE DRIVING.

The following dimensions of pile rings are compiled from the replies to Circular No. 104, issued by the Committee in 1908:

Dimensions in Inches.	No. of Replies.	Dimensions in Inches.	No. of Replies.	Dimensions in Inches.	No. of Replies
2 x ⅜	1	2½x ¾	2	3 x 1	7
2 x ½	4	2½x ⅞	1	3½x ⅞	1
2 x ¾	1	2½x 1	1	3½x 1	2
2 x 1	1	2¾x ¾	1	4 x ¾	1
2½x ½	2	3 x ⅝	1	4 x 1	2
2½x ⅝	1	3 x ¾	7		
				Total........	36

The diameter is variable in all cases.

Norfolk & Southern Railway Company

Pile-Driving Record, Trestle No. ________ Across ______________________________

____ Residency ____ Division ______________ Contractor ________________ Recorder

Mile		No. of Bent	No. of Pile	Kind of Timber	Length of Pile	Diameter of Butt	Diameter of Top	Length below Cut-off	Length of Cut-off (Waste)	Depth of Water	Distance Driven	Elevation of Top of Pile	Elevation of Point of Pile	No. of Blows	Fall of Hammer	Weight of Hammer	Penetration for each Ten Consecutive Blows (in inches)											
Date	Station																40	50	60	70	80	90	100	110	120	130	140	150

Pile Record

Bridge No. ________ Mile Post ________ Near ________________ Division

Weight and kind of Hammer ______________ Week ending ____________ 19__

Bents numbered from North or East End.

Piles numbered from Left to Right.

Bent No.	No. of Pile	Size of Pile			Cut Off	Base of Rail to Ground	Total Penetration	Last Three Blows		Day of Week	Remarks.
		Lower End	Upper End	Length				Drop of Hammer	Penetration		

Record of Piles Driven for ______________________________

____

Description of Driver ______________________________

____

Weight of Hammer ______ lbs. Fall of Hammer ______ ft.

Date	Range	Bent	Kind of Timber	Diameter at Cut-off	Diameter at Point	Length of Pile in leads	Length of Cut-off	Length below Cut-off	Elevation of Ground			Elevation of Point of Pile	Distance Driven	Depth of Gravel Fill	Number of Blows Struck	Settlement Under Hammer	Penetration for a given number of consecutive blows

______________________________ Inspector.

Pile Record

For ________________

At ________________

Driver ________________

Weight of Hammer ________________

Date	Bent	Row	Kind of Timber	Diameter Cut-off	Diameter Tip	Length (Original)	Length Cut-off	Length below Cut-off	Elevation of Tip	Elevation of Ground		Depth of	Distance Driven	Total Number of Blows	Settlement Under Hammer	$\frac{\text{Penetration in Inches}}{\text{Number Consecutive Blows}} = \frac{P}{N}$							
																Fall Ft.	$\frac{P}{N}$	Fall Ft.	$\frac{P}{N}$	Fall Ft.	$\frac{P}{N}$	Fall Ft.	$\frac{P}{N}$

________________ Inspector.

Record of Piles Driven for ______________________

Description of Driver ______________________

BLOW STRUCK IN FT. POUNDS.

Full Head ________ ¾ Head ______ ½ Head _______ ¼ Head __________ Light __________

STATION	No. of Bent	No. of Pile	Kind of Timber	Diameter of Butt	Diameter of Top	Length of Pile	Length of Cut-Off	Length Below Cut-Off			Elevation of Ground	Elevation of Point of Pile	Distance Driven	Depth of Gravel Fill	Number of Blows Struck	Penetration for a given number of consecutive blows

Date ______________

______________ Inspector.

New York Central & Hudson River Railroad Company

MAINTENANCE OF WAY DEPARTMENT.

DAILY REPORT of PILE DRIVER No.______ Engine No.________ _____________ Division. Bridge No.______

Headquarters______________ Time Leaving________M., Time Returning________M., Date________________19__

Conductor______________ Pile Driver Foreman __________________ Delays during day ________________

Engineman______________ Pile Driver Engineman________________ ______________________

Fireman______________ Pile Driver Watchman________________ ______________________

Brakeman______________ No. of other men __________________ ______________________

Brakeman______________ __________________________ ______________________

	No of Pile	Length raised in leads, feet	Length below cut-off, feet	Kind of Wood	Settlement last blow, inches	Fallhammer last blow, inches	Total distance in ground, feet	Total No of blows	Weight of hammer, lbs	REMARKS—Sketch of Pile, Bridge, Pier, or Abutment showing how piles are numbered, will be furnished If contract work, give name of contractor and engineer in charge.

INSTRUCTIONS—To be filled out each day by FOREMAN or INSPECTOR and forwarded to SUPERVISOR of BRIDGES.
Separate reports must be sent in for each bridge.
On completion of work at each bridge, give statement of pile driver supplies, fuel, oil, etc., used.
Under "Remarks" put other labor, such as sawing off piles or driving new piles for broken ones.

____
Foreman or Inspector.

Portland Bridge District Commission

RECORD OF PILES DRIVEN

Pier ____________ Number of Pile ____

Abutment ____________ Observer ____________________ Date ________________

Length of Pile ________ Feet Depth Driven ________ Feet Number of Blows ____________

Penetration by own Weight ____________ Feet. Penetration Last Blow ____________ Inches

Remarks ____

____

____

____

____

____

____

No. of Blows	Drop Feet	Pene-tration	No. of Blows	Drop Feet	Pene-tration	No. of Blows	Drop Feet	Pene-tration
1			43			85		
2			44			86		
3			45			87		
4			46			88		
5			47			89		
6			48			90		
7			49			91		
8			50			92		
9			51			93		
10			52			94		
11			53			95		
12			54			96		
13			55			97		
14			56			98		
15			57			99		
16			58			100		
17			59			101		
18			60			102		
19			61			103		
20			62			104		
21			63			105		
22			64			106		
23			65			107		
24			66			108		
25			67			109		
26			68			110		
27			69			111		
28			70			112		
29			71			113		
30			72			114		
31			73			115		
32			74			116		
33			75			117		
34			76			118		
35			77			119		
36			78			120		
37			79			121		
38			80			122		
39			81			123		
40			82			124		
41			83			125		
42			84			126		

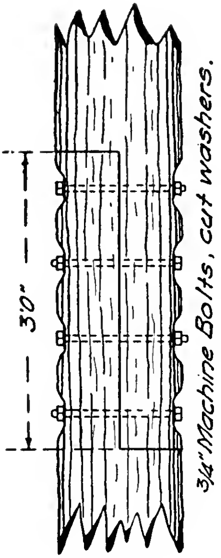


FIG. 1.

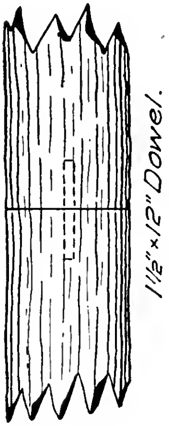


FIG. 2.

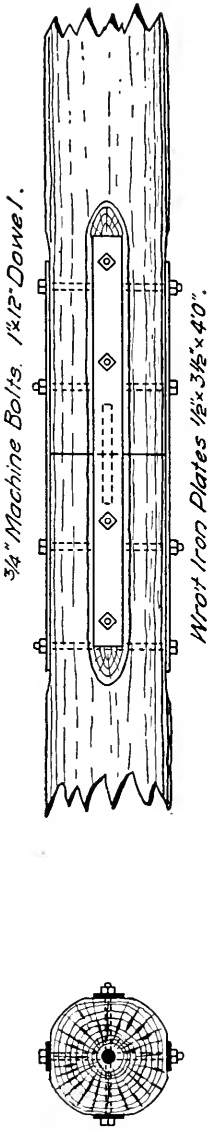


FIG. 3.

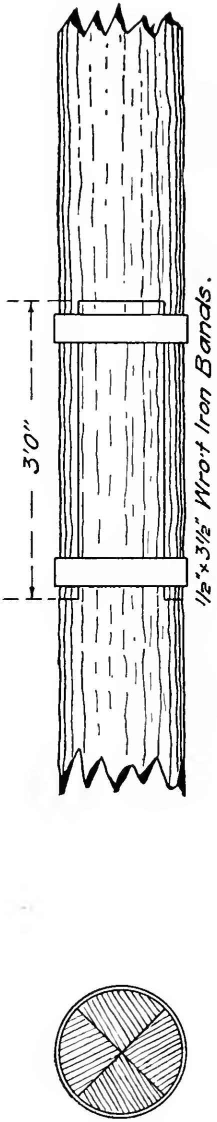


FIG. 4.

PILE SPLICES.

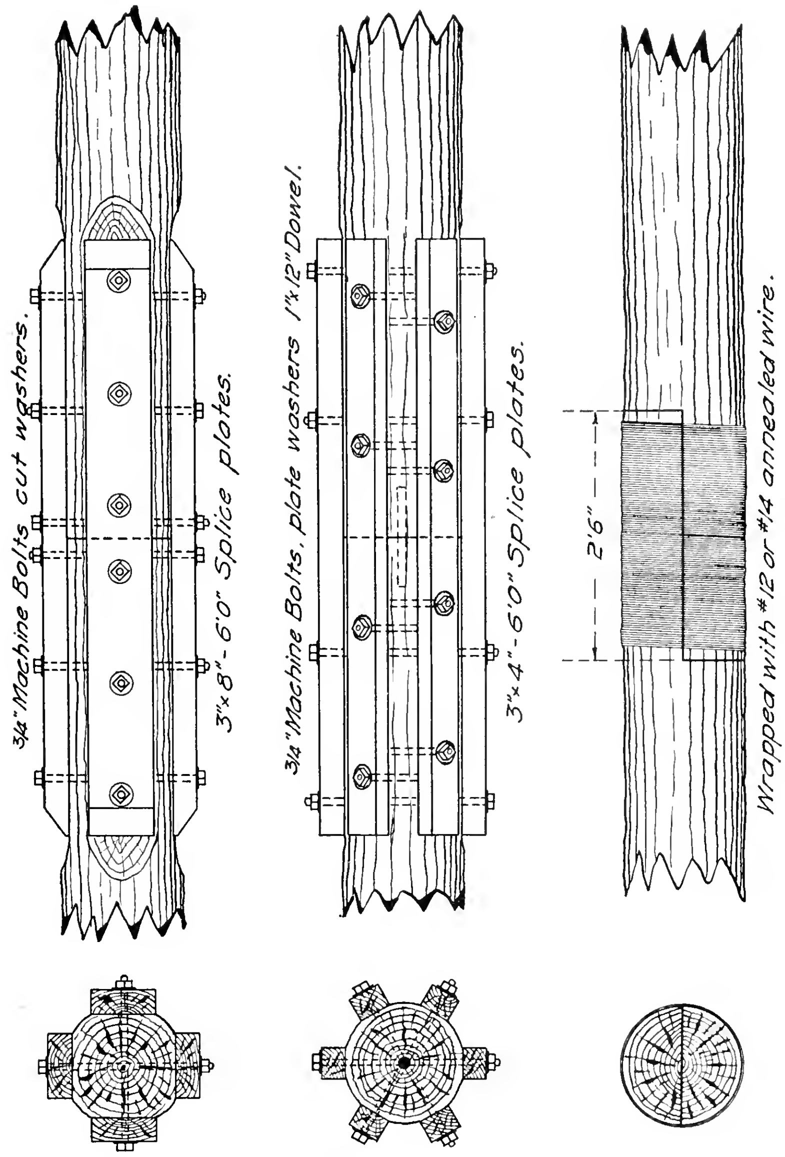


FIG. 5. FIG. 6. FIG. 7.

PILE SPLICES.

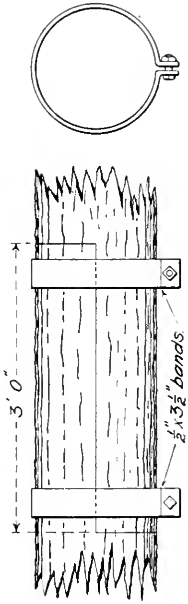


FIG. 8

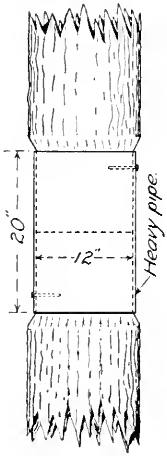


FIG. 9.

PILE SPLICES.

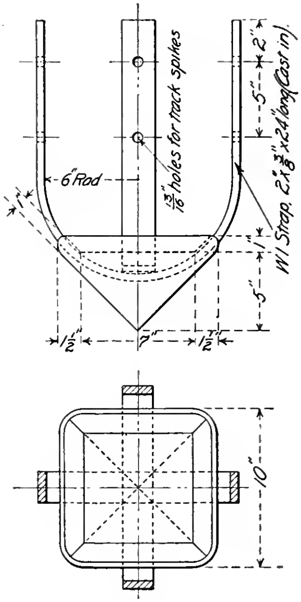


FIG. 10.
PILE SHOE.

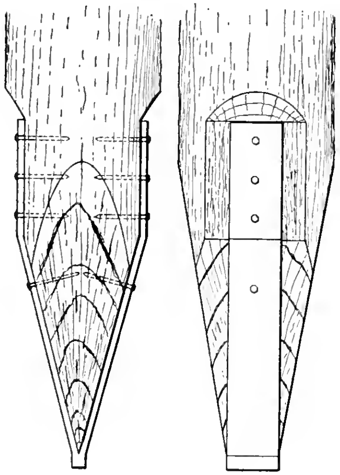


FIG. 11.

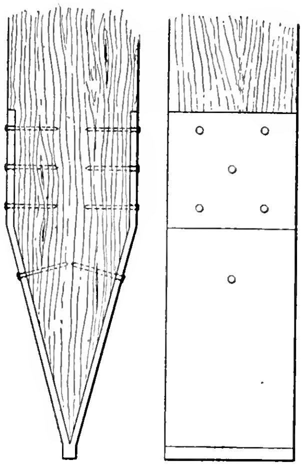


FIG. 12.

PILE SHOES.

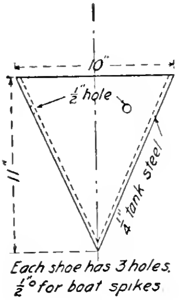


FIG. 13.

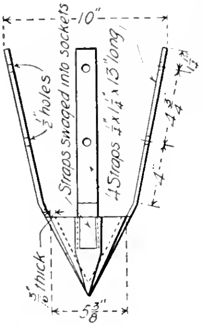


FIG. 15.

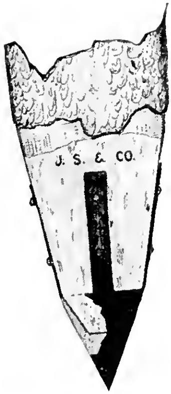


FIG. 14.

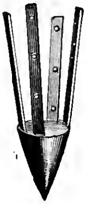


FIG. 16.

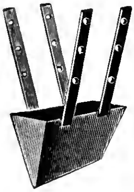


FIG. 17.

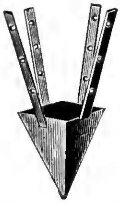


FIG. 18.

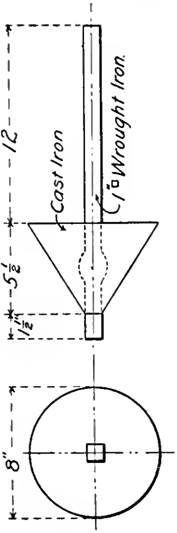


FIG. 19.

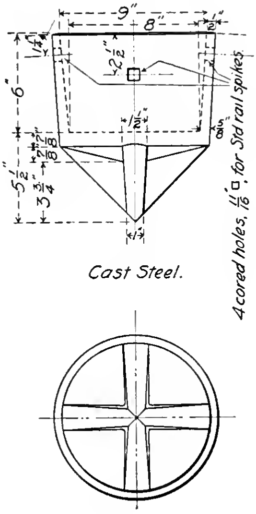


FIG. 20.

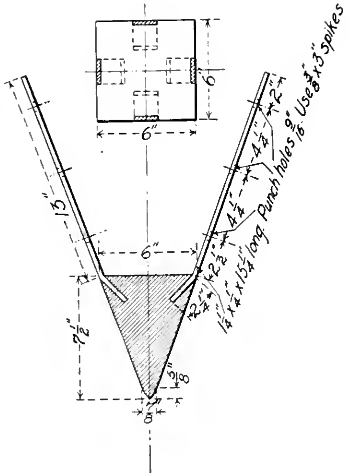


FIG. 21.

PILE SHOES.

OVERDRIVING.

While the Engineering profession has never claimed that Pile Driving was a scientifically determinate art, certain specifications and formulas (and their application at the hands of more or less experienced inspectors) encourage such a claim. The possible combinations of the varying elements of size and character of piles, material and stratification of soils, splices, method of driving and injury to the pile during driving, would seem to make specific procedure, or any unvarying formula, inapplicable for general use.

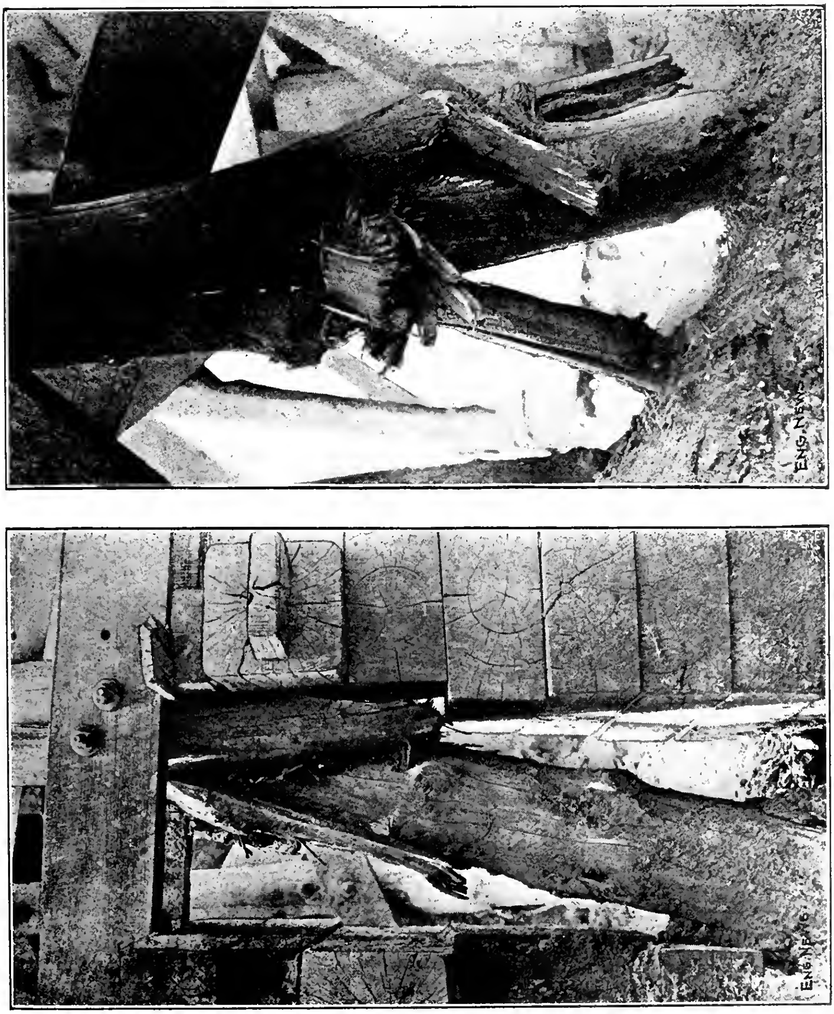
In many cases, if the character of the soil is known, by borings or otherwise, to be of a favorable nature, the real purpose of the pile driving operations is to drive to position, with the least injury and in the shortest time, a certain number of piles. The conditions of "least injury" and "shortest time" are more or less antagonistic, and lead to improper methods in order to reduce the cost. The object of the work, however, is to drive piles rather than make inaccurate tests of pile formulas, and it is unfortunate that specifications can be so written that the foreman must choose between doing his duty to his employer and obeying the specifications.

When on the other hand the soil conditions are unfavorable, due to the presence of soft material, hardpan, boulders, etc., the proper procedure is a matter requiring both skill and judgment, and one which is not intelligently covered by the usual specifications. Still less applicable is the ordinary pile formula, which covers a limited range of conditions. Assuming absolutely identical conditions for both the piles and the soil, the manner of driving and the type of equipment might be varied in several cases and yet all of the piles be driven without injury. Again a different set of soil conditions might make one of these methods almost useless.

The action of the piles during driving, which depends upon intelligent requirement as to the number, force and rapidity of the blows, combined with a more or less accurate knowledge of the surface friction developed after driving, are the foundation of the skilled foreman's judgment, which judgment has yet to be successfully replaced by any specification or formula of which the profession is generally aware.

If it is desired to develop a new pile formula an effort should be made to obtain one with a variable set of constants so that such a formula may apply with some accuracy to different conditions. The formulas in most general use are based upon a certain set of conditions but are applied in practice to very different conditions, and used to control the driving, which latter would seem to be an exact reverse of the proper procedure. It would be desirable to have a specification varying for different conditions; or else to consist merely in certain limitations in method, with the object of preventing bad workmanship, overdriving or insufficient penetration, while the pile formula on which the design is based depended upon the conditions existing at the site.

It is within the experience of most engineers that a specification is issued to govern certain pile driving work and when operations are started in the field it is found absolutely impracticable to follow the specification.



FIGS. 22 AND 23.—OVERDRIVEN PILES.

FIG. 24.

Figs. 22-25 show overdriven piles in the N. & W. R. R. crossing over Groveport Pike, near Columbus, Ohio, 1908. These piles were driven through 8 ft. of new fill and into the original soil of dry compact boulder clay. Subsequent excavation for a highway exposed the piles. A railway track driver with 40-ft. leads and a 3800-lb. drop hammer was used. The piles were of good quality seasoned oak, 12 to 16-in. butts, 8 to 10-in. tips, 26 ft. long, and provided with cast-iron shoes. In a total number of 34 piles, 15 were found to be defective.

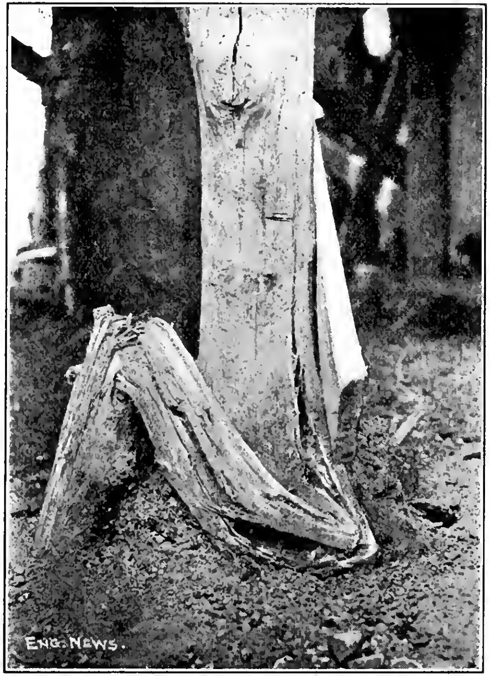


FIG. 25.

In one instance wharf piling was driven on 6 ft. centers through 20 ft. of water, 10 ft. of soft mud and 25 ft. of blue clay. At times the piles drove very easily, a 2800-lb. hammer, with a maximum fall of 15 ft., would cause a penetration for the last blow of from 3 to 6 inches. Such driving would not be in accordance with the usual specification which requires a ½-in. penetration for the last blows, and yet

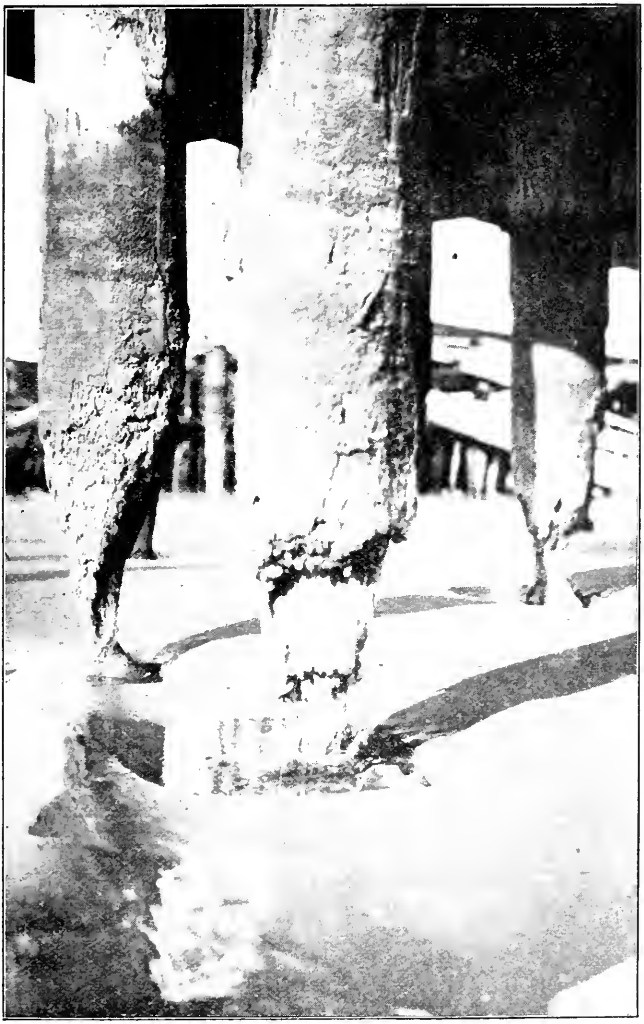


FIG. 26.—TIMBER PILES DESTROYED BY LIMNORIA IN OAKLAND HARBOR, CALIFORNIA.

subsequent to the driving so much surface friction was developed by the clay that the piles successfully carried a load estimated at 30 tons per pile.

In the second case a corporation whose engineering offices were in a distant city, issued specifications and asked for bids for wharf piling with the requirement that spruce piles should be driven to a final penetration of ½ in. for the last blow of a 3000-lb. hammer falling 25 ft. The soil through which these piles were to be driven was hard sand and gravel and a large portion of the piles would have been broken in driving had the specification requirements been enforced.

(Abstracted from U. S. Forest Service Circular 128 on Preservation of Piling Against Marine Wood Borers, by C. Stowell Smith.)

MECHANICAL PRESERVATION OF PILING AGAINST MARINE WOOD BORERS.

"In many places along both the Atlantic and Pacific coasts the timber used for piles in wharfs and other marine structures is attacked by marine wood borers. The result is that the length of service of the piles is greatly shortened.

"Almost invariably the marine wood borers are confined to salt water. In our waters there are two genera of mollusks, Xylotrya and Teredo,* and three of crustaceans, Limnoria, Chelura, and Sphaeroma, that seriously damage marine structures.

"The portion of the pile commonly attacked is that between mean tidewater mark and a point about 4 ft. below low water, though sometimes it extends downward as far as the pressure of the water will permit. The entrance holes do not indicate the extent of attack, as the entrance may be at mean tidewater mark and the active boring head several feet above. On the other hand, part of the excavation may be below the mud line, though the entrance is never so situated.

"All the woods commonly used for piling are subject to the attacks of marine borers. Some doubt has been expressed whether borers attack certain species, which are not indigenous to this country and some native woods that have an extremely porous structure. Examples of the first class are certain eucalypts, and of the second class, palms and palmettos. From investigation it is clear that species of the first class are not immune from attack, and that those of the second, although practically immune, are found in such small quantities and are so lacking in the requirements of structural timbers that the fact is not important. Hardness is no barrier to attack, although boring is probably slow in dense woods, like ebony, eucalyptus, etc. Whenever partial or complete immunity is reported, it is perhaps largely due to local conditions rather than to the kind of wood.

---

*There seems to be much confusion in the identification of these two borers. During the present study Teredo was found in a single locality, while Xylotrya, popularly supposed to be the Teredo, was very abundant along the Atlantic and Gulf coasts.

"Experience has shown that marine borers require only a minute exposed surface in order to gain entrance and completely destroy a pile. Therefore, to be effective, all external coatings must maintain an absolutely intact covering over the wood.

"Any of the external coatings or sheathings properly applied will increase the life of the pile. There are three factors, however, which decrease their efficiency. These are (1) the chemical action of salt water, which corrodes metallic sheathings; (2) the mechanical action of waves which wash the fillers from the casings, and often break the casings themselves, and (3) the danger from floating timbers and debris, which strike the coatings and break them. The last factor is the most serious. One blow from a floating timber will often ruin the

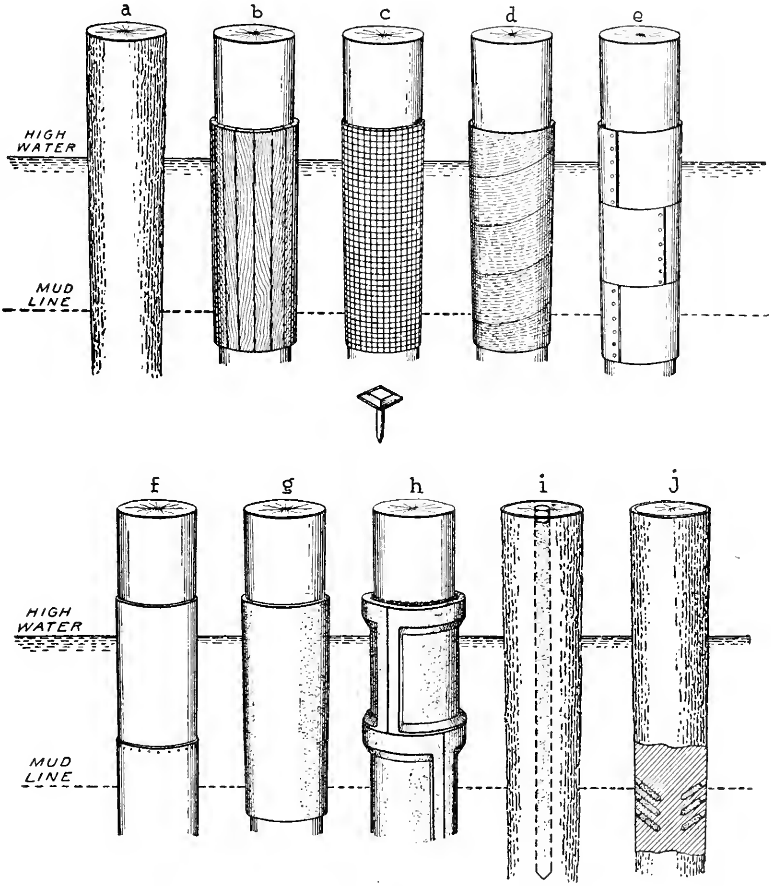


FIG. 27. TYPES OF MECHANICAL PROTECTION.

protective covering of a pile. Thick iron casings resist the chemical and mechanical factors for a long period, but their initial cost is so great that their use must be limited.

Methods of Protection.

"1. External Coatings.—These need be applied only to the portions of the pile exposed to attack, while the parts below the mud line and above high water, often 50 to 60 per cent. of the entire pile, can be ignored.

"(a) Bark left on the pile. This is an absolute protection against marine borers as long as it remains intact. (Fig. 27a.) On the other hand, above the water line it offers an excellent place for insects and fungi, both of which may assist materially in the destruction of the pile.

"(b) Thin plank, joined closely on the surface of the pile. This acts as an artificial bark, and partially eliminates the dangers from insects and fungi. (Fig. 27b.)

"(c) Flat-headed nails, resembling ordinary upholsterer's tacks except that the heads are square, and larger. These are driven in close together, forming a continuous covering over the exposed surface. (Fig. 27c.)

"(d) Hot paints, tars, asphalt, etc. These are applied alone, or are further reinforced with fabrics, such as burlap soaked in the mixture or strips of coated batting. (Fig. 27d.) Some of the combinations which have been used are:

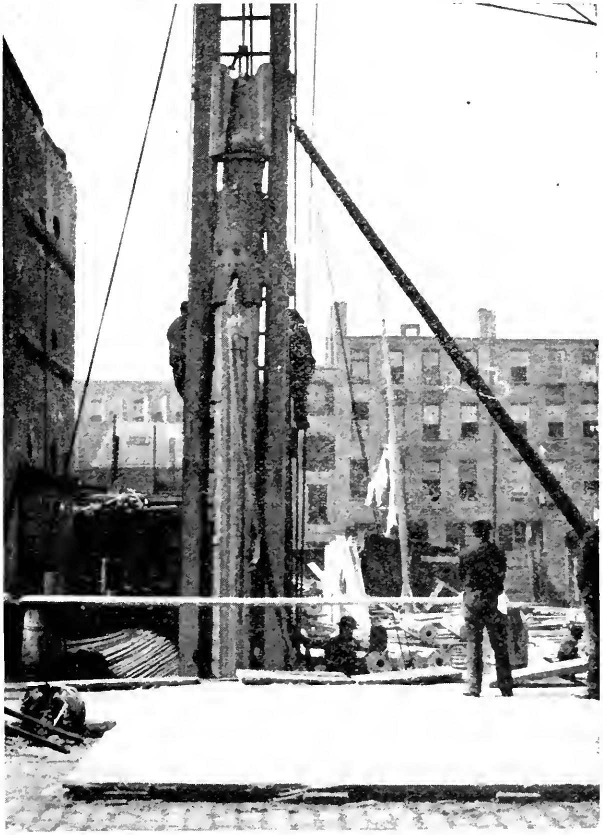
"A mixture of asphalt, coal tar, oxide of copper, fish oil, oxalic acid, and salt, in varying proportions, applied hot to the barked pile, and protected with strips of batting to prevent breaking the coating during handling.

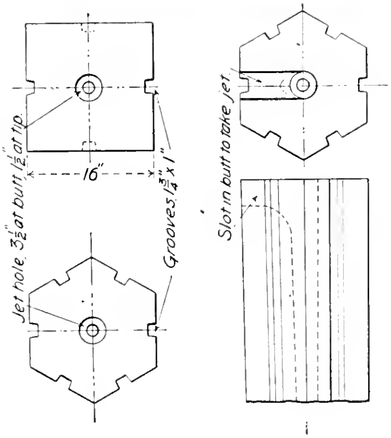
"A mixture of coal tar, pitch, and asphaltum, in varying proportions, applied hot to the barked pile; then a mixture of ground glass and flint sand added. This is protected by narrow strips of batting, coated with a mixture of all of these substances.

"A mixture of slaked lime, asphaltum, hydraulic cement, brimstone, crude creosote, and asbestos, in varying proportions, applied hot to the barked pile; then sharp sand or crushed granite added, and the whole wound with a fabric such as coarse burlap soaked in the above mixture.

"A mixture of tar asphalt, paraffin, cement, phosphorus, and hair, applied hot to the barked pile; then a mixture of fire clay, sand, and cement added as a further protection.

"(e) Metallic Sheathings.—Thin sheets of copper, yellow metal, or zinc, are fastened over the entire exposed surface of the pile with copper nails, or sections of iron pipe are bolted together around it, and packed with cement or sand. These form a solid mechanical barrier against the entrance of borers. (Figs. 27e and f.)





FIGS. 32 AND 33.
GILBRETH PILE.

The first concrete piles were made in France, by M. Hennebique, in 1896, and were made of the cast-and-driven type. During the following decade, this general type was developed by different engineers, and is now more generally used in Europe than any other. In the United States, the Gilbreth (patented in 1908), Chenoweth (patented in 1904) and Raymond (patented in 1896) are the best known varieties of cast-and-driven piles.

In 1890, A. A. Raymond, of Chicago, Ill., conceived the idea of a cast-in-place concrete pile, a further development of the caisson principle. His first patents were issued in 1896, and the first piles driven in 1901. The Simplex pile, patented in the United States in 1903, is of the cast-in-place type, though differing from the Raymond, in method of construction.

These two systems have thus far been used, in this country, to a much greater extent than cast-and-driven piles, though owing to our comparatively recent development in concrete construction, our total use of concrete piles is less than the European. Prior to 1900 practically no concrete piles had been used in the United States.

Cast-and-Driven Types.

The chief objection to cast-and-driven concrete piles has been based upon the possibility of injury to the reinforced concrete during driving. Most of the systems in vogue care for this by jetting the piles, or by the use of a special driving cap designed to protect the head of the piles. The patents covering these various systems refer principally to the driving caps, the arrangement of the reinforcement, provision for jetting, method of molding, and the shape of the pile itself. All of the items entering into the manufacture and placing of cast and driven piles may be varied to suit the local conditions.

The Gilbreth pile is a corrugated, tapering, concrete pile, reinforced with Clinton electrically welded fabric of ⅜-in. wires 3 in. on centers longitudinally, and ⅛-in. wires 12 in. on centers transversely, or other reinforcement of suitable design. The piles are made of any shape desired, but are usually octagonal, tapering from 16 in. in diameter at the butt to 11 in. at the tip, with corrugations running the entire length. In case the piles are intended to project above the ground, the corrugations may be stopped at the ground level. The taper is designed to develop the bearing power of the soil throughout the entire length and the corrugations are added to form outlets for the water from the jet. A hole is made through the center of the pile for jetting. The piles are cast horizontally in wooden forms and allowed to set for various periods; in some instances they have been driven after seven days. They are handled by an ordinary pile driver and jetted into place using a 2-in. jet, flowing through the hole in the center of the pile. The weight of the hammer resting on the driving cap helps to force the pile into place. The special driving cap consists of a steel shell with wooden blocks at each end between which are pieces of

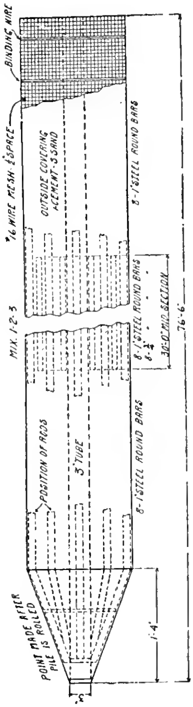
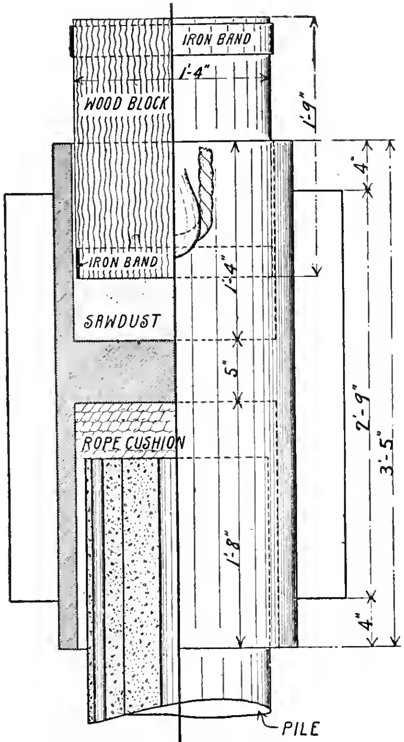
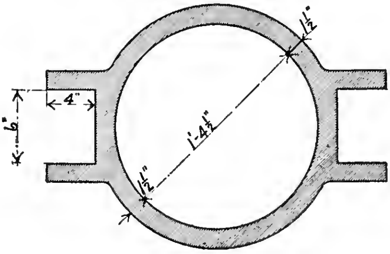


FIG. 34.

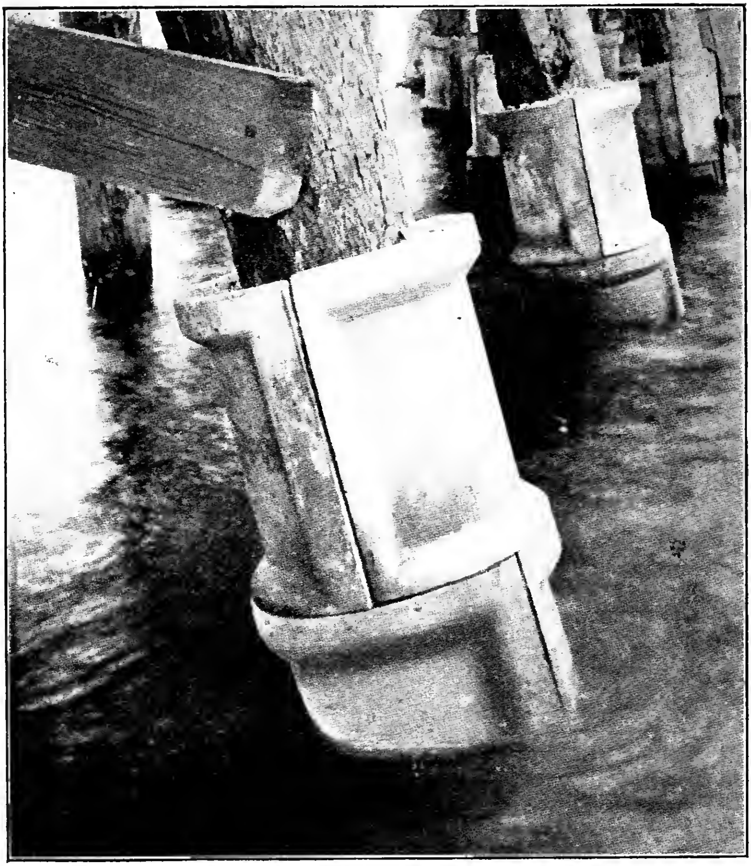
CHENOWETH PILE.

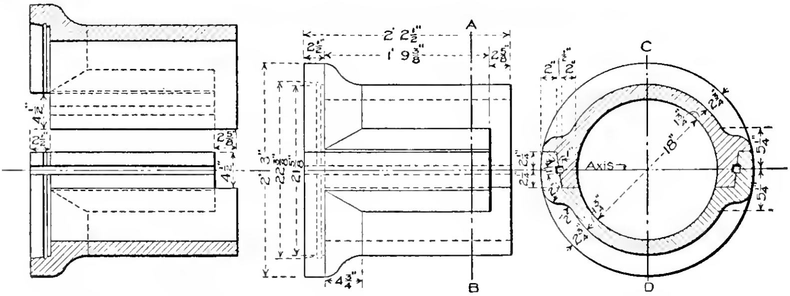


DRIVING | CAP
HALF SECTION AND ELEVATION OF CAP



SECTION OF CAST IRON CAP
DRIVING CAP
FIG. 35.





Section C-D. Side Elevation. Section A-B.

FIGS. 28 AND 29. LOCK JOINT PIPE.

"(f) Cement Casings.—These are made in two ways, (1) with no space between the casing and the pile, and (2) with an intervening space of from 2 to 4 inches.

"The first are manufactured as follows: The bark and knots are removed and the pile driven. A jacket of iron, wood, or sewer pipe is placed around it, and the space between jacket and pile, which is from 2 to 4 in. wide, is filled with hydraulic cement. When this becomes hard, the jacket is removed. Some jackets are so made that they can be applied to the pile without disturbing the superstructure of the wharf, thus making repairs to broken casings easy. (Fig. 27g.)

"The second class is composed of cement pipes divided longitudinally into two halves, which, when placed together round the pile, are joined by a scarf joint keyed with a wooden plug soaked in hot tar. These are made in iron molds nearby, and are placed around the pile from a raft. The intervening space between pile and casing is filled with sand. (Fig. 27h.) The chief advantage of this kind of casing is the fact that broken sections can easily be replaced without removing the superstructure of the wharf, an operation which would otherwise make replacement very expensive. [See also Figs. 28 and 29.]

"(g) Earthenware piles, joined by a special cement. These are lowered over the piles when driven, and the intervening space is filled with sand. The top section is either left open or capped with cement."

The Ripley Combination Pile, illustrated in Fig. 30, is composed of a wooden pile encased in concrete. A ½-in. mesh of No. 16 wire is wound spirally about the pile and attached thereto by staples, the final lap being tied with wire. Before concreting, spikes are driven into the timber at various points along the length of the pile. A 1:2:3 mixture of Portland cement, sand and broken stone is used. This construction is largely experimental, though it is stated that work has been started on an order of 1,100 piles of this type.

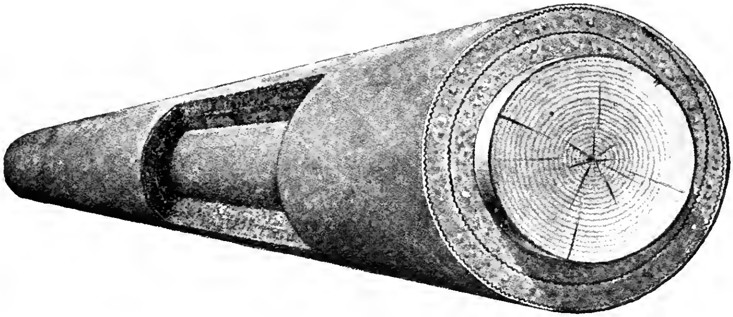


FIG. 30. THE RIPLEY COMBINATION PILE.

CONCRETE PILES.

Historical.

Concrete piles may be divided into two general classes, "cast and driven," and "cast in place." The "cast-and-driven" type are always of reinforced concrete, are molded prior to being placed in the ground, and are driven like wooden piles. "Cast-in-place" piles are usually, though not necessarily, without reinforcement, and the pile hole is made artificially and afterward filled with concrete.

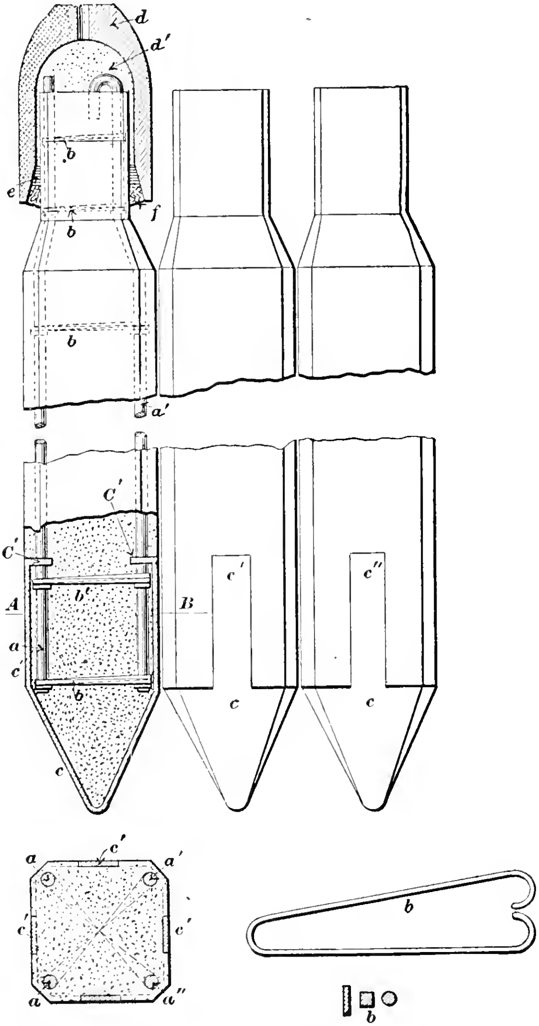
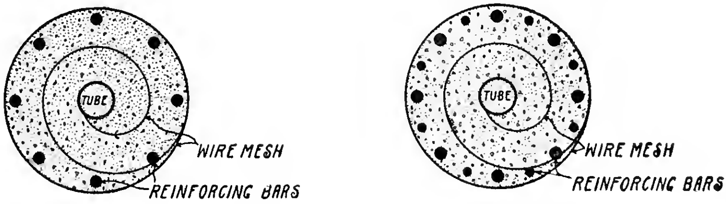


FIG. 31. HENNEBIQUE PILE.

hose and rope to form a cushion. When the pile has been jetted nearly into place the hammer and cushion cap may be hoisted, the jet removed, the cushion cap replaced, and the pile driven to the desired penetration per blow.

The Chenoweth pile is round and is made without forms by a special machine. It is reinforced with a coiled sheet of wire netting and longitudinal steel rods placed near the surface, at equal distances apart.



END CROSS SECTION FOR ALL PILES MID CROSS SECTION FOR LONG PILES

FIG. 36. CHENOWETH PILE.

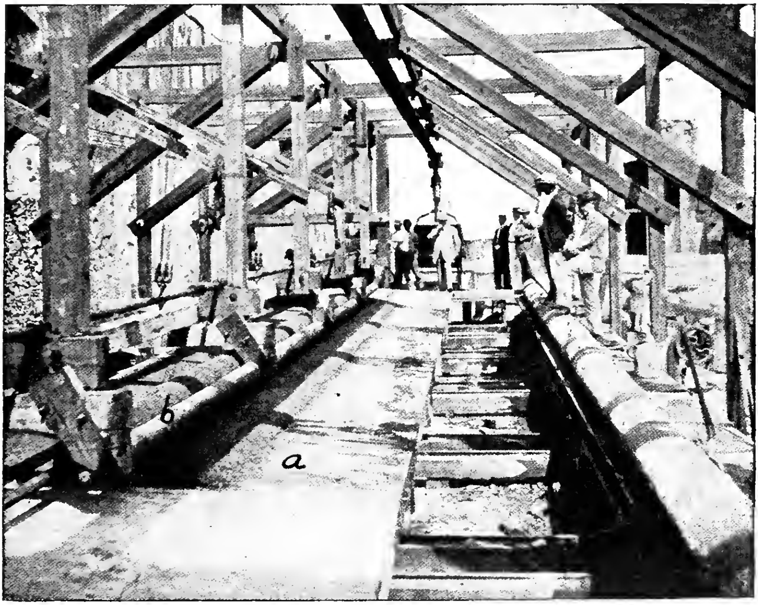


FIG. 37. APPARATUS FOR MAKING THE CHENOWETH PILE.

The apparatus for rolling the pile consists of a traveling platform and roller between which the pile is formed. The winding rod in the center is set in line with the shaft of the large spur wheel shown. In operation the steel wire netting, with the longitudinal rods attached, is spread on the platform and covered with a layer of concrete. One edge of the netting is attached to the edge of the platform, and the other to the winding pipe or mandrel. The mandrel is then rotated and the netting and its covering of concrete is wound or coiled up as shown in the accompanying illustration. At the same time, and as fast as the netting and concrete are coiled, the platform *a* (Fig. 37) moves under the roll *b*, and the roll itself rotates, thus pressing the pile into shape.

To bind the roll of concrete, wires are wound around it at intervals of 6 in. and tied. The wires are placed upon the platform beneath the mesh so that when the pile reaches the lower edge of the platform and is entirely rolled, they can be tied about the pile. The spools containing the wires are placed 4 in. apart for the first 6 ft. of the pile from the driving end, and 6 in. apart for the remainder of its length. The pile is removed from the machine and rolled upon a car, by which it is transported to a platform, where the point is formed, and on which it is allowed to remain until hardened.

The driving cap is a steel cylinder, with a diaphragm in the center. The lower end of the cylinder fits on the head of the pile, and the upper end receives the wooden driving block. A cushion of rope is used between the head of the pile and the diaphragm, while a cushion of sawdust is placed between the diaphragm and the driving block.

The piles are driven with an ordinary pile driver and an extra heavy hammer. The concrete used is generally a 1:2:3 mixture of Portland cement, sand and screenings or broken stone.

Cast-in-Place Piles.

The Raymond system is an economic way of placing caissons. A heavy mandrel, called a core, is surrounded by a casing of sheet steel and the whole is driven into the ground by means of a steam hammer. When the desired depth is reached the core is collapsed and withdrawn from the hole, leaving the steel shell in the ground as a form for the pile; the concrete is then shoveled into the hole and the pile is complete. The sheet steel shell is made heavy enough to withstand the pressure of the earth along the sides of the hole, and protects the concrete from mixture with the surrounding earth. These shells are usually made in eight-foot sections, and each section laps the other 6 in. The point section is first placed on the core, then the next above, etc., until the core is covered. This brings the lap on the outside and each section is pushed into place as the driving proceeds.

After the core is withdrawn and before placing the concrete, the interior of the shell can be inspected, by means of an electric light, by reflected light from a mirror, or by the light reflected from the surface of water thrown into the hole. The 20-ft., 25-ft. and 30-ft. cores taper from a 6-in. point to a 20-in. head; the 35-ft. from an 8-in. point to a 20-in. head; and the 40-ft. from a 10-in. point to an 18-in.

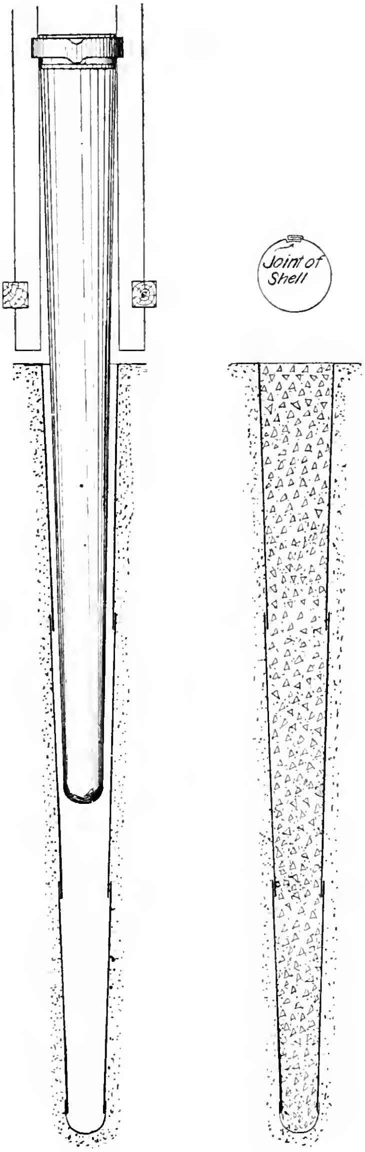


FIG. 38. RAYMOND PILE.

head. This is a greater taper than is found in any other type of concrete pile and is as great as practical limitations will permit. The diameter of the head, and the taper, are designed to provide a large bearing surface for the concrete footings, a large surface area for frictional bearing, and a maximum compression of the earth surrounding the pile.

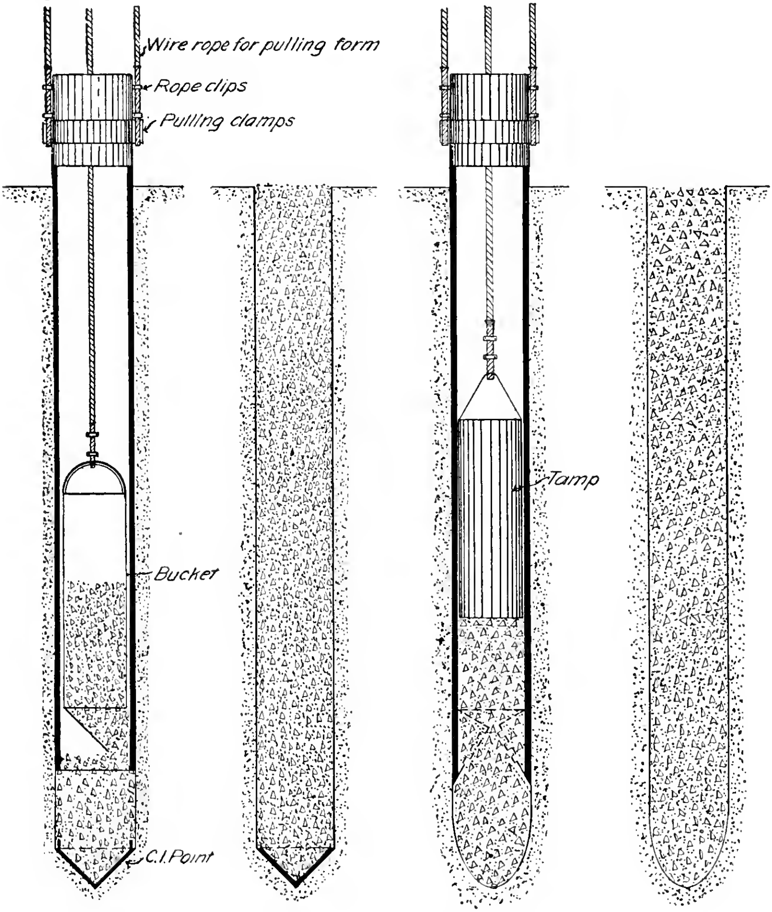


FIG. 39. SIMPLEX PILES.

While the Raymond pile is rarely reinforced, reinforcement may be added by lowering a fabricated skeleton into the shell before the concrete is placed. Rods may also be placed by churning them through the concrete after the shell has been filled.

The Simplex system consists in driving an extra heavy iron pipe into the ground with a special point to exclude the dirt; when this pipe is driven to the proper bearing, a drop-bottom bucket, filled with concrete, is lowered to the bottom of the pipe and dumped. The bucket is then removed, a heavy weight lowered into the pipe, and the pipe raised nearly to the top of the concrete, the weight being repeatedly dropped on the concrete, thus forcing it out of the end of the pipe. Another bucket of concrete is then placed in the pipe and the operation repeated until the pile is formed.

Two kinds of points are used, depending upon the character of soil through which pipe is driven. If in soft soil, a cast-iron point closes the end of the pipe, while in stiff clay, a pair of jaws are used. These jaws are attached by hinges to the bottom of the pipe, and automatically open to permit the concrete to flow through them as the pipe is raised. The pipes used are extra heavy steel, banded where necessary, and are made up in sections of varying lengths to suit the length of pile required.

The pipes are cylindrical and are usually 16 in. in diameter. The only limit to the length of pile, which can be driven by this method, is the ability to drive and pull the pipe. In stiff, non-water bearing, or clay soils, where the ground has no tendency to flow, this is the cheapest system of installing concrete piles.

Estimated Commercial Use.

After careful inquiry it is estimated that about 2,500,000 linear feet of cast-in-place piles are now in use in this country. No definite data in regard to the use of cast-and-driven piles could be obtained, but the quantity is believed to be less than 250,000 linear feet.

Advantages of Concrete Piles.

Wooden piles are loaded to about fifteen tons, and while many engineers think they are capable of carrying greater loads, this load represents conservative practice. The loads allowed on concrete piles vary from 25 to 50 tons each, depending upon the nature of the ground, and the system used; in European practice they are loaded to 40 or 50 tons each, and there are records of piles loaded to 80 tons; the best American practice, however, limits the load to 35 tons.

To prevent decay wooden piles are cut off at low water and the foundations must be carried down to this level. The tops of concrete piles may be at any elevation desired and the depth of the footing course will be governed by the spacing of the piles, and the weight of the superstructure. In this way the expensive excavation for deep footings, as well as the cost of the additional depth of footings, is saved.

Concrete piles cannot be driven as rapidly as wooden piles, but since the load per pile is greater, their use may result in a saving of both time and cost. If concrete piles are used, no delay is occasioned by waiting for the arrival of the piles; wooden piles are difficult to obtain in certain parts of the country, but sand, stone and cement are generally available. There is no reason why concrete should vary in quality, while it is becoming more and more difficult to obtain wooden piles of a standard grade.

A wooden pile rots if alternately wet and dry and is subject to attack by the teredo and other wood borers, when placed in salt water. The elevation of ground water fixes the point of cut-off, but the building of deeper sewers in the neighborhood may lower the ground-water level, and when this occurs wooden piles are subject to decay.

Possible Disadvantages of Concrete Piles.

The argument most frequently urged against concrete piles is their cost. The cost per linear foot is certainly greater for a concrete pile than for one of wood, but when the saving in excavation, size of footings, number of piles and time of completion, are taken into consideration, this additional cost per foot is discounted. Generally when these items of cost are considered, they should show a decided advantage in favor of concrete piles.

The length of cast-in-place piles is limited, but piles cast and driven may be of any length. When driven with a core or pipe, the maximum length thus far attained is 45 ft.; no cores have been made longer than this, while the difficulty experienced in pulling the pipe, renders a greater length impracticable.

Cast-and-driven piles require careful handling if made in long lengths, as cracks cannot be readily detected, and the piles should preferably be allowed to set several weeks before using. If made on the job this delays the work, while if made in distant yards, the exact lengths are hard to gage, and the piles may be either too short or too long. As the operations of lengthening or shortening cause delay and expense, it is very desirable that the penetration be determined before the piles are brought to the site.

If shells are used, they should be made of steel heavy enough to withstand the side pressures of soft ground or the shearing effect of boulders or gravel. Some objection has been made to dropping concrete through the longer lengths of a cast-in-place pile. As a wet mixture is used, and the concrete is deposited by shovels, it should be properly graded when the pile form is full.

The driving of an adjacent pile tends to settle the concrete in the pile just filled, thus forcing out the air bubbles, and while distortion may occur, particularly in the case of piles driven without a shell, this danger has not been manifest in actual practice.

In cast-in-place piles, unprotected by a shell, it is impossible to inspect the integrity of the pile. After the concrete leaves the end of the pile, it is subjected to the action of the surrounding ground without protection. Soils bearing running water may carry off a part of the cement, leaving the coarser aggregates; very dry, porous soils may absorb the water needed in setting; in either case the bearing power of the pile would be affected.

As in the case of peeled wooden piles, a smooth exterior offers less resistance to movement than a rough one. However, when the attempt is made to increase the skin friction by cementing the pile to the earth in which it is cast, a question arises as to how much the pile itself is weakened by an admixture of earth. The necessity of reinforcing concrete piles in certain soils is apparent, and the greater the dependence placed upon point bearing, the greater the necessity for reinforcing.

The bearing power of all piles is dependent upon a combination of two elements, viz., point bearing and skin friction. Point bearing depends upon the class of material upon which the pile rests, the area of the point, and the material of which the pile is made. Skin friction depends upon the compression of the earth through which the pile is driven, and all the earth, from the top to the bottom of the pile, adds to its bearing power if subject to compression.

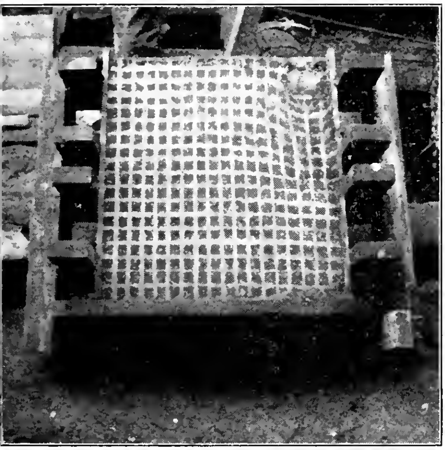


FIG. 40.

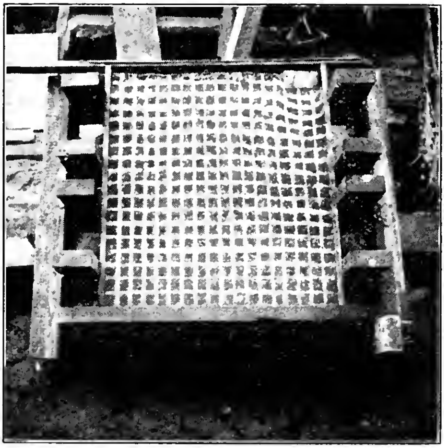


FIG. 41.

Probably the bearing power of every pile driven is dependent upon both the above factors, the percentage of each varying with the character of the soil and the shape of the pile. The larger the point, and the less the taper of the pile, the more point bearing is dependend upon, and vice versa. A pile depending upon point bearing, acts as a column, supported more or less at the sides, and any pile acting as a column should be reinforced. When subjected to bending stresses or placed in semi-liquid or shifting soil, piles should be reinforced. Piles, whose method of manufacture precludes the insertion of reinforcement, are not adapted to use in service which requires action as a column.

Figures 40 and 41 illustrate an experiment made to ascertain the distance to which a pile compacts and otherwise influences the surrounding soil and also how the earth acts under the lower end of a pile. A box about 1-ft. deep and 3-ft. square was constructed with a removable side. Sand of ordinary consistency was dumped into the box and compacted to a moderate extent. The side of the box was then removed and the surface divided into squares by shallow grooves filled with white sand. The side was replaced and bolted in position and a block of wood driven into the sand in exactly the manner in which a blunt pile would be treated. The effect of the penetration of the pile is shown by the distortion of the white lines in the photographs, and can be seen best by sighting along the surface of the paper. It was interesting to note the distance below the block to which the earth was influenced and how the sand was actually bulged upward to some extent.

LIST OF QUESTIONS ON PILES AND PILE DRIVING.

Circular No. 123. Issued July, 1909.

1. Sheet Piles. Please advise in regard to your use of sheet piles with particular reference to the following data: (a) Kind and length used (maximum, average and minimum lengths); (b) Describe driving apparatus; (c) Dimensions of enclosed area; (d) Depth of water and penetration; (e) Depth of excavation; (f) Character of soil; (g) Were piles braced? If so, how? (h) Had the piles been used before? (i) Conditions when removed; (j) Was service entirely satisfactory? Why?

2. Water Jet. Please advise in regard to your use of water jet, with particular reference to the following data: (a) Kind of pile, size, and purpose; (b) Describe apparatus; (c) Character of soil; (d) Describe jetting apparatus; (e) Water in gallons per minute; (f) Results of test loads, if any; (g) Give weight of hammer, fall, penetration, etc., of any piles driven in same locality without jet; (h) Give description of failures of jetting piles.

3. Concrete Piles. (a) What system have you used? (b) How many of each? (c) Were they satisfactory? If not, why not?

4. Record Blanks. Please forward copy of pile driving record you recommend.

5. Mechanical Protection. What do you consider the best mechanical method of protecting wooden piles from teredo, decay, abrasion, etc.? Please send sketch and other data.

Appendix F.

THE SUPPORTING POWER OF PILES.

BY ERNEST P. GOODRICH, M. AM. SOC. C. E.

Piles, whether of timber, concrete, steel or other material, sustain the superimposed load by acting either (a) as columns, more or less restrained; (b) as floats; or (c) as combinations of these two. Their supporting power, in each instance, is due to an entirely different series of phenomena, each of which must be separately considered in any endeavor to predetermine the ultimate supporting power of the pile.

PILES ACTING AS COLUMNS.

A method of design has sometimes been employed where the bed of a waterway has been found to consist of solid rock, of drilling shallow holes a foot or more in depth, and placing blunt piles in these recesses with their tops carefully swaybraced and capped. The weight of the structure prevents damage from a certain variety of wave or tidal action, while the swaybracing is depended upon to prevent lateral motion and collapse of the structure as a whole. In this instance each pile acts entirely as a column, more or less restrained at or near the head, while the foot is practically free to turn and more nearly approaches the condition of a so-called "round-ended" strut.

In case the rock happens to be overlaid with a thin stratum of comparatively dense material, it is sometimes unnecessary to drill holes into the rock, dependence being placed upon the overlying stratum of soil to prevent lateral motion of the foot of each pile. Where the rock is of a shelving nature, this type of design must be studied with special care, as the slipping of the bottoms of the piles has been known to wreck the structure entirely. In an endeavor to prevent such action taking place, riprap has sometimes been deposited among the piles after they have been driven, but the added weight upon the material overlying the rock has been the probable cause of a subsequent sliding which moved the bottoms of the piles.

Where a stratum of hardpan exists, it serves in practically the same capacity as a rock bottom, so far as affording sufficient support for the piles is concerned. Because the latter are usually made to penetrate the hardpan to a limited extent, they receive some lateral restraint at the lower ends, and need no longer to be computed as "round-ended" members, but may be considered as struts with square ends.

In this connection, attention is called to the fact that the greatest care should be employed in driving piles, which are expected to rest on bed rock or penetrate slightly a stratum of hardpan, in order to prevent shattering or crushing the bottom of wooden or concrete piles, or the permanent bending or curling of the lower ends of metal piles. Otherwise, the supporting power of the member may be seriously impaired. More damage has probably been done by "overdriving" under such conditions than has been caused by settlement or other trouble from underdriving.

When, as is usually the case, the soil is composed of strata of different consistencies, it is customary to endeavor to drive the piles so that their points will penetrate a stratum which is firmer and offers more resistance to driving than those which lie above it. Under such circumstances, the lower end of each pile receives a considerable restraint, varying with the consistency of the soil, and it has been found that wooden piles driven in such soft material as Hudson River silt will break off, in case of trouble, approximately at the mud line. It is evident that such piles may be considered as fully restrained members, so far as the bottom of the pile is concerned, whenever they penetrate a sufficient distance into a firm stratum. Experiments can well be made and experience recited to determine the necessary penetration required to produce full restraint in different soils under different degrees of saturation. Experience with telegraph poles, and the few reported examples of pile failures of this type seem to show that only a relatively short length of penetration is necessary. It would be a very easy matter, where piles are being driven for a trestle across a swamp, with varying degrees of consistency and humidity of the soil, ranging from the firm material on the bank to the soft material at the center, to use a block and fall for actual tests of a number of piles to ascertain the resistance offered in the way above mentioned. The amount of this resistance should be measured, from time to time, over a period of several days, together with the deflection produced at several points along the pile, so as to ascertain the shape of the bent member and deduce its curve at the bottom for each penetration, kind of soil and lateral force.

The amount, stiffness and other characteristics of the swaybracing required near the top of a pile, when driven under each of the conditions above described, has a very great influence on its supporting power, and must therefore always be considered in computing this factor. The usual rules of diagonal bracing for bridge portals are entirely applicable to such conditions. The amount of natural curvature in the pile is also a factor which must be considered, together with the amount of flexure produced after the pile is driven by forcibly drawing the heads over out of their natural locations, to properly line poorly driven piles for capping or other similar purposes. Two-inch new hemp rope in a four-part tackle has been broken in such an effort, and the resulting bending stresses produced in the pile must have been correspondingly large.

Where dependence for the supporting power of a pile is placed upon a deep-lying firm stratum, both theory and experience have shown that the depth of the stratum below the surface has an appreciable effect on the actual supporting power afforded the bottom of the pile. A thorough investigation of the literature on the subject discloses so few experiments and so little information relating to this important topic, that accurate tests are exceedingly desirable, and every opportunity of securing accurate data should be embraced. In order to prevent complications arising through the action of friction on the sides of piles, the tests can probably best be made by first carefully sinking a large pipe, and, after the soil has resumed its natural condition, inserting through this pipe a heavy timber with a blunt cap just large enough to pass through to the earth to be tested. A platform at the upper end of the timber can then be loaded and accurate observations made to determine the compressibility of the soil in amount and rate under different loads. The latter should be alternately increased and decreased, to ascertain whether any elasticity exists, and the experiment should be continued over several days or weeks, in order to ascertain whether the special soil under examination possesses any characteristic comparable with the viscosity of certain materials. Pipes and plungers of several sizes should also be employed. The few experiments which have been made, and a study of the records of load tests of piles seem to show that soils possess each of the three qualities previously mentioned, viz., compressibility, elasticity and viscosity; and it is only after accurate information is obtained regarding each of these three items that the actual supporting power and the amount of settlement, which is to be expected in any given instance, can be computed.

The pipe should be sunk by dry methods, and accurate data secured of the weight per cubic foot, amount of humidity, and internal friction coefficient peculiar to each varying depth and kind of soil. Having ascertained these items, a further examination of them by methods similar, for example, to those used by the writer,* should be made, with varying amounts of water in combination, to investigate the possible effects which may be expected with changes in the amount of ground water present under any foundation. Piles which were considered entirely satisfactory, driven into a stratum of firm clay, have been known to become displaced to the extent of several feet even after some years of satisfactory service, because of a change in the amount of water in the clay stratum, which caused a marked reduction in its friction coefficient, so that the clay acted as a lubricant, the superimposed strata squeezing it aside and sliding upon it, carrying the piles downward and sideways to varying distances.

Since a pile must displace the soil, through which it is driven, the latter must either become considerably compressed, or actually move

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*Lateral Earth Pressures and Related Phenomena, by E. P. Goodrich, Trans. Am. Soc. C. E., Vol. 53, p. 272, Dec., 1904.

aside to allow the pile to take its proper position. This compression in itself changes the nature of the soil in many instances to such an extent that while piles which have been driven with a large spacing have been found to settle badly, other piles under the same conditions with a closer spacing have been found entirely satisfactory. Reference is now made solely to the action near the point of the pile with regard to the supporting power afforded, and has no relation to the shape of the pile above this point, whether the member be straight or tapered.

For piles which act as columns under any of the conditions above described, the cylinder is probably the most efficient shape which can be employed for separate piles, while square or rectangular sections are best for sheet piling of timber or concrete. In the case of sheet piles, special metal shapes may be employed advantageously, because the supporting power is not involved then to any appreciable extent.

PILES ACTING AS FLOATS.

Where a pile is placed so that its tip does not rest upon nor penetrate a supporting stratum, the resistance which it offers to superimposed loads is due to the frictional resistance between the surface of the pile and the surrounding soil. In any endeavor to ascertain the amount of this frictional resistance through other than experimental methods which involve the piles themselves and which are very difficult of execution, the general conditions involved in the problem of earth pressures must be studied.

The cohesion which characterizes solid bodies from the point of view of the physicist exists in soils under ordinary conditions only to a limited extent. Few investigators have given this subject any study, but the best discussion in English is contained in Prelini's book on Earth Slopes, Retaining Walls and Dams. While a rigorous discussion must include the effect of cohesion, it has been the usual practice to ignore this element in the problem, both because of the mathematical difficulties introduced by its inclusion in formulas, and because of its widely varying nature due to changes in the degree of saturation, and in the compression produced by driving adjacent piles, or by similar causes. Rankine's celebrated discussions consider earth only as a granular mass, and his deductions are open to criticism since the results obtained differ from those of actual experiment, the difference being due to his omission of cohesion and because most engineers employ in his formulas the angles of surface slope, which the writer's experiments* have shown are quite different from those of the internal friction of the material. The latter should obviously be used for all earth pressure computations and give results by using Rankine's formulas which are very closely in accord with the results of properly conducted experiments. When the angle of internal friction is employed, the effect of cohesion seems to be automatically included, so that complicated mathematical conditions are not necessary.

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*See preceding footnote.

Under relatively heavy pressures and a varying degree of saturation depending upon the material, almost every variety of soil discloses phenomena, which can be most easily explained on the assumption of the existence of a sort of viscosity, such as is observed even in solids of high cohesive strength.*

Tests of the compressibility of earths show a certain amount of elastic deformation, of course always in combination with a large amount of permanent set, the elastic reaction being very small in dry sand and relatively very large in garden soil. In a purely granular mass devoid of cohesion and disclosing no elastic reaction, a pile could be driven only by an absolute displacement of material, and the resulting pressures against the displacing body would be purely those due to the weight of the material above any given area of the displacing body. Where the material, however, is compressible and exhibits any elastic properties, it is possible that the pressures exerted against the displacing mass may be greater than under the conditions above mentioned. Finally, any material which is of a viscous nature will tend to shift, so that the pressures which might have been produced against the surface of such a displacing body as a pile would be entirely altered with lapse of time, in some cases increasing, and in others decreasing. For example, a pile of slightly irregular surface would displace the material, so that voids would be left adjoining the hollows in the surface of the solid into which the viscous material would ultimately flow and exert a greatly increased resistance to subsequent motion. This is the usual phenomenon observed under most conditions with regard to piles. On the other hand, where considerable elasticity exists in a soil, in combination with a large compressibility, the lateral pressures immediately after the displacement of the material by the solid are actually greater than exist at later periods after the surrounding material has had an opportunity to flow slightly away from the penetrating body, so as to readjust and equalize the stresses throughout the whole mass. Occasionally phenomena which are traceable to this condition have been encountered in connection with pile-driving observations in which a pile showed a large resistance to driving and subsequently settled *through* the surrounding soil. This phenomenon is not to be confused with that often observed in which settlement takes place, due to the compression of deeply underlying strata, into which the pile and its surrounding earth settles en masse.

Similar changes of the lateral friction and attending lateral pressure may also be due to vibration, which may produce effects similar to those observed when a pile of irregular shape is driven and voids are produced, thus reducing the actual area of contact. Vibration may also expedite the viscous action, the readjustment in pressures taking place more rapidly and to a greater extent, causing the resulting frictional resistance to fall below the necessary requirements. Changes in

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*See article by Ira H. Woolson, Eng. News, Vol. 54, p. 459, Nov. 2, 1905.

the humidity of the soil are also apt to produce changes in the lateral pressures. This is sometimes caused by actual changes in the coefficient of sliding friction between the solid mass and the soil. Again it may be due to the fact that the lateral pressure will vary with the coefficient of internal friction, as indicated by the writer's experiments. In the last paragraph, it was explained how a reduction in pressure may be produced through viscous action. An actual increase in pressure may also be developed through a readjustment of stresses caused by the displacement of soil by driving other piles in the vicinity.

While considering increases of pressure, the well-known arch action must not be overlooked, especially with non-viscous materials. This arch action serves to prevent the full theoretical lateral stresses, which will only be produced where a marked viscosity exists. Arch action also influences the upward pressure against the bottom of a pile and is indirectly the cause of carrying down of a group of piles by a single overloaded one.

Every one familiar with the phenomena of pile driving is aware of the considerable changes which take place, especially in the interval immediately after the driving of the pile. The writer has observed increases of resistance amounting to over one thousand per cent. within twenty-four hours. His investigations have discovered practically no data in regard to this phenomenon, which is universal in effect and which absolutely governs the ultimate supporting power of a pile, but is ignored in every pile formula with which he is acquainted. It seems to be possible to collect data from a comprehensive series of experiments with different kinds of soils, and at very little cost, by simply measuring the resistance offered by several piles, in terms of any pile formula, where the soil conditions had been previously ascertained. Comparisons between individual cases will be much more difficult to reduce to any proper basis upon which to draw conclusions with regard to different soils, than is the case with regard to the time rate of change of pressure for any special pile in a known soil, which can be even more easily determined and is of equally great value. It is strongly recommended that such data be collected.

PILES AS COMBINED COLUMNS AND FLOATS.

In making computations of pile resistance, the course is often pursued of computing independently the supporting power of the soil at the point of the pile and the frictional resistance offered by the sides. This is done on the assumption that the two elements which correspond to the coefficients of elasticity are equal. It is needless to say that this is rarely the case. Other investigators treat the problem as if the bottom of the pile were provided with a long tapering point, so that the whole phenomenon is one of frictional resistance, which later may vary from point to point along the pile surface due to variation in the strata penetrated. That a compressed earth point actually exists under the bottom of a blunt pile, has been practically demonstrated to the writer's satisfaction by his observations not only in the case of the model with a glass side,* but also in the case of full-sized models driven in boxes of earth, and from excavations made under the points of actual piles. Theoretically, each change in the slope of the pile surface, as well as each change in the character of the surrounding soil, produce a variation in the unit resistance. That the theoretical conditions approximate very closely to those actually existing in nature has been demonstrated in several instances, notably in the experiments of Stern, described in "Das Problem der Pfahlbelastung."

THE FORCES ACTING ON PILES.

Under any conditions in which piles act as columns, both the unit compressive strength of the material and its bending strength are involved. Every pile-driving specification should give the maximum unit compressive stress to be allowed and the load which may be carried, whenever the pile acts as a column. For this information it is necessary only to turn to the experiments made by engineering laboratories. It is a difficult matter to arrange any pile-driving formula, to take account of these items, but manifestly an ideal formula should do so. The only trouble with laboratory experiments is in their wide difference from practical conditions. In the laboratory, an effort is usually made to simplify conditions to the utmost, so as to be able to change but a single condition at a time and thus measure its effect upon the general problem. In the field, innumerable extraneous conditions enter to complicate matters, so that laboratory data are to be employed with this point constantly in mind. However, with a properly equipped laboratory, it would be possible to make actual tests with a large number of stock piles, one end of the piles to be bedded in earth to varying depths, so as to afford varying degrees of restraint, or the tests might be made with square ends, and the restraint provided by means of steel springs or other equivalent devices. A very large number of such experiments would be necessary to ascertain true averages under different conditions, or what is even more important, the extreme range of strength secured and the average variation from the mean. It is only from a number of results that the measure of their accuracy can be determined either theoretically or practically. On the basis of such laboratory tests, only a very few comparative field tests would be needed to determine actual conditions and hence what sort of a formula is required and its method of application.

A close approach can doubtless be made to the laboratory work above described by means of indirect experimental evidence and its application in purely theoretical mathematical formulas. For example, the writer always makes use of his experiments concerning the compressibility and elasticity of various soils with various degrees of saturation, to determine in any special case whether the earth pressure

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*The Supporting Power of Piles, by E. P. Goodrich, Trans. Am. Soc. C. E., Vol. 48, p. 180, Aug., 1902.

initially developed will increase or decrease with the lapse of time. The actual lateral pressures to be expected are computed by the writer on the basis of his experiments with the shallow cylinder described in "Lateral Earth Pressures and Related Phenomena." These results are checked as far as possible in individual cases by making the described experiments to determine the internal friction of the earth. With this data available, results can be predicted with a fair degree of precision except for the influence of the factor of viscosity. The writer knows of no experiments on viscosity except his own, which were performed only on clay and hence are too meager to obtain accurate results. This field is one in which the testing laboratory can be of material service to the engineer who has to do with the effects of lateral pressure in the design of pile foundations, masonry footings, retaining walls, earth embankments, etc.

A more elaborate experiment, which is sometimes performed, and which gives results combining the effects of compressibility and viscosity, is the one described above for ascertaining the carrying capacity of the earth at varying depths. Information of this character is of considerable value, because it often happens that the driving of a cluster of piles simply serves to consolidate the soil throughout a given region. The latter, in its turn, rests on underlying and supporting strata, which may actually be incapable of resisting the stresses developed, and hence settlement of the whole mass may occur. The result is often attributed to improper piling or pile driving, whereas the true causes are entirely different. This difficulty is often encountered where the piles are too short. On the other hand, in the effort to overcome this particular source of trouble, needlessly long piles are employed. The aim should be to discover the proper length of pile to consolidate the soil to a depth at which the resistance is sufficient to support the superimposed loads, and where the character of the material is such, that no viscous action will take place in any of the underlying strata.

INDIRECT METHODS OF TEST.

The usual procedure which was followed by those who desired to secure some measure of the forces which resisted the load upon a pile, has been by a theoretical consideration of the phenomena observed during the sinking or driving of the pile, especially of its action under the blows of a hammer. At best, however, such information will afford data which is applicable only at the time of driving, since it ignores entirely the subsequent changes in the condition of the earth, which have been shown to modify materially the supporting power of the pile. In the mathematical development of the subject, the general theory of impact is employed. With regard to the theoretical phenomena which would be expected during the impact of perfectly elastic materials, with perfect freedom of motion, there is no question; and even when the masses are not perfectly elastic with known coefficients of restitution, the matter still remains comparatively simple. In the case of a hammer falling upon the head of a pile and of the pile moving under the effect of this blow, perfect freedom of motion is impossible. The hammer, if of the gravity type, is restrained from falling freely, by the friction of the guides, that of the rope through the sheaves, by the stiffness of the rope, by the friction of the drum of the hoisting engine, etc. It may be possible in any given case to determine the influence of each of these factors, and thus to ascertain the exact velocity, and hence the corresponding momentum with which the hammer strikes the head of the pile. By assigning proper coefficients applicable to the size, shape and material of the hammer, and of the pile, it is possible to determine the velocity of the latter at each instant during the impact, provided, however, that the actual masses moved by the hammer are known. Besides the pile itself, these masses must include an absolutely unknowable mass of soil. Granting, however, the possibility of assuming a proper value for the mass acted upon by the hammer and the further possibility of computing accurately its initial velocity, the problem again immediately enters the region of the unknown, because the real item concerning which knowledge is desired is the measure of the force which brings the pile to rest. If this force is assumed constant and the initial velocity and mass of the pile are known as well as the distance which it travels, before it is brought to rest, then .the measure of the force can be computed. There is every reason to believe, however, that this force is not a constant during the motion of the pile, and that it should vary in character and strength at different depths, with different degrees of compactness of soil, with the shape of pile and the velocity of its motion, is to be expected from the general theory of earth pressures. It was in an endeavor to solve some of the problems arising with regard to the kind of force acting that the writer devised his graphical method of indicating the action of a pile during the blow of the hammer.* In connection with this work, the writer also endeavored to ascertain the amount of variation encountered in the several phenomena investigated, and the limits of accuracy for the several devices employed.

As a result of his investigations, the writer is of the opinion that, as far as the phenomena connected with the driving of a pile are concerned, a very simple formula may be employed in connection with a coefficient, which may be determined for a special set of conditions with a fair degree of accuracy, but which must vary widely, in order to cover the great variety of conditions actually met in practice. This simple formula might be employed as the basis around which to arrange a number of dependent functions or coefficients, which should take account of the soil conditions, the length of pile acting as a column, etc. For a number of years, the writer has been working intermittently toward the construction of such a formula, but so much experimental data yet remains to be obtained that no definite form has

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*The Supporting Power of Piles, by E. P. Goodrich, Trans. Am. Soc C. E., Vol. 48, p. 180, Aug., 1902.

yet been decided upon. With the co-operation of your Society, it might be possible to secure the necessary information which would then go far to settle a point, which has been in controversy among engineers for a century or more, viz.: the actual supporting power of a pile under known conditions.

FACTORS THEOROETICALLY ESSENTIAL TO A COMPLETE PILE FORMULA.

The following items should be known and included in a theoretically complete pile formula to be used for piles supported only by friction, the formula being based on data obtainable from the effect of the hammer on the pile and the subsequent action of the earth around the pile: (1) Weight of pile. (2) Weight of hammer. (3) Fall of hammer. (4) Coefficient of friction during fall. (5) Penetration of pile. (6) Spacing of piles. (7) Coefficient and factor for the compressibility of the soil and the effect of spacing. (8) Coefficient for the effect of the shape of the pile on the compression of the earth, etc. (9) Length of pile below ground surface. (10) Coefficients and factors to allow for subsequent changes in lateral pressure throughout the length of the pile. (11) Length of pile above ground. (12) Area of pile. (13) Coefficient and factors to govern column action and unit compressive stress on pile.

TESTS REQUIRED.

The following items should receive attention and special tests be made with regard to them: (1) Lateral restraint afforded by soils of different kinds and degrees of saturation. (2) Lateral pressures exerted by different soils, etc. (3) Compressibility of different soils. (4) Elastic reaction produced by different soils. (5) Viscosity exhibited by different soils. (6) Effects of jar on each of these characteristics. (7) Effect of lapse of time on these characteristics.

Appendix G.

STRENGTH OF REDWOOD TIMBER.

The following abstract is made from a progress report by the U. S. Forest Service, dated March 31, 1909, the tests having been made in co-operation with the Redwood Association. The material was selected by a member of the Forest Service, assisted by experienced mill men, an attempt being made to represent the various qualities occurring in commercial material and in amounts proportional to the general output.

The trees were felled in February, 1908, in Central Mendocino County, Albion District, California, and shipment to the laboratory included 4,867 ft. of sawed lumber in 70 pieces with sizes ranging from 2x8 in. to 8x16 in., and 16 ft. long.

The beams tested were loaded at the third points, the average percentage of moisture being 68.1, the average results for 21 beams ranging in section from 7x9 to 8x16 in. and a span of 15 ft., expressed in lbs. per sq. in., are 4,210 for the extreme fiber stress at the elastic limit, 5,190 for the ultimate stress in the outer fiber, 260 for the longitudinal shear and 1,249,000 for the modulus of elasticity. The corresponding values for 24 beams from 2x8 to 3x14 in. and a span of 15 ft., are 3,160, 4,240, 190 and 1,030,000. By comparing the larger sizes the strength of redwood in flexure expressed as a percentage of that of Douglas fir is 96 at the elastic limit, 81 for the ultimate stress in the outer fiber, and 74 for the modulus of elasticity.

The average results for the elastic limit in compression on the side of the fibers are as follows: 19 tests on sticks, 7x9 to 8x16 in. in cross-section, give 470; 43 tests on sticks 2x8 to 8x16 in., give 450; and 113 tests on sticks 2x2 to 8x16 in., give 550 lbs. per sq. in. All the sticks were 24 in. long and contained an average of 65.7 per cent. of moisture.

For compression parallel to the grain the following average results are obtained: For 17 tests on blocks 6x6 in. and 20 in. long, the elastic limit is 3,270, and the ultimate stress is 4,160 lbs. per sq. in.; and for 70 tests on 2x2-in. blocks, 6 in. long, the corresponding values are 3,560 and 4,150 lbs. per sq. in. The average percentage of moisture is 76. For a comparison of the larger sizes the strength of redwood is 111 per cent. of that of Douglas fir.

DISCUSSION.

The President:—Prof. Henry S. Jacoby, Chairman of the Committee on Wooden Bridges and Trestles, will present the report of that Committee.

Prof. Henry S. Jacoby, Chairman (Cornell University):—Before taking up the work of the Committee in detail, I wish to present a brief appreciation of Mr. James Keys, the late vice-chairman of this Committee, to whom reference was made this morning in the presidential address.

Mr. Keys served the Association nearly five years as vice-chairman of the Committee on Wooden Bridges and Trestles. In behalf of the Committee I wish to express the most hearty appreciation of the personal interest manifested by Mr. Keys in the work of the Association, and of his valuable aid in the investigations undertaken by the Committee and in the preparation of its reports.

On turning to Appendix A of the report, it will be noticed that the first item relates to amendments to the material in the Manual. Two paragraphs are involved, the first on steel, and the second on cast-iron; and on page 32 the revised text is given to bring it into conformity with the specifications on steel bridges. It seems desirable that these paragraphs be the same in both specifications, and I therefore move to adopt them as revised.

Mr. T. L. Condron (Consulting Engineer):—I notice it reads, "if made by the acid process it shall contain not more than 0.08 per cent. phosphorus." The other Committee changed this phosphorus to 0.06 per cent.

Prof. Jacoby:—The idea is to have perfect agreement. It is understood that the same change will be made in these specifications.

The President:—Is there any discussion on the proposed amendments relating to the specification to be covered in the Manual? In the absence of discussion they will be considered adopted.

Prof. Jacoby:—Turning next to Appendix B, these specifications were adopted last year in almost exactly the form in which they are now printed. At that time the titles adopted for the two grades of yellow pine were "R. R. Heart Grade" and "R. R. Falsework Grade," but at the meeting of the Yellow Pine Manufacturers' Association, these titles, although agreed to by their committee, were not approved, and hence on consultation with our sub-committee, which was present at their meeting, it was agreed to substitute the terms "Standard Heart

Grade" and "Standard Grade," respectively. One other addition was made. In connection with the next specification which is to be considered, that on Douglas fir and Western hemlock, the term "full length" was found to be necessary, and it was thought desirable to add this term also in these specifications. This has been agreed to by the Committee of the Yellow Pine Manufacturers' Association and by Committee Q of the American Society for Testing Materials. The word "corner" has also been substituted for "edge" to conform with the trade terms.

Mr. L. C. Fritch (Chicago Great Western):—I notice in the Standard Grade there is no provision for ties and guard timbers.

Prof. Jacoby:—It was not intended to include that.

Mr. L. C. Fritch:—It seems to me ties and guard timbers should be covered, because we may want to use standard grade on inferior lines.

Mr. G. H. Tinker (New York, Chicago & St. Louis):—In paragraph 9, page 34, the specifications call for ties and guard rails, and in Appendix A, page 31, the Committee has defined a guard rail to be usually a metal rail. They should have the words "Guard Timber" here. I think "Guard Timber" is intended in paragraph 9, page 34.

Prof. Jacoby:—There are several cases of that sort in the specifications as printed, but it was thought desirable to let the text pass in its present form, in order that it might be absolutely uniform as issued by the three associations, hoping before long to take up these minor matters and have them adjusted. The term "Guard Rail" should be interpreted as "Guard Timber" in accordance with the new definitions submitted. It will be noted in the next specifications that the term "Guard Timber" has been inserted. We did not think it wise to make the minor changes referred to until the further revision of the specifications is taken up by all of the three committees.

Mr. W. H. Courtenay (Louisville & Nashville):—I would like to see the knot specification limited a little. I think the specification as written admits too large knots in stringers and also caps and sills. Rather than have the specification with reference to the knots as written, it would seem to me preferable to merely say that no loose or unsound knots be accepted. That is a common specification in the yellow pine district, but I fear with this specification as to knots we would get a good deal of bad stuff; you frequently find yellow pine with the grain running across the stringer; such material is weak and should be rejected.

Prof. Jacoby:—The specifications were gone over in detail at the last meeting and adopted in the form in which they are here presented with the exception of a few items previously pointed out, and they are now brought forward simply for the purpose of receiving the approval of the Association with respect to these few modifications in order that they may be printed in proper form in the Manual.

Mr. L. C. Fritch:—I move that a clause be inserted in the specification for standard grade longleaf and shortleaf yellow pine, covering ties and guard timbers.

Mr. Courtenay:—I would beg to say that a railroad company would not want yellow pine ties and guard rails according to the specification for standard grade, for anything except temporary purposes. The sap rots very rapidly on yellow pine.

Mr. L. J. Hotchkiss (Chicago, Burlington & Quincy):—It was the idea of the Committee that such timber as is included under the standard grade would only be used for temporary construction, falsework and other construction of that sort, and for that reason these timbers were omitted and included only in the standard heart grade.

Mr. J. C. Nelson (Seaboard Air Line):—In reply to Mr. Fritch's remark, the practice where I have been, under these circumstances, has been to use a first-class tile and figure on re-using it for some other purpose after it had served the temporary purpose. The ties need not be handled so that they could not be again used, and the inferior timber you would get under this secondary specification would not be of any account after you used it temporarily in falsework. We always used the better class of ties and guard rails, and figure on getting our money back in using them again in another place.

Mr. J. P. Snow (Boston & Maine):—Concerning Mr. Fritch's motion, it does not seem to me consistent for this Committee to specify the use of poor material—you can always buy poor material if you want to without a specification.

Mr. L. C. Fritch:—There are many places where we have trestles for industrial tracks, where we are not justified in using first grade stuff, and second grade stuff would give all the service required. That was my object.

The President:—The matter before us is the adoption of Appendix B.

(The motion was carried.)

Prof. Jacoby:—It will be remembered that last year the specifications as printed in Bulletin 107 included Douglas fir and Western hemlock, but investigation by the Committee just preceding the annual meeting led to the elimination of these species with a view to preparing separate specifications for those timbers. This has been done and the result is given in Appendix C. These specifications represent the result of extensive correspondence in order to learn the practice of different railroads, as well as correspondence with manufacturers and others.

The President:—I will ask the chairman to take up Appendix C section by section.

Mr. L. C. Fritch:—I think the terms used, "Standard Heart Grade" and "Standard Grade," are unfortunate. In the first place, we here use the term "Standard Grade" for inferior material. It seems to me that there is opportunity for making errors in requisitions—if you leave out the word "heart" you get an inferior grade of material, and that is easily done. We should find better terms for these two classes of material, so as to avoid the chance of making that mistake.

The President:—What do you suggest?

Mr. L. C. Fritch:—I suggest "Standard Heart Grade" and "Second Grade."

Prof. Jacoby:—The matter of terms, as you will remember from our report last year, has been taken up for several years in the meetings of the three committees: those of the Yellow Pine Manufacturers' Association, of the American Society for Testing Materials and of this Association; and it has been found exceedingly difficult to select terms which will be satisfactory to the manufacturers. They will not consider for a moment the use of "Second Grade," because of its confusion with that term as employed in the trade in other ways. Last year we had a second conference after our report was adopted, and the next morning, upon our recommendation, there was substituted for "Railroad No. 1" and "Railroad No. 2" the terms "R. R. Heart Grade" and "R. R. Falsework Grade." When the report came before the Yellow Pine Manufacturers' Association it refused to adopt the part relating to grade names, and then the three committees agreed on the terms now submitted as the best that can be secured at present. Possibly in the future better names may be agreed upon.

Mr. Snow:—I am in considerable sympathy with Mr. Fritch's remarks. I do not think that term is a good one. I ask the Committee if they have tried the term "Merchantable" with the manufacturers, to see if that would be acceptable for this low grade?

Prof. Jacoby:—The Committee is glad to receive the suggestion.

The President:—Do you wish to suggest a substitute, Mr. Snow?

Mr. Snow:—I do not think this is the place to force a substitute on the Committee, but I would like them to consider that when they take the matter up.

(Prof. Jacoby read sections 1 and 2 of Appendix C, which were adopted.)

Mr. L. C. Fritch:—I desire to go back to Appendix B and call attention to the fact that the word "live" is left out of the general requirements. Is that intentional?

Prof. Jacoby:—It was pointed out to members of the Committee by those who had experience with Douglas fir that it was very much more important to exclude dead timber in specifications for Douglas fir than in those for yellow pine, and it was so agreed to be the wisest course to have this fact definitely stated.

(Prof. Jacoby read sections 3 to 8 inclusive of Appendix C, which were adopted.)

Mr. L. C. Fritch:—It seems to me that the specifications are inconsistent. In the first place we say that white Douglas fir will not be accepted, and in the same specification we include white Douglas fir.

Prof. Jacoby:—This is now a different part of the specification, relating to a different grade of timber.

Mr. L. C. Fritch:—The numbers are continuous; there is no distinction made. It seems to me we ought to say, in the first place, that white Douglas fir will not be accepted as standard heart grade.

Prof. Jacoby:—That change may be made. Perhaps in the printing of the Manual the division can be indicated by the use of different type, or a dash may be inserted between paragraphs 7 and 8, the subsequent paragraphs being numbered separately. Will that meet your suggestion?

Mr. L. C. Fritch:—There are really two specifications.

Prof. Jacoby:—It seems to me that it might answer all purposes to insert above paragraph 1 the words "Standard Heart Grade" right in the center in small capital letters, as a sub-title, and similarly just above paragraph 8 the sub-title "Standard Grade."

The President:—Does that meet your views?

Mr. L. C. Fritch:—Yes.

Prof. W. K. Hatt (Purdue University):—As to the name of that inferior grade, my understanding is that the manufacturers will not object to the term "No. 2," but that the objection has come from the members of this Association. I think the term "Merchantable" is better.

The President:—I think the members of the Yellow Pine Manufacturers' Association strenuously objected to the use of the term "No. 2," and gave us a number of reasons for doing so.

Mr. C. H. Ewing (Philadelphia & Reading):—Did the Committee intend to cover timbers 10 by 10 and over in size?

Prof. Jacoby:—In proportion; you will notice the word "proportion."

The President:—Clause 9 is adopted.

(Prof. Jacoby then read clause 10.)

The President:—Clause 10 is adopted.

Mr. L. C. Fritch:—I do not think we ought to pass over these names of standard heart grade and standard grade without fixing them definitely. We can readily see how easy it is in making up a requisition and leave out the word "heart" and have a lot of material delivered on the ground which would be unfit for use. It seems to me if we would use the word "merchantable" instead of "standard grade" it would lessen the possibility of error.

The President:—Will you make a motion, Mr. Fritch, to qualify it?

Mr. Fritch:—I will make a motion that the words "standard grades" be changed to "merchantable grades."

Mr. J. O. Osgood:—I will ask if there is any danger of a conflict. In some kinds of timber the manufacturers have a merchantable grade. I do not know whether that is the case in this Western country or not. But if they do have such a program, it might be very confusing to have a merchantable grade for the Association and another merchantable grade of the manufacturer.

Mr. L. C. Fritch:—I think the specifications will fix that.

Mr. O. E. Selby (Cleveland, Cincinnati, Chicago & St. Louis):—I think the term "heart grade" should be retained. It is distinctive and shows the quality most desired in that kind of timber. The term "standard grade" is not distinctive, but it is not objectionable to anybody. The term "merchantable grade" is a trade term that, I think, should be left out of the Proceedings of this body. It is a common trade term, and if adopted here would be confused with other similar terms of different meaning adopted by manufacturers' associations. It seems to me that the objection suggested by Mr. Fritch, the possibility of confusing the two specifications on the requisitions and orders, could be obviated by omitting the word "standard" from the first grade, calling that "heart grade" and retaining the word "standard" for the second grade, calling that "standard grade." I move to amend by making that substitution.

Prof. Jacoby:—There might not be a serious objection to the term, so far as it relates to Douglas fir and Western hemlock, but it is not desirable to make any change in the previous specifications for yellow pine, because, in accordance with the instructions of the Association the Committee has been endeavoring for three years to bring about absolute uniformity between the three associations. The specifications for yellow pine, as adopted to-day, have been published and extensively circulated throughout the country in pamphlet form, and it is desirable that they should be given a thorough test; and then if any modifications be found desirable they can be brought up in subsequent revisions. The Committee has done its best to secure this result, and it is not believed to be wise to change the terms at present. These specifications have been adopted by the American Society for Testing Materials and the Yellow Pine Manufacturers' Association. Of course, any suggestions to be offered can be considered in consultations with the conference committee.

Mr. L. C. Fritch:—With the consent of my second I will withdraw the motion, with the understanding that it will be taken up with the Yellow Pine Manufacturers' Association to see if they can agree upon terms that are not confusing or liable to cause mistake.

Mr. Selby:—I will make a motion that the term "standard" be dropped from the first grade; that the first grade be called "heart grade" and the second grade be called "standard grade."

Mr. Snow:—I think Mr. Fritch was right in withrawing his motion and leaving this matter with the Committee to thresh out.

(Mr. Selby's motion was lost.)

Prof. Jacoby:—I move the adoption of conclusion 2.

(The motion was carried.)

(Prof. Jacoby read conclusion 3.)

Prof. Jacoby:—It was suggested that there be added to the definitions of structural timber, as printed in Appendix B, the definition of "full length," as follows: "Long enough to square up to the length specified in the order."

The President:—With the change suggested, conclusion 3 will be considered adopted.

Prof. Jacoby:—The fourth conclusion is that the report on piles and pile driving be received as information.

The President:—Conclusion 4 is adopted. The Committee is relieved with the thanks of the Association.

REPORT OF COMMITTEE IV—ON RAIL.

(Bulletin 118.)

To the Members of the American Railway Engineering and Maintenance of Way Association:

The Board of Direction instructed us as follows:

(1) Consider revision of Manual; if no changes are recommended, make statement accordingly.

(2) Continue the investigation of the breakage and failure of rails and present summary of conclusions drawn from reports received.

(3) Report on the results obtained from the use of Open-Hearth and Special Alloy Steel Rails, and chemical composition of such rails.

(4) Present report showing diagrams or photographs of typical characteristic rail failures corresponding to the adopted classification of rail failures.

(5) Report on any recommended changes in specifications for steel rails heretofore adopted, and prepare specifications for Open-Hearth Steel Rails.

(6) Present recommendations on standard rail sections.

(7) Consider the rail joint question and recommend design and specifications.

(8) Reconsider and report any recommended change in standard drilling for rails as given in the Manual.

The Committee also considers as a part of its instructions the following resolution submitted by the Committee on Rail and Wheel Sections to the American Railway Association, and adopted by that Association at the meeting held in New York, April 22, 1908:

"Your Committee respectfully recommends that the series of sections of types 'A' and 'B,' and the specifications for Open-Hearth and Bessemer Steel Rails, submitted with this report, be adopted as the recommended practice of the Association, and that the sections and specifications be referred to the American Railway Engineering and Maintenance of Way Association, with the request that they follow up the question of determining the details as to drop test, etc., by observing the actual results of rails rolled under the new sections, and that they also arrange to collect from the different members and tabulate all information as to comparative wear of rails rolled from the different parts of the ingot, and all other information necessary to a proper study of the problem. That they be further requested to keep careful record of the comparative results in service of rails of types 'A' and 'B,' and to prepare and submit to this Association a single type of section which will embody their ideas as to the best type that can be designed for use as a single standard to be adopted by this Association, giving due weight to every factor entering into the problem."

The work was subdivided as follows:

Sub-Committee A—Experiments and Tests:

(a) Confer with the Manufacturers' Committee, through its Chairman, Mr. F. W. Wood, from time to time, in order to keep each Committee posted in regard to the work of the other. It is of the greatest importance that we should not lose the harmonious feeling which has been established by the American Railway Association between the railway men and the manufacturers.

(b) Report upon the results of drop tests.

(c) Recommend additional methods of testing rail.

(d) Exchange statistical information with the Committee of the Manufacturers' Association, and under instructions from the General Committee, confer with kindred Associations.

(e) Make such tests as may be deemed advisable by the General Committee; investigate and report upon tests made by outside parties, such as the Watertown Arsenal, when available, and examine into and report upon methods of manufacture and handling of rails at the mills.

Members: J. A. Atwood, Chairman; R. Montfort, F. A. Delano, P. H. Dudley, J. D. Isaacs, Thos. H. Johnson, J. P. Snow, A. W. Thompson.

Sub-Committee B—Sections and Specifications:

(a) Consider revision of Manual; if no changes are recommended, make statement accordingly.

(b) Report on any recommended changes in specifications for steel rails heretofore adopted, and prepare specifications for Open-Hearth Steel Rails.

(c) Present recommendation on standard rail sections.

(d) Consider the rail joint question and recommend design and specifications.

(e) Reconsider and report any recommended changes in standard drilling for rails as given in the Manual.

Members: J. B. Berry, Chairman; M. L. Byers, J. W. Kendrick, George W. Kittredge, Jos. T. Richards, Robert Trimble.

Sub-Committee C—Rail Service:

(a) Continue the investigation of the breakage and failure of rails and present summary of conclusions drawn from reports received.

(b) Report on the results obtained from the use of Open-Hearth and Special Alloy Steel Rails, and chemical composition of such rails.

(c) Present report showing diagrams or photographs of typical characteristic rail failures corresponding to the adopted classifications of rail failures.

(d) Make comparative statement of the results of the use of series "A" and "B," and other sections of rail.

Members: W. C. Cushing, Chairman; E. B. Ashby, A. S. Baldwin, C. H. Ewing, H. G. Kelley, D. W. Lum.

STATISTICS OF RAIL FAILURES.

The first rail failure statistics for the six-months period from April 30 to October 31, 1908, have been printed in Bulletin No. 111, on pp. 3 to 42, inclusive.

The rail failure statistics for the period of six months from October 31, 1908, to April 30, 1909, have been printed in Bulletin No. 116, on pp. 67 to 155, both inclusive, and the circular requesting statistics for the six-months period from April 30 to October 31, 1909, has just been issued by the Secretary of the American Railway Association, and it is expected that these statistics will be tabulated and printed in a Bulletin before the annual meeting in March, 1910.

Such comments as could be made on the information have already been made and will not be repeated.

OPEN-HEARTH AND SPECIAL ALLOY STEEL RAILS.

The information obtained for the six-months period from April 30 to October 31, 1908, has been printed in Bulletin No. 111, on pp. 43 to 47, both inclusive, and in the same Bulletin, on pp. 110 to 145, Mr. A. W. Thompson, Chief Engineer of Maintenance of Way of the Baltimore & Ohio Railroad, has given the results of the use of Titanium Rail by that Company.

In Bulletin No. 116, on pp. 156 and 157, the information on the comparative wear of "Special" rail has been given for the period of six months, from October 31, 1908, to April 30, 1909.

It is hoped that additional information will be given in response to the call, just issued, of the Secretary of the American Railway Association, and be printed in a Bulletin before the annual meeting in March, 1910.

PHOTOGRAPHS OF TYPICAL CHARACTERISTIC RAIL FAILURES.

The information obtained relative to this subject has been printed in Bulletin No. 116, pp. 3 to 66. It is recommended that no more general photographs be published, as they require a large amount of space, but when special reports are made of valuable studies with illustrations of failures, they should be received and printed for the benefit of the Association.

SPECIFICATIONS.

A new specification should not be proposed at this time without careful consideration. So far as we know, no railroad company has purchased rails under the specifications approved by the American Railway Association and referred to us; nor do we know of any railway company that has succeeded in buying rails during the past two years according to a specification entirely satisfactory to the railroad company. We believe that all of the specifications under which rails have been rolled have been compromises on the part of both parties, with the general result that neither party is entirely satisfied. Our experience during the year has brought to our attention some defects in all of the specifications now before us, and acting under the impression that there is a distinct feeling that we should revise our specifications, we offer the attached specifications for your consideration. Our Association has no specification for Open-Hearth Steel Rails, and in order to comply with the instructions, a specification for Open-Hearth Steel Rails is included.

We believe it necessary to submit a sliding scale for the percentages of carbon and phosphorus, which provides for increasing the carbon as the phosphorus decreases. The fixing of this scale properly is a matter requiring care and we admit that our knowledge on the subject is limited. The American Railway Association specification calls attention to this matter in the following words: "When lower phosphorus can be secured, a proper proportionate increase in carbon should be made." The amount of increase is not provided for in the specifications and this appears to us to be necessary in order to secure uniformity of practice; otherwise, the fixing of these percentages becomes a matter of special arrangement. Bessemer rails are being furnished regularly with phosphorus under the maximum allowed, and where this is done, the carbon should be raised above the higher limit now fixed in our specifications, or a soft and poor wearing rail will result; yet this condition has not been fully guarded against in rails furnished under existing specifications. The lower and upper limits for carbon have heretofore been fixed with the intention that the mills furnish rails with a composition as near between the two limits as possible. The mills, however, in order to meet the prescribed drop tests with the least difficulty, keep both the carbon and manganese as nearly as possible to the lower limits, with the corresponding result that a generally poor-wearing rail is furnished.

Some roads have prescribed the limits of deflection to be allowed under the drop test. With our present knowledge, we believe that we should fix a minimum deflection to eliminate brittle rails and to secure greater uniformity of product; also maximum deflection to eliminate soft rails. We are not able at the present time to fix these limits, but our ultimate object will be to determine and fix such limits for the specifications.

With reference to the amount of discard, time of holding in ladle, size of nozzles, and other such details of manufacture or machinery, we are of the opinion that the physical and chemical tests required should be prescribed and that we should see that the material submitted for acceptance meets the prescribed tests. We should not dictate to the manufacturers the amount of crop which shall be removed from the top of the ingot, as this should vary with the care and time consumed at the various mills. The railroads should not be asked to take anything but sound material in their rails. The mills can furnish such sound material if the proper care and sufficient time are taken in the making of the ingots. Information derived from the tests being made at the Watertown Arsenal shows definitely that sound rails cannot be made from unsound ingots, and that, therefore, the prime requisite in securing a sound rail is to first secure the sound ingot.

We recommend that the present Specifications for Steel Rails be withdrawn from the Manual of Recommended Practice of the Association, as no longer representing the current state of the art.

We submit herewith, as Appendix "A," a form for specifications. It will have to be amended from time to time as we receive further information on the subject.

STANDARD RAIL SECTION.

The instructions of the American Railway Association require us to study the A. R. A. sections "A" and "B" in use and submit a single type for standard. Owing to the conditions existing in 1908, very little rail was laid, and practically none of the A. R. A. sections, in such manner as to give the needed information. This year, several roads have laid A. R. A. sections of rail, with a view of determining the relative merits of the respective sections. These rails have been in the track so short a time that we are not justified in drawing any conclusions as to which of the A. R. A. types, "A" or "B," or if either is better than the A.S.C.E. sections.

Bulletin No. 116, issued October, 1909, gives the statistics for rail failures for six months from October 31, 1908, to April 30, 1909, as reported to the Committee. These statistics do show that the difference in section can be entirely annihilated by difference in chemical composition and by the treatment in furnace and mill.

The results so far obtained from the heavy base A. R. A. sections are disappointing, as we have received some rail from the mills of the new section which was as bad as we did with the old A.S.C.E. section, showing that the quality of the rail does not depend entirely upon the section.

The tests to be inaugurated by the Committee, combined with the results of the tests at Watertown and the performance of the rail in the track, will give us valuable data to aid us in coming to a final conclusion.

The small demand as indicated by mill sales data and the slight possible variation in section of rail below 75 lbs. weight per yard, makes inadvisable the consideration of new sections for this light-weight rail.

No recommendation as to sections of 75 lbs. and over is made at this time, because of the lack of undisputed data upon which to base such design, the service value of the rail unquestionably being dependent upon chemical composition, furnace practice and mill practice, as well as upon the detail differences of dimensions, and the exact effect of each of these various factors is largely in doubt.

RAIL JOINTS.

The tests at Watertown have not progressed as far as we would wish. It is deemed advisable to await these results before submitting recommendations on this subject. The Committee will compile the information received from the Watertown tests and publish a special Bulletin with the information at hand.

STANDARD DRILLING. (See Manual, Page 65.)

We are not ready to recommend any changes, although we are of the opinion that it is desirable to make a change. The tests now being made on joints at the Watertown Arsenal should give some information to aid us in fixing a proper drilling. The drilling now adopted as standard and incorporated in the Manual causes interference in the six-hole angle bars between bolts and spikes where slotted holes for spikes are used. We would recommend that railroad companies which have not adopted the standard drilling postpone action for another year.

TESTS.

The Committee is arranging for a series of tests on rails of different sections and weights of both Bessemer and Open-Hearth Steel, manufactured by different mills, with a uniform chemical composition for each kind of rail. The tests are to embrace drop tests, tests on revolving machine at Steelton, tests on reciprocating machine at Sparrows Point, and a service test in track, the work to be done under the supervision of a man working under the Committee.

DROP TESTING MACHINE SPECIFICATIONS.

The following changes in the specifications as now printed in the Proceedings are recommended:

Paragraph 2: Eliminate the last sentence and substitute the following: "Anvil to be guided in its vertical movement by removable finished wearing strips, these wearing strips to be suitably attached to the finished edges of the column base."

Paragraph 5: Insert the following after the word "castings" in the first sentence: "And the surface of the anvil between these pedestals shall be formed to receive a wooden block to absorb shock under broken test pieces."

Paragraph 6: In the first sentence, substitute the words "column base" for "base plate."

With the above corrections, the Committee submits the specifications as printed in Bulletin No. 102, August, 1908, for record in the Manual.

We submit, as a part of this report, Bulletin No. 111, May, 1909, and No. 116, October, 1909, on the subject of breakage.

(B) FORMS FOR COLLECTING RAIL FAILURE STATISTICS.

The Sub-Committee on Blanks and Statistics submitted the following report, recommending changes in the forms for rail statistics, which recommendations were approved by the whole Committee:

The preparation of rail failure statistics on Form 2004-A, and the analysis of the data, has convinced us that there should be a change in the form. You will observe in the report just submitted that two variations of the unit are used:

(a) Failures in percentage of tons laid, or what is the same thing, failures in tons per 10,000 tons laid.

(b) Number of failures per 10,000 tons laid in the diagram illustrating the failures.

We now think the best unit to use is that in the diagram, viz.: number of failures per 10,000 tons of new rail laid, and we, therefore, submit a revised copy of this form.

We call your attention to the shape of this form, which enables it to be folded letter size.

If the changes in Form 2004-A are adopted, the same changes are required for 2004-B and 2004-C. Prints showing changes are submitted herewith.

As it is advisable to have these forms as near correct as possible before they are included in the Manual of Recommended Practice, we also recommend the following changes:

Form 2002-A: Report of Rail Failures in Main Tracks.

"Question No. 3-A, Kind of Steel," should be introduced for evident reasons, and, in order to balance the upper part of the form, Question No. 15 should be removed to the right hand side at the top.

Form 2002-B: Superintendent's Monthly Report of Rail Failures.

In order to have this correspond with 2002-A, it is necessary to introduce the same information, "Kind of Steel." At the same time, some columns which have been found to be of little use have been eliminated.

Form 2003-A: Laboratory Report.

These changes are suggested to correct evident imperfections in the form, report under the column "Physical Test."

Form 2004-D: Position in Ingot of Steel Rail.

The names of the Steel Companies should not be printed on the blank, as is actually the case with the form as issued, and provision should be made for the "Kind of Steel," these corrections being shown on print of the present blank.

Revised Form M. W. 2004-A.

_ _ _ _ _ lb. _ _ _ _ Section _ _ _ _ _ _ _ _ _ Steel. Rolled by _ _ _ _ _ _ _ _ _ _ Steel Co.

Lines	Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approximate Gross Tons over Rail.	
			C.	P.	Mn.	Si.	S.		Freight	Passenger		
1												
2												
3												
4												
5												
6					For filling in with typewriter columns should be spaced in							
7							tenths of an inch as given by the figures.					
8	5	7	5	5	5	5	5	5	7	7	10	
9						Size of sheet required, 8x 21 inches.						
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
Totals												

NOTE—Do not fail to foot up all the columns of each group and give the "No. of Failures per 10,000 Tons of New Rail laid" (Total.)

Revised Form M. W. 2004-A.

American Railway Engineering and Maintenance of Way Association

______________________________ Railroad

Summary of Steel Rail Failures for One Year compared with same period of previous year.

Record for period of one year ending ____________ 19___

	Kind of Failure														Grand Total	Failures per 10,000 tons of New Rail laid		Lines
	Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total*					
	Tang	Curve	Tang	Curve	Tang	Curve	Tang	Curve	Tang.	Curve	Tang	Curve	Tang	Curve		Last Year	Present Year	
%	~																	
No.	~																	1
%	~																	
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%	~																	
No.	~																	3
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No.	5 ~	5	5	5	5	5	5	5	5	5	5	5	5	5	7	5	5	8
%	~																	
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No.	~																	18
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No.	~																	19

NOTE—Rails broken or injured by wrecks, broken wheels or similar causes, are not to be included in this report

Only statistics of rails weighing over 70 lbs. per yard are required

Revised Form M. W. 2004-B.

______ lb.________Section _________Steel. Rolled by____________ Steel Co.

Lines	Year Laid	Tons of New Rail Laid	Number of Rails which have failed each year below.														
1																	
2																	
3																	
4																	
5																	
6																	
7				For filling in with typewriter columns should be spaced in tenths of an inch as given by the figures:													
8	5	7	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
9							Size of sheet required, 8 x 21 inches.										
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15																	
16																	
17																	
18																	
19																	
Totals																	

Revised Form M. W. 2004-B.

American Railway Engineering and Maintenance of Way Association

____________________________ Railroad

Summary of Steel Rail Failures for a Period of Years

Record for period of ________ years ending ____________ 19___

	Kind of Failure														Grand Total	Failures per 10,000 tons new rail laid	Lines
	Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total				
	Tang.	Curve	Tang.	Curve	Tang.	Curve	Tang.	Curve	Tang.	Curve	Tang	Curve	Tang.	Curve			
%	~																1
No.	~																
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No.	~																
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No.	~																
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%	~																18
No.	~																
%	~																19
No.	~																

NOTE—Rails broken or injured by wrecks, broken wheels or similar causes, are not to be included in this report.

Revised Form M. W. 2004-C.

A. B. & C. R. R. Co.

Sheet No.________ of ________Sheets.

________________________________Division

Comparative Number Of Failures of Steel Rails of Different Section or Pattern Rolled by Different Steel Companies.

Record for Period of ____________________ending _________________19____

Steel Company and Mill where Rail was Rolled	Rail weight per yard, lbs.	Rail Section or Pattern	No. of Tons of Rail laid in Track	Kind of Failure														Grand Total	No. of Failures per 10,000 Tons of New Rail Laid
				Broken		Flow of Metal		Crushed Head		Split Head		Split Web.		Broken Base		Total			
				Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve		
			4	2															
				2															
			4	2															
				2															
			4	2															
				2															
			4	2															
				2															
			4	2															
				2															
			4	2															
10	4	5	7	2 4	4	4	4	5	4	5	4	4	4	4	4	5	5	7	5
			4	2															
				2															
			4	2															
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			4	2															
				2															
			4	2															
				2															
			4	2															
				2															

For filling in with typewriter columns should be spaced in tenths of an inch as given by the figures:

Size of sheet required, 8x10½ inches.

Note: The percentages which the record figures are of the total are to be put above the record figures in the several columns under "Kind of Failures."

Revised Form M. W. 2002-A.

A. B. & C. R. R. Co.

--------------------Division

REPORT OF RAIL FAILURES IN MAIN TRACKS.

Section No.---------

Date of Report---------------19---

1. Weight per yard, New--lbs; Re-rolled--lbs.
2. Rail Section--------------------
3. Brand on Rail--------------------
3A. Kind of Steel-------------
4. Heat No. on Rail--------------------
5. Rail No. or Letter, (See Note "D" on back)-
6. Original Length of Rail---------------
7. Month and Year Rail was Laid----------
8. Location------ft.------of Mile Post---
9. Which Track?------Which Rail?------
10. On Curve or Straight Line?------------
10½. No. of Curve--------------------
11. Degree of Curve------------------
12. High or Low Rail, if on Curve---------
13. Superelevation of Curve at break--------
14A. Was Rail broken?-----------------
14B. Was Rail damaged?----------------
14C. Was Rail defective?----------------
15. Was Rail much or little worn?---------
16. By whom discovered?---------------
17. Date and Time found---------------
18. Was Rail removed?-----------------
19. If removed give date----------------
20. Exact gage 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)------------------
34A. If break was at Joint, state kind, number of holes, and whether it was full bolted or insulated

----

34B. Were any bolts at joint loose?------If so, how many?-------------------------
35. If broken, state cause of break and describe any flaws found at point of break-------------
36. If damaged, describe nature and cause, if known. (See instructions on back.)------------
37. If defective, describe location of flaws or defects, and if possible what caused them. (See back of report for description of failures.)------------------------------------

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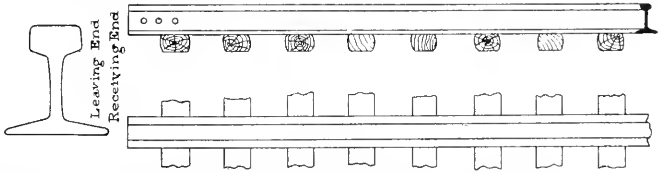
----

38. 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 is in one direction.)



39. If accident or detention to trains was caused by break, state circumstances------------

Correct

------------------(*)---

Approved

--------------------(*)---------

*Each railroad will fill in these blanks to suit its practice.

Revised Form M. W. 2202-A.

INSTRUCTIONS.

A. The (_____*_____) will send this report to the (_____*_____) 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 (_____*_____) will forward this report direct to the (_____*_____)

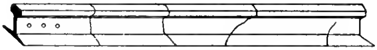
C. The (_____*_____) will have copies of this report made immediately upon receipt and send copy to each of the following officers (_____*_____) and (_____*_____).

D. The Rail Number or letter in 5 (front page) will be found a few inches to the right of the Heat Number and is marked with a letter of the alphabet or number

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.

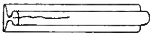


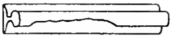
2. **Damaged.** Under this head will be included all rails broken or injured by wrecks, broken wheels, or similar causes.

3. **Flow of Metal.** This term means a "Rolling out" of the metal on top of the head toward its sides without there being any indication of a breaking down of the head structure; that is, the underside of the head is not distorted.

4. **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 sketch.

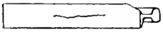
5. **Split Head.** This term includes rails split through or near the center line of the head or rails with pieces split off the side of the head. When this term is used it should be further defined by stating whether it is or is not accompanied by a seam or hollow head.





6. **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.

7. **Broken Base.** This term covers all breaks in base of rail and should be described and illustrated on sketches on front page.



*Each railroad will fill in these blanks to suit its practice.

A. B. & C. R. R. Co.

Sheet No.......of.......Sheets

....Division.

Superintendent's Report of **Rail Failures** in Main Track for the Month of 19

Report Number	Description of Rail									Location of Rail.					Date Laid		Day of Month Found	Time in Service		Nature of Failure							In Splice	Out of Splice	Line No.
	Weight per Yard	Type of Section	Marks on Rail						Lengths	Mile Post		Which Track	Curve or Tangent	Degree of Curve	Mo.	Year		Year	Mos.	Damaged.	Broken.	Flow of Metal.	Crushed Head	Split Head	Split Web	Broken Base			
			Manufacturer	Rolled		Kind of Steel	Heat No	Rail Letter		No.	Feet																		
				Mo.	Year																								
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	
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																													16
																													17
																													18
																													19
																													20
																			Total Failures →										
																				Grand Total of Failures for Month →									

Use following Marks for making entries in Columns.
In Column 4 use Cor. for Carnegie. Ill.S.W. for Illinois, South Works.
Ill. G. for Illinois, Gary. Cam. for Cambria. Mar. for Maryland.
In Column 13 use E.B.P. for East Bound Passenger Etc.
" " 14 " T. for Tangent. I.C. for inner rail on Curve. O.C. for outer rail on Curve.
" " 21-22-23-24-25-26-27 use fig. I. to designate proper column
Entries in Columns 21 to 27 should be repeated in Columns 28 or 29.

INSTRUCTIONS ON BACK.

Correct.

....Engineer M. of W.

Approved.

....Superintendent.

Revised Form M. W. 2003-A.

Copy Ink
Report No

A. B. & C. R. R. Co.

Laboratory Report of Chemical and Physical Examination of Rail and Other Track Material.

Referred to in____

Laboratory No.__________Sample represents______________________

Place and Date______________________19__

Chemical Analysis											Physical Test.						
Location of Borings	C.	P	Mn	Si	S						Tensile S'gth Elastic Limit Pounds Per Square Inch		Elongation Per Cent in. inches of Or Lth		Reduc. of Area, % of Orig Sec		
11	5	5	5	5	5	5	5	5	5	5	7	7	6	6	6	6	6

For filling in with typewriter columns should be spaced in tenths of an inch as given by the figures

Size of sheet required, 8x10½ inches

Location of Borings

Remarks.

Approved

______________________ Chemist
Engineer of Tests

Note The word "Borings" refers also to "Chippings" and other kinds of test fragments.

Revised Form M. W. 2004-D.

A. B. & C. R. R. Co.

------------------------------------ Division

Position in Ingot of Steel Rails which Failed for Period of ____________ ending ________ 19___

Sheet No. ________

of ________ Sheets

-------------------- Type of Rail Section

Kind of Failure	---Steel Co.------Mill-------Steel								---Steel Co.-----Mill---Steel								--Steel Co. Mill -----Steel								---- Steel Co. -- --Mill------Steel							
	100 lb.								85 lb								100 lb.								- 85 lb							
	A	B	C	D	E	F	Un-known	Total	A	B	C	D	E	F	Un-known	Total	A	B	C	D	E	F	Un-known	Total	A	B	C	D	E	F	Un-known	Total
Broken																																
Flow of Metal																																
Crushed Head																																
Split Head																																
Split Web																																
Broken Base																																
Totals																																
	-Steel Co.------Mill------Steel								--Steel Co.------Mill------Steel								-Steel Co. -----Mill---- --Steel								---Steel Co. Mill --Steel							
Broken																																
Flow of Metal																																
Crushed Head																																
Split Head																																
Split Web																																
Broken Base																																
Totals																																
	--Steel Co.---- - Mill - Steel								---Steel Co. ------Mill ------Steel								---Steel Co. Mill- Steel								----Steel Co.- - Mill --Steel							
Broken																																
Flow of Metal							For filling in with typewriter columns should be spaced in tenths of an inch as given by the figures:																										
Crushed Head	4	4	4	4	4	4	5	5	4	4	4	4	4	4	5	5	4	4	4	4	4	4	5	5	4	4	4	4	4	4	5	5
Split Head													Size of sheet required, 8x15$\frac{8}{10}$ inches.																			
Split Web																																
Broken Base																																
Totals																																

Note The letters A, B, C, etc., denote the position of the Rail in the ingot, "A" being the top rail, "B" the second, etc
The percentages which the record figures are of the total are to be put above the record figures in the columns under A, B, C, etc.,
Only Statistics of Rail weighing over 70 lbs. per yard are required.

CONCLUSIONS.

The Committee presents the following conclusions for your approval:

(1) That the Specifications and Plan for Drop Testing Machine, approved by the Association, be revised as follows:

Paragraph 2: Eliminate the last sentence and substitute the following: "Anvil to be guided in its vertical movement by removable finished wearing strips, these wearing strips to be suitably attached to the finished edges of the column base."

Paragraph 5: Insert the following after the word "castings" in the first sentence: "And the surface of the anvil between these pedestals shall be formed to receive a wooden block to absorb shock under broken test pieces."

Paragraph 6: In the first sentence substitute the words "column base" for "base plate."

(2) That the Specifications and Plan for Drop Testing Machine, as revised above, be printed in the Manual of Recommended Practice.

(3) That the present Specifications for Steel Rails be withdrawn from the Manual of Recommended Practice of the Association as no longer representing the current state of the art.

(4) That the Specifications for Bessemer and Open-Hearth Rails, as recommended above, be printed in the Proceedings, and that a note be added to the effect that these specifications are intended for a guide in the preparation of future specifications, and it is recommended that all railroads embody in their specifications such matter from the specifications herewith presented as in their judgment is necessary to secure better results from the mills.

(5) That Rail Failure Statistics be collected for tabulation and analysis from Railroad Companies for the period of one year ending October 31, instead of for a period of six months, as recommended in the Proceedings, A. R. E. and M. W. Assn., Vol. 10, Part 1, page 375, Conclusion No. 2, and that the title of form M. W. 2004-A, Proceedings, Vol. 10, Part 1, page 355, be changed to read "Summary of Steel Rail Failures for One Year, Compared with the same Period of Previous Year," with corresponding change in the footnote of the same form.

(6) That the changes in the Rail Record forms recommended be approved.

Respectfully submitted,

Chas. S. Churchill (*Director*), Chief Engineer, Norfolk & Western Railway, Roanoke, Va., *Chairman.*

R. Montfort, Consulting Engineer, Louisville & Nashville Railroad, Louisville, Ky., *Vice-Chairman.*

Robert Trimble, Chief Engineer Maintenance of Way, Northwest System, Pennsylvania Lines, Pittsburg, Pa., *Secretary.*

E. B. Ashby, Chief Engineer, Lehigh Valley Railroad, New York, N. Y.

J. A. Atwood, Chief Engineer, Pittsburg & Lake Erie Railroad, Pittsburg, Pa.

A. S. Baldwin, Chief Engineer, Illinois Central Railroad, Chicago, Ill.

J. B. Berry, Chief Engineer, Chicago, Rock Island & Pacific Railway, Chicago, Ill.

M. L. Byers, Chief Engineer Maintenance of Way, Missouri Pacific Railway, St. Louis, Mo.

W. C. Cushing (*Second Vice-President*), Chief Engineer Maintenance of Way, Southwest System, Pennsylvania Lines West, Pittsburg, Pa.

F. A. Delano, President, Wabash Railroad, Chicago, Ill.

Dr. P. H. Dudley, Rail Expert, New York Central Lines, New York.

C. H. Ewing, Engineer Maintenance of Way, Philadelphia & Reading Railway, Reading, Pa.

John D. Isaacs, Consulting Engineer, Harriman Lines, Chicago, Ill.

Thos. H. Johnson, Consulting Engineer, Pennsylvania Lines West, Pittsburg, Pa.

Howard G. Kelley (*Past-President*), Chief Engineer, Grand Trunk Railway System, Montreal, Canada.

J. W. Kendrick, Second Vice-President, Atchison, Topeka & Santa Fe Railway, Chicago, Ill.

George W. Kittredge (*Past-President*), Chief Engineer, New York Central & Hudson River Railroad, New York, N. Y.

D. W. Lum, Chief Engineer Maintenance of Way and Structures, Southern Railway, Washington, D. C.

Jos. T. Richards, Chief Engineer Maintenance of Way, Pennsylvania Railroad, Philadelphia, Pa.

J. P. Snow (*Director*), Chief Engineer, Boston & Maine Railroad, Boston, Mass.

A. W. Thompson (*Director*), Chief Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

Committee.

Appendix A.

THE AMERICAN RAILWAY ASSOCIATION.

THE AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION.

SPECIFICATIONS FOR STEEL RAILS.

NOTE.—These specifications are intended as a guide in the preparation of future specifications.

Process of Manufacture.

1. The entire process of manufacture shall be in accordance with the best current state of the art.

(a) Ingots shall be kept in a vertical position until ready to be rolled, or until the metal in the interior has had time to solidify.

(b) Bled ingots shall not be used.

Chemical Composition.

2. The chemical composition of the steel from which the rails are rolled shall be within the following limits:

	BESSEMER.		OPEN-HEARTH.	
	70 lbs. and over, but under 85 lbs.	85 to 100 lbs. inclusive.	70 lbs. and over, but under 85 lbs.	85 to 100 lbs. inclusive.
Carbon.	0.40 to 0.50	0.45 to 0.55	0.53 to 0.66	0.63 to 0.76
Manganese.	0.80 to 1.10	0.80 to 1.10	0.70 to 1.00	0.70 to 1.00
Silicon.	0.07 to 0.20	0.07 to 0.20	0.07 to 0.20	0.07 to 0.20
Phosphorus not to exceed	0.10	0.10	0.04	0.04
Sulphur not to exceed	0.075	0.075	0.06	0.06

3. When the average phosphorus content of the ingot metal used in the Bessemer Process at any mill is below 0.08 and in the Open-Hearth Process is below 0.03, the carbon shall be increased at the rate of 0.035 for each 0.01 that the phosphorus content of the ingot metal used averages below 0.08 for Bessemer steel, or 0.03 for Open-Hearth steel.

The percentage of carbon in an entire order of rails shall average as high as the mean percentage between the upper and lower limits.

Shearing.

4. The end of the bloom formed from the top of the ingot shall be sheared until the entire face shows sound metal.

All metal from the top of the ingot, whether made from the bloom or the rail, is the top discard.

Shrinkage.

5. The number of passes and speed of train shall be so regulated that, on leaving the rolls at the final pass, the temperature of the rails will not exceed that which requires a shrinkage allowance at the hot saws, for a 33-ft. rail of 100 lbs. section, of 6½ in. for thick base sections and 6¾ in. for A.S.C.E. sections, and ⅛-in. less for each ten pounds decrease of section, these allowances to be decreased at the rate of 1-100 in. for each second of time elapsed between the rail leaving the finishing rolls and being sawed.

The bars shall not be held for the purpose of reducing their temperature, nor shall any artificial means of cooling them be used between the leading and finishing passes, nor after they leave the finishing pass.

Section. 6. The section of rail shall conform as accurately as possible to the templet furnished by the Railroad Company. A variation in height of 1-64 in. less or 1-32 in. greater than the specified height, and 1-16 in. in width of flange, will be permitted; but no variations shall be allowed in the dimensions affecting the fit of splice bars.

Weight. 7. The weight of the rail shall be maintained as nearly as possible, after complying with the preceding paragraph, to that specified in the contract.

A variation of one-half of one per cent. from the calculated weight of section, as applied to an entire order, will be allowed.

Rails will be accepted and paid for according to actual weight.

Length. 8. The standard length of rail shall be 33 ft.

Ten per cent. of the entire order will be accepted in shorter lengths varying by 1 ft. from 32 ft. to 25 ft.

A variation of ¼-in. from the specified lengths will be allowed.

All No. 1 rails less than 33 ft. shall be painted green on both ends.

Finishing. 9. Care shall be taken in hot-straightening rails, and it shall result in their being left in such condition that they will not vary throughout their entire length more than four (4) in. from a straight line in any direction for thick base sections, and five (5) in. for A.S.C.E. sections when delivered to the cold-straightening presses. Those which vary beyond that amount, or have short kinks, shall be classed as No. 2 rails and be so marked.

The distance between supports of rails in the straightening press shall not be less than forty-two (42) in.; supports to have flat surfaces and out of wind. Rails shall be straight in line and surface and smooth on head when finished, final straightening being done while cold.

They shall be sawed square at ends, variations to be not more than 1-32 in., and prior to shipment shall have the burr caused by the saw cutting removed and the ends made clean.

Drilling. 10. Circular holes for joint bolts shall be drilled in accordance with specifications of the purchaser. They shall in every respect conform accurately to drawing and dimensions furnished and shall be free from burrs.

Branding. 11. The name of the manufacturer, the weight of the rail, and the month and year of manufacture shall be rolled in raised letters and figures on the side of the web. The number of the heat and a letter indicating the portion of the ingot from which the rail was made shall be plainly stamped on the web of each rail, where it will not be covered by the splice bars. Rails to be lettered consecutively A, B, C, etc., the rail from the top of the ingot being A. In case of a top discard of twenty or more per cent. the letter A will be omitted. Open-

Hearth rails to be branded or stamped O. H. All marking of rails shall be done so effectively that the marks may be read as long as the rails are in service.

Drop Testing.

12. (a) Drop tests shall be made on pieces of rail rolled from the top of the ingot, not less than four (4) ft. and not more than six (6) ft. long, from each heat of steel. These test pieces shall be cut from the rail bar next to either end of the top rail, as selected by the inspector.

The temperature of the test pieces shall be between forty (40) and one hundred (100) degrees Fahrenheit.

The test pieces shall be placed head upward on solid supports, five (5) in. top radius, three (3) ft. between centers, and subjected to impact tests, the tup falling free from the following heights:

70 lb. rail	16 ft.
80, 85 and 90 lb. rail	18 ft.
100 lb. rail	20 ft.

The test pieces which do not break under the first drop shall be nicked and tested to destruction.

(b) (It is proposed to prescribe, under this paragraph, the requirements in regard to deflection, fixing maximum and minimum limits, as soon as proper deflection limits have been decided upon.)

Tests.

13. (A) Two pieces shall be tested from each heat of steel. If either of these test pieces breaks, a third piece shall be tested. If two of the test pieces break without showing physical defect, all rails of the heat will be rejected absolutely. If two of the test pieces do not break, all rails of the heat will be accepted as No. 1 or No. 2 classification (according as the deflection is less or more, respectively, than the prescribed limit.*)

(B) If, however, any test piece broken under test A shows physical defect, the top rail from each ingot of that heat shall be rejected.

(C) Additional tests shall then be made of test pieces selected by the inspector from the top end of any second rails of the same heat. If two out of three of these second test pieces break, the remainder of the rails of the heat will also be rejected. If two out of three of these second test pieces do not break, the remainder of the rails of the heat will be accepted, provided they conform to the other requirements of these specifications, as No. 1 or No. 2 classification (according as the deflection is less or more, respectively, than the prescribed limit.*)

(D) If any test piece, test A, does not break, but when nicked and tested to destruction shows interior defect, the top rails from each ingot of that heat shall be rejected.

---

*Note: The clause in brackets in sections A and C to be added to the specifications when the deflection limits are specified.

Drop Testing Machine.

14. The drop-testing machine shall be the standard of the American Railway Engineering and Maintenance of Way Association, and have a tup of 2,000 lbs. weight, the striking face of which shall have a radius of five (5) in.

The anvil block shall be adequately supported and shall weigh 20,000 lbs.

The supports shall be a part of or firmly secured to the anvil.

No. 1 Rails.

15. No. 1 rails shall be free from injurious defects and flaws of all kinds.

No. 2 Rails.

16. Rails which, by reason of surface imperfections, are not accepted as No. 1 rails, will be classed as No. 2 rails, but rails containing physical defects which impair their strength, shall be rejected.

No. 2 rails to the extent of five (5) per cent. of the whole order will be received. All rails accepted as No. 2 rails shall have the ends painted white, and shall have two prick punchmarks on the side of the web near the heat number near the end of the rail, so placed as not to be covered by the splice bars.

Rails improperly drilled, straightened, or from which the burrs have not been properly removed, shall be rejected, but may be accepted after being properly finished.

Different classes of rails shall be kept separate in shipment.

All rails shall be loaded in the presence of the inspector.

Inspection.

17. (a) 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 rails have been made in accordance with the terms of the specifications.

(b) For Bessemer Steel the manufacturer shall, before the rails are shipped, furnish the inspector daily with carbon determinations for each heat, and two complete chemical analyses every twenty-four hours representing the average of the other elements specified in section 2 hereof contained in the steel, for each day and night turn respectively. These analyses shall be made on drillings taken from the ladle test ingot not less than ¼-in. beneath the surface.

For Open-Hearth Steel, the makers shall furnish the inspectors with a complete chemical analysis of the elements specified in section 2 hereof for each melt.

(c) On request of the inspector, the manufacturer shall furnish drillings from the test ingot for check analysis.

(d) All tests and inspections shall be made at the place of manufacture, prior to shipment, and shall be so conducted as not to unnecessarily interfere with the operation of the mill.

Appendix B.

RAIL FAILURE STATISTICS FOR PERIOD OF SIX MONTHS, APRIL 30, TO OCTOBER 31, 1908.

(Bulletin 111.)

Two of the instructions of the Board of Directions to your Committee were as follows:

(1) *Continue the investigation of the breakage and failure of rails and present summary of conclusions drawn from the reports received.*

(2) *Report on the results obtained from the use of open-hearth steel rail, and the chemical composition of such rail.*

It was decided to have a circular issued by the American Railway Association, asking for rail failure statistics, and, on November 13, 1908, Circular No. 884 was issued by Mr. W. F. Allen, Secretary of the American Railway Association, asking to have blanks 2004-A, 2004-D and 2005-D of the American Railway Engineering and Maintenance of Way Association, filled in and returned to him.

Fifty-three replies were received in answer to the circular, but quite a number stated that they were unable to furnish the information desired, but hoped to be able to do so in the future. Of the information given by the others quite a considerable portion is incomplete, so that it is rather a difficult matter to draw any conclusions from the statistics. The Committee calls especial attention to the fact that it does not at this time draw any conclusions from the statistics presented.

Nevertheless, the answers have been entered on Forms 2004-A, 2004-D and 2005-D, and are presented herewith for the consideration of the members of the Association.

In order to show how this information will be used when in complete form, the following two tables have been prepared, and they are graphically represented in the diagrams herewith. These comparisons are made for the purpose of illustration rather than to derive any actual information from them, because the reports received are entirely too incomplete to enable valuable deductions to be made at present.

For the same reason conclusions are not offered in connection with the statistics which are herein presented.

RAIL FAILURES

Comparison between different weights of rail in percentages of total failures, classified into "Broken," and "Head," " Web," and "Base" Failures.

Period of 6 months, May 1 to Oct. 31, 1908.

	Broken	Failures in		
		Head	Web	Base
100-lb. Bessemer	23	55	16	6
95-lb. "	30	24	23	23
90-lb. "	15	66	4	15
85-lb. "	15	71	8	6
80-lb. "	55	38	3½	3½
75-lb. "	40	51	8	1
95-lb. Open-Hearth	0	75	25	0
90-lb. "	58	35	7	0
*80-lb. "	14	14	0	72
80-lb. "	21	58	15	6
85-lb. Nickel	8	92	0	0

*Very small number of failures.

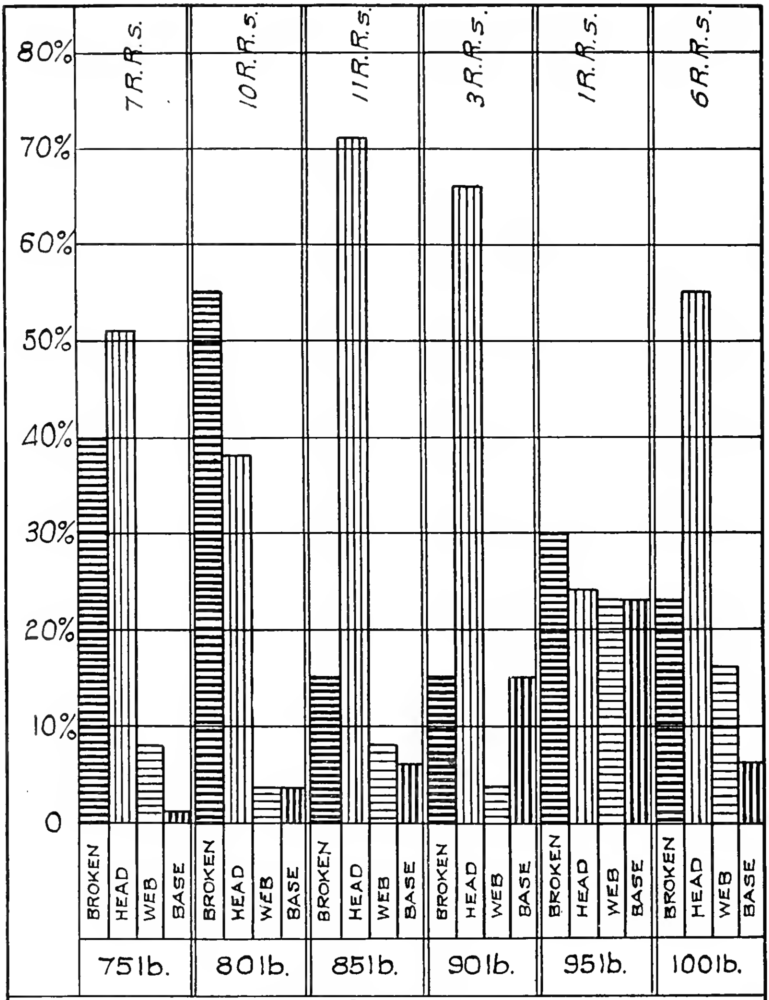
RAIL FAILURES

Comparison between different types of rail in percentage of total failures, classified into "Broken," and "Head," Web," and "Base" Failures.

100-lb. Weight.

Period of 6 months, May 1 to Oct. 31, 1908.

	Broken		Failures in					
			Head		Web		Base	
	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve
P. R. R.	23	11	18	23	15	7	2	1
A. S. C. E.	3	5	26.3	47.7	2	5	10	1
Dudley.	10	24	......	47	......	14	5	......
95-lb. Weight.								
B. & A.	......	30	16	8	23	......	23	......
90-lb. Weight.								
A. S. C. E.	8	7	41	25	3	1	2	13
85-lb. Weight.								
P. R. R.	12	10	30	23	4	6	3	12
A. S. C. E.	7	6	32½	42	4	4	2	2½
80-lb. Weight.								
A. S. C. E.	41	16½	19	16½	3	½	3	½
75-lb. Weight.								
A. S. C. E.	9	13	39	21	9	6	3	......
7506 Chicago Gt. Western.	46	17	23	8	......	6	......	......
Mo. Pacific.	16	......	32	52	......	......	......	......
72-lb. Weight.								
A. S. C. E.	25	6	26	19	......	6	18	......



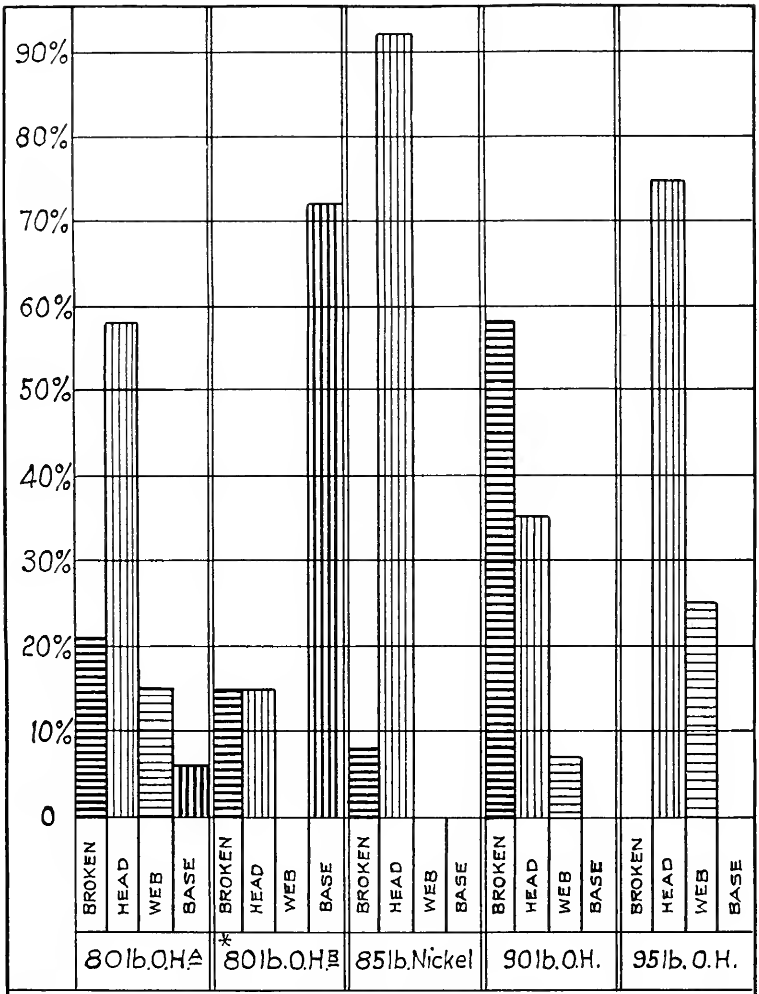
RAIL FAILURES

Comparison between Different Types of Rails in Percentage of failures, classified with Broken and Head, Web and Base failures.

Bessemer Steel

Period of 6 mos. May 1st to Oct. 31st 1908.

Reports to A.R.A. from 24 Railroads.



RAIL FAILURES

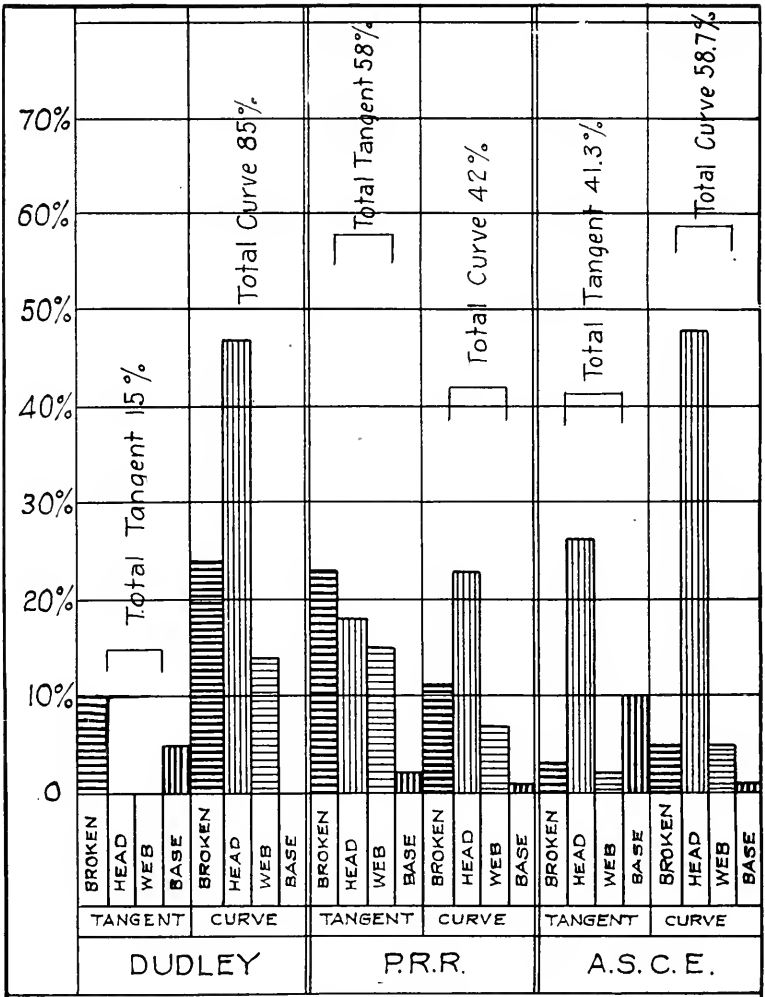
Comparison between, Different Types of Rails in Percentage of failures, classified into Broken and Head, Web and Base failures.

Open Hearth and Nickel Steel

Period of 6 mos. May 1st to Oct. 31st, 1908.

Reports to A.R.A. from 24 Railroads.

*Very small number of failures.



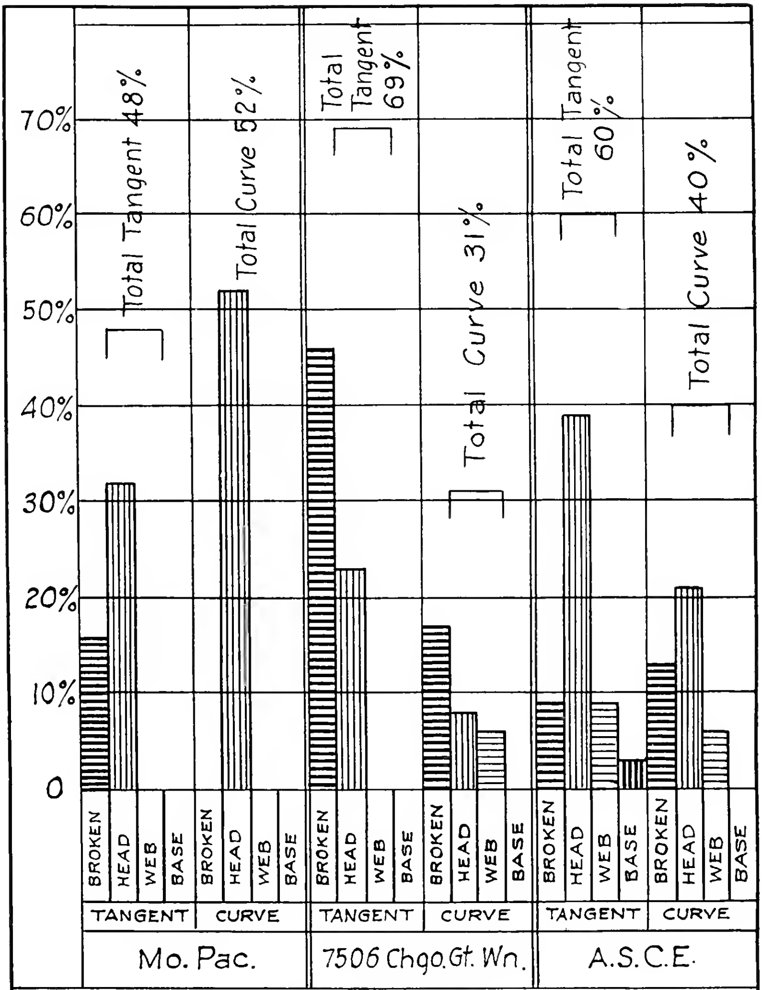
RAIL FAILURES

Comparison between Different Types of Rails in Percentage of Failures, classified into Broken and Head, Web and Base failures and Tangent and Curve.

100lbs. Weight.

Period of 6 mos. May 1st to Oct. 31st 1908.

Reports to A.R.A. from 24 Railroads.



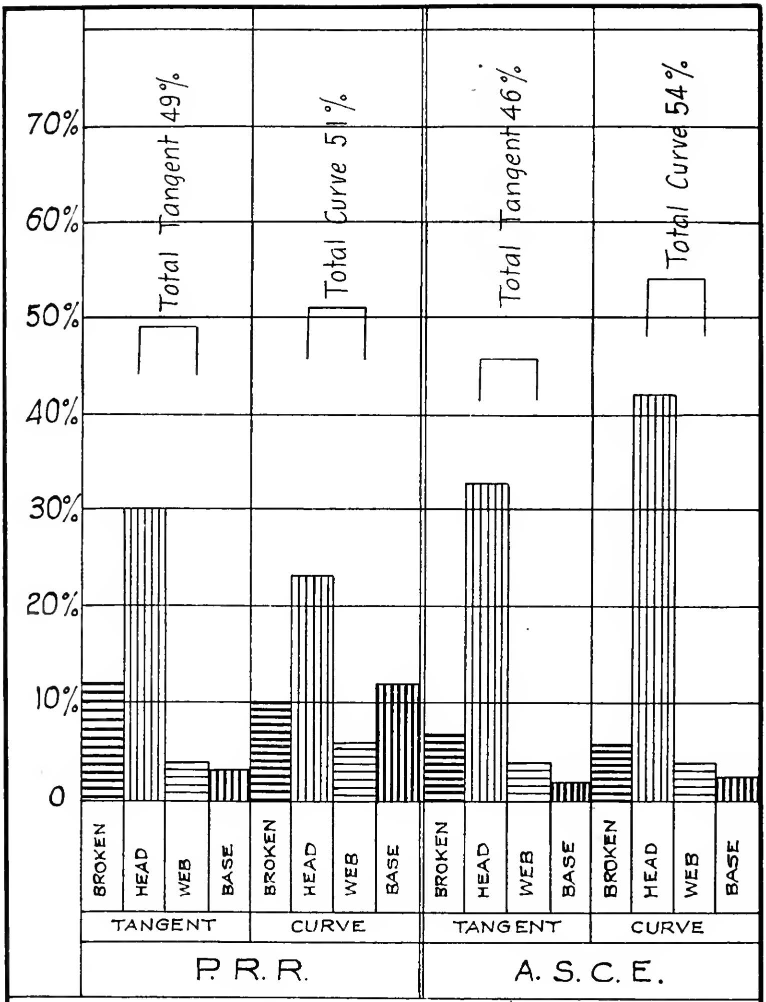
RAIL FAILURES

Comparison between Different Types of Rails in Percentage of Failures, classified into Broken and Head, Web and Base failures and Tangent and Curve.

75 lbs. Weight.

Period of 6 mos. May 1st. to Oct. 31st, 1908.

Reports to A.R.A. from 24 Railroads.



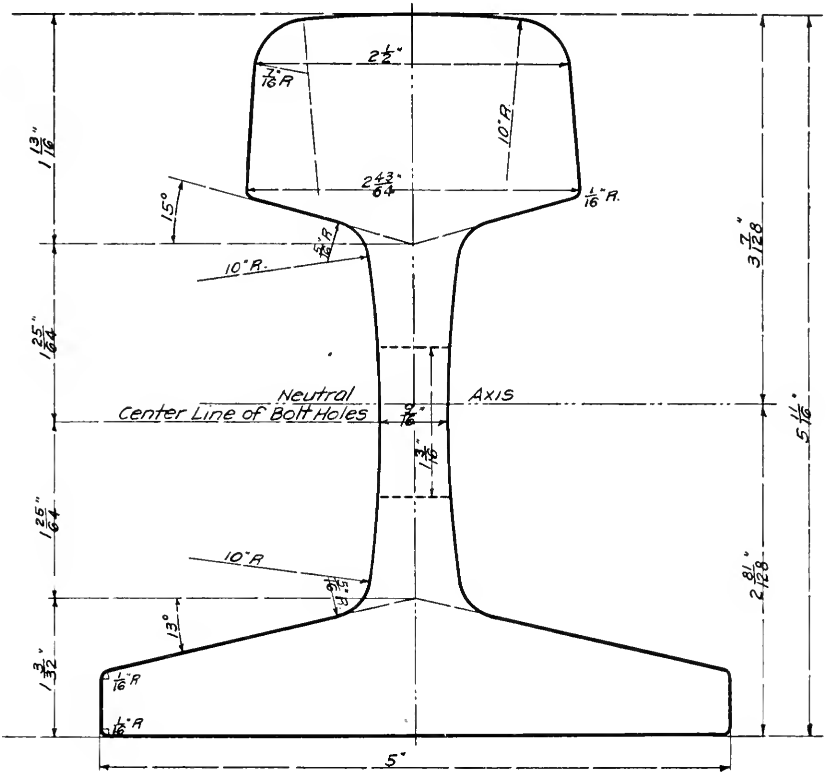
RAIL FAILURES

Comparison between Different Types of Rails in Percentage of Failures, classified into Broken and Head, Web and Base failures and Tangent and Curve. 85 lbs. Weight.

Period of 6 mos. May 1st to Oct. 31st, 1908.

Reports to A.R.A. from 24 Railroads.

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%

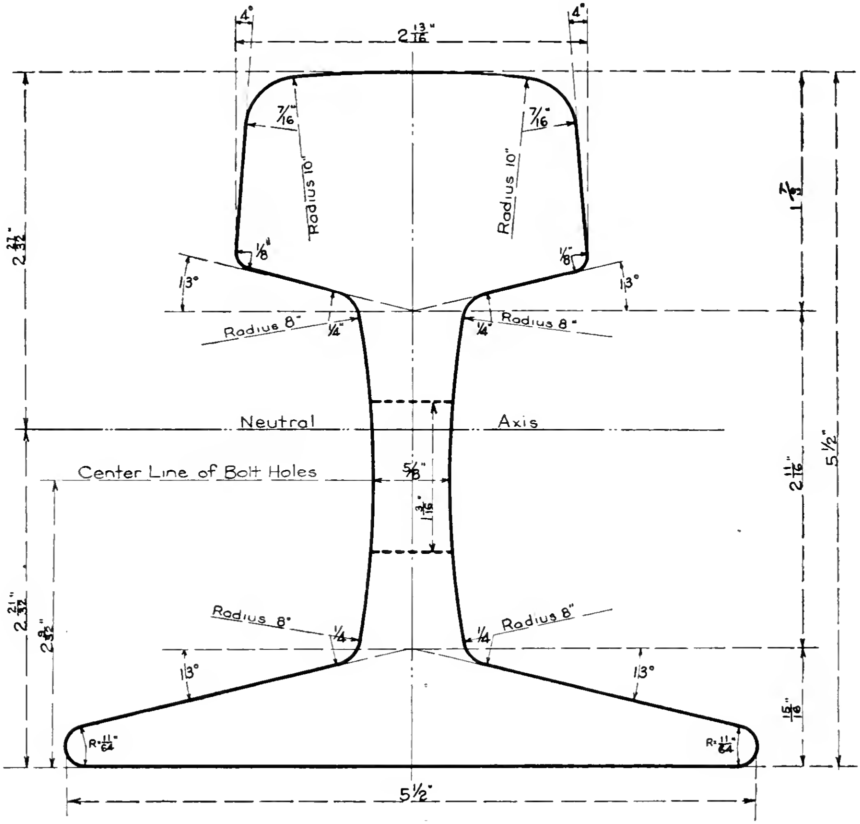
Moment of Inertia = 41.9

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

P.R.R. 100 lb.



Area of Head	4.512	sq. in	45.7	%
" Web	1.986	" "	20.11	"
" Base	3.378	" "	34.2	"
Total	9.876	" "	100.0	"

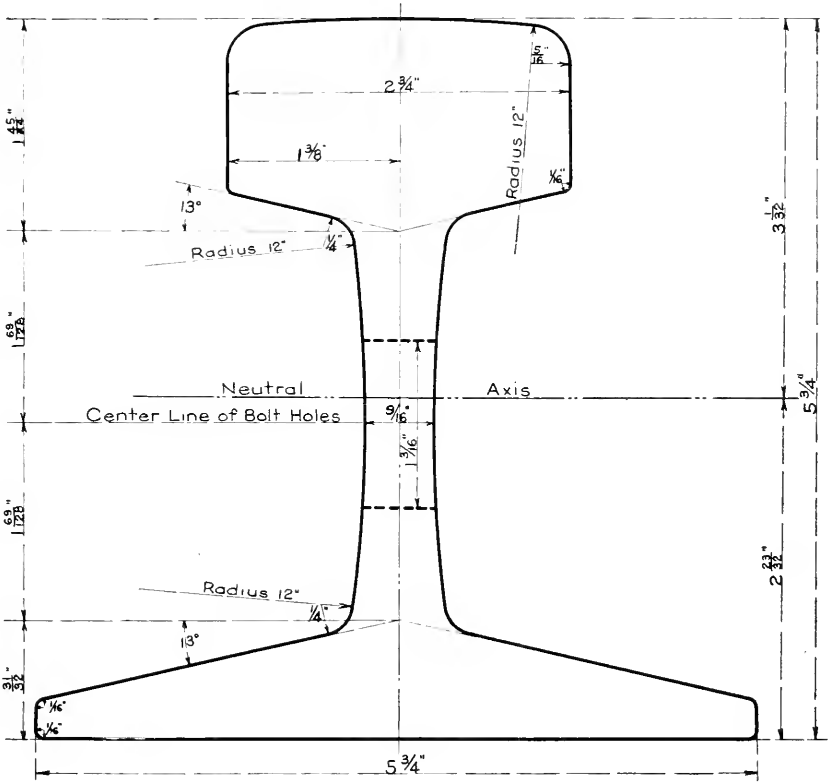
Moment of Inertia = 37.956

Section Modulus of Head = 13.502

" " " Base = 14.115

PENN'A. LINES WEST OF PITTSBURGH.
Office of Chief Engineer M of W
SOUTH-WEST SYSTEM.

A.S.C.E. 100 lb.



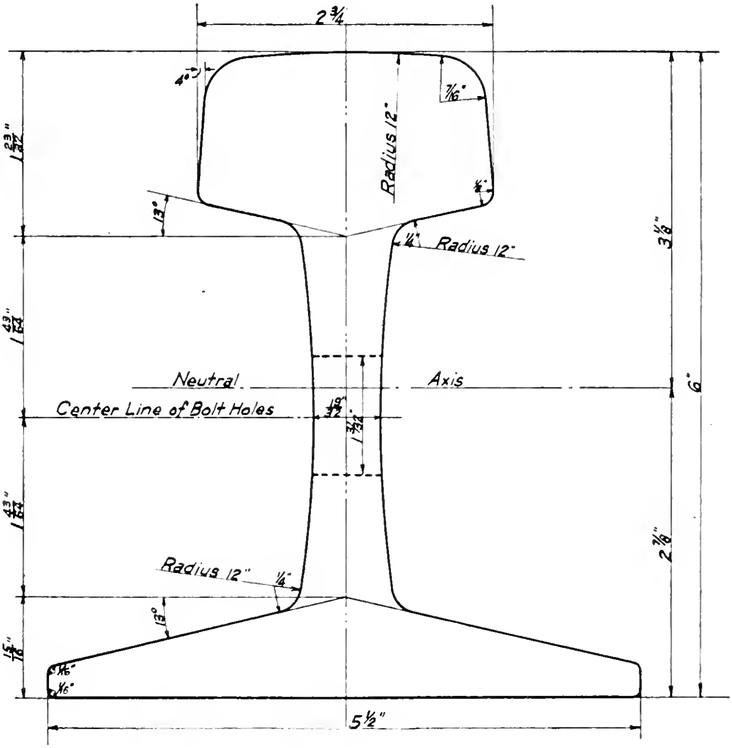
Area of Head	4.13	sq in	42 %
" Web	2.06	" "	21 "
" Base	3.63	" "	37 "
Total	9.82	" "	100.0 %

Moment of Inertia = 43.80

Section Modulus of Head = 14.85

" " " Base = 15.64

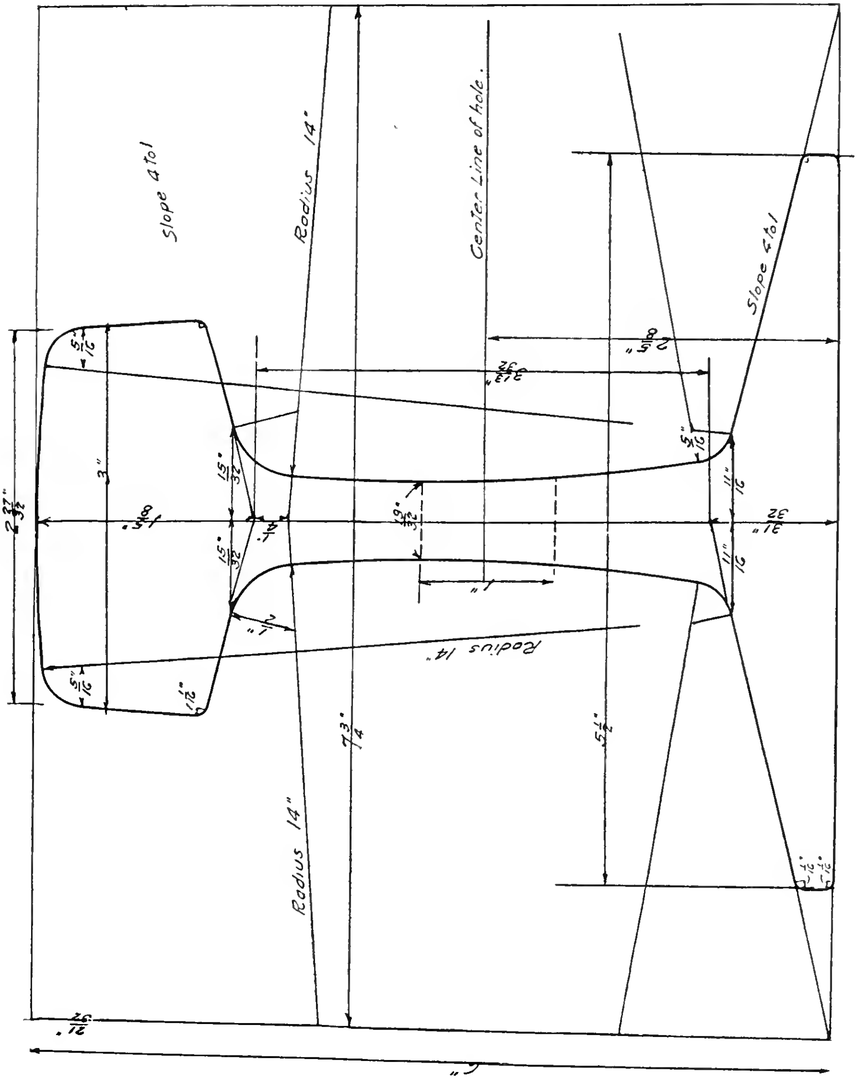
PENN'A. LINES WEST OF PITTSBURGH.
Office of Chief Engineer M of W
SOUTH-WEST SYSTEM.



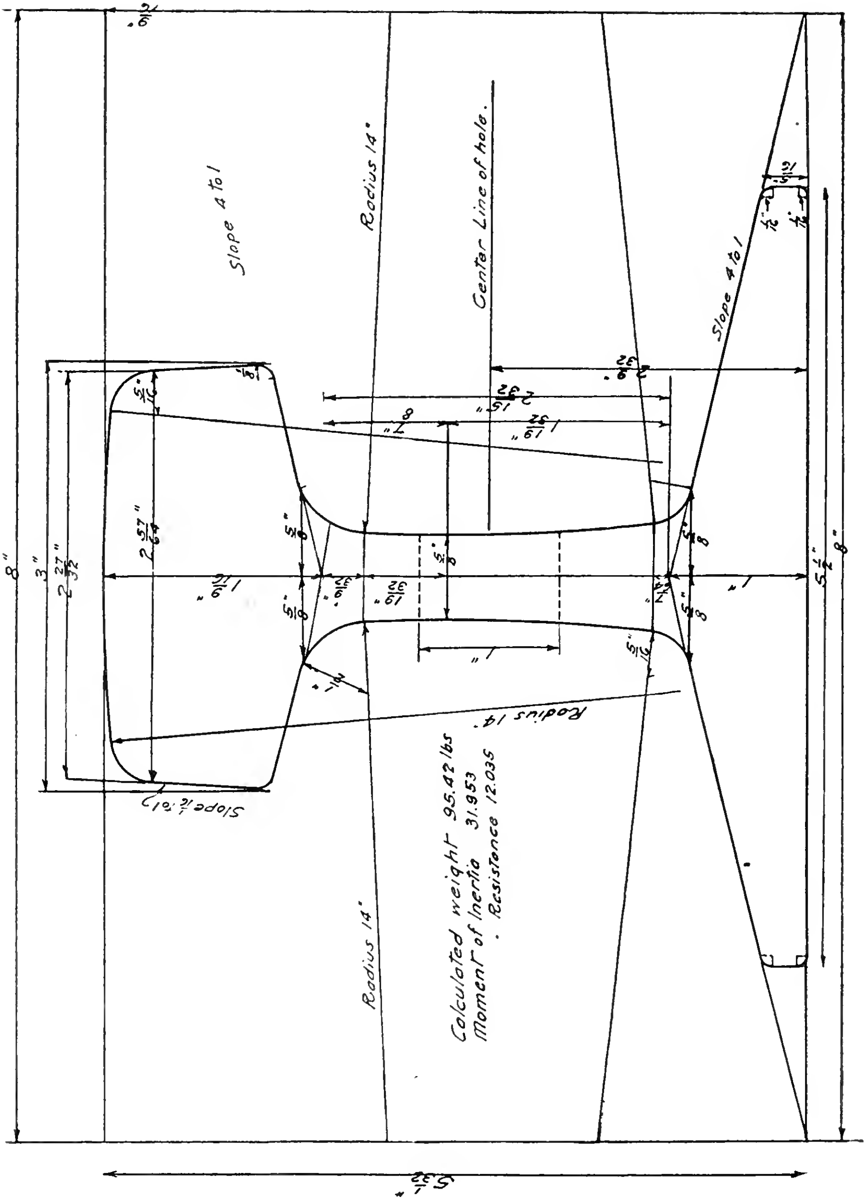
NY. NH & H. R.R. 100 lb. RAIL.

Area of Head	4.04	sq. in.	41 %
" " Web	2.33	" "	24 %
" " Base	3.40	" "	35 %
Total	9.77	" "	100 %

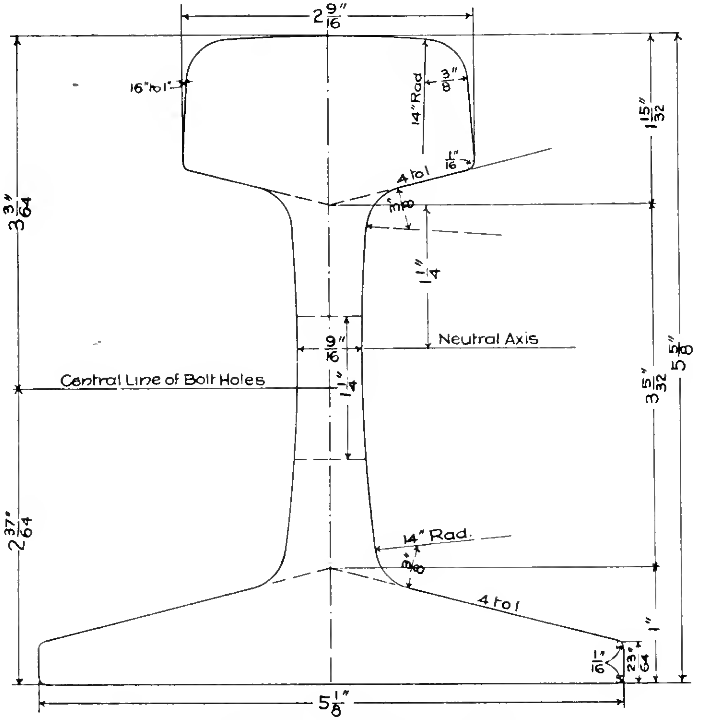
Moment of Inertia = 47.18
Section Modulus of Head = 15.10
" " " Base = 16.41



Six-Inch 100-Lb. Dudley Section—B. & A. R. R.



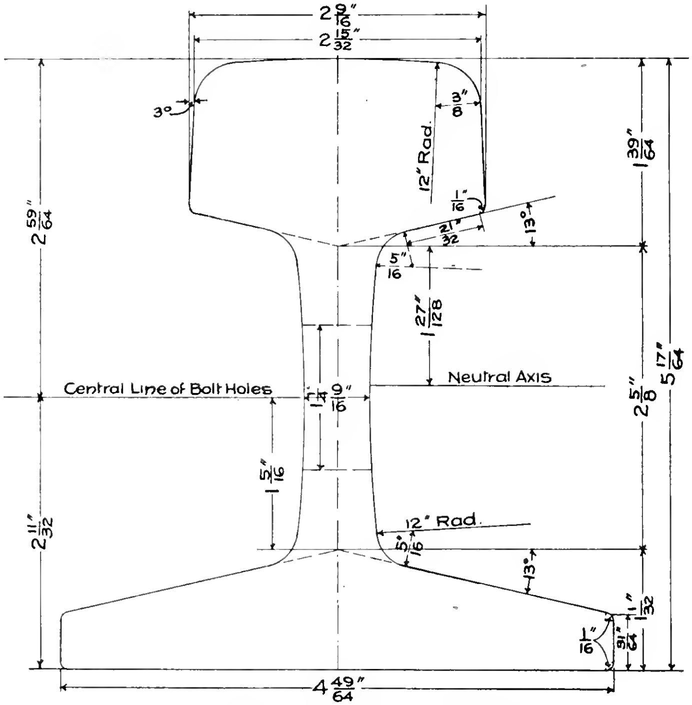
FIVE-INCH 95-LB. BOSTON & ALBANY SECTION.



Area of Head = 3.20 sq.in. = 36.2%
" " Web = 2.12 " " = 24.0%
" " Base = 3.50 " " = 39.8%
Total area ---- = 8.82 " " = 100.0%
Moment of Inertia ---------- = 38.70
Section Modulus of Head ---- = 12.56
Section Modulus of Base --- = 15.23.

B. & O. R. R.
STANDARD 90 Lb. A.R.A. RAIL SECT. "A".
Office of Chief Engr. M. of W.
Baltimore, Md.

6317

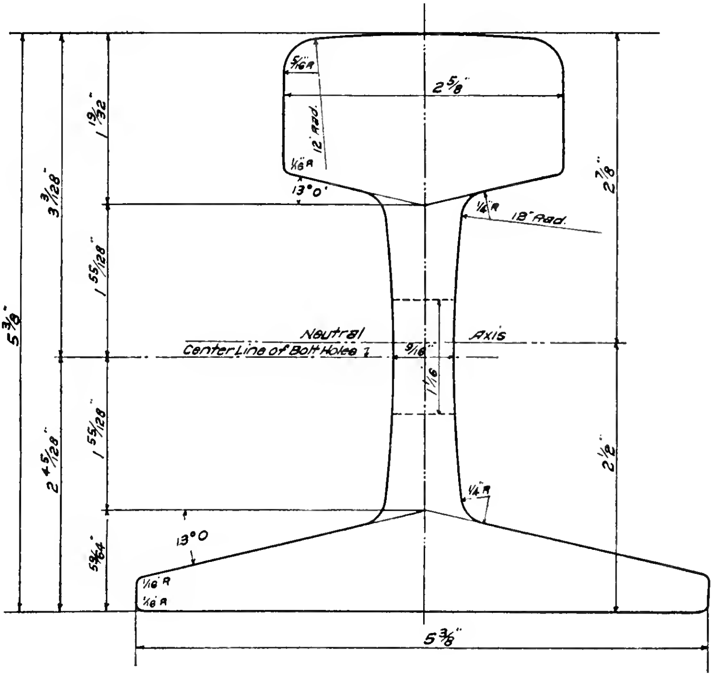


Area of Head	=	3.56	sq. in.	=	40.1 %
" " Web	=	1.70	" "	=	19.2%
" Base	=	3.61	" "	=	40.7%
Total area	=	8.87	" "	=	100.0%

Moment of Inertia .... = 32.30
Section Modulus of Head ... = 11.45
Section Modulus of Base ... = 13.21

B. & O. R. R.
STANDARD 90 Lb. A.R.A. RAIL SECT. "B."
Office of Chief Engr. M. of W.
Baltimore, Md

6318



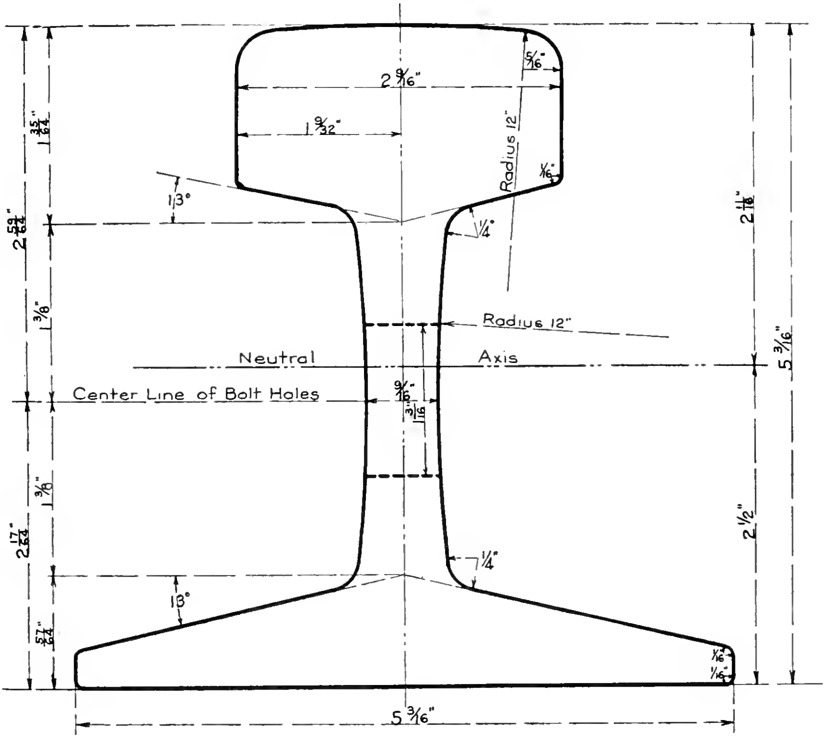
Area of Section = 8.83 sq. in
" Head = 368 " " = 42.0%
" Web = 1.85 " " = 21.0%
" Base = 3.30 = 37.0%

Moment of Inertia = 30.46
Section Modulus = 10.61
" " Base = 12.16
Ratio of Height to Base = 1.00

A.S.C.E. 90 lb. RAIL.

Ratio; Periphery of Head to Area of Head = 1.73
" " Web " Web = 3.51
" " Base " Base = 3 10
Ratio, Total Periphery to Total Area = 2.70

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 %

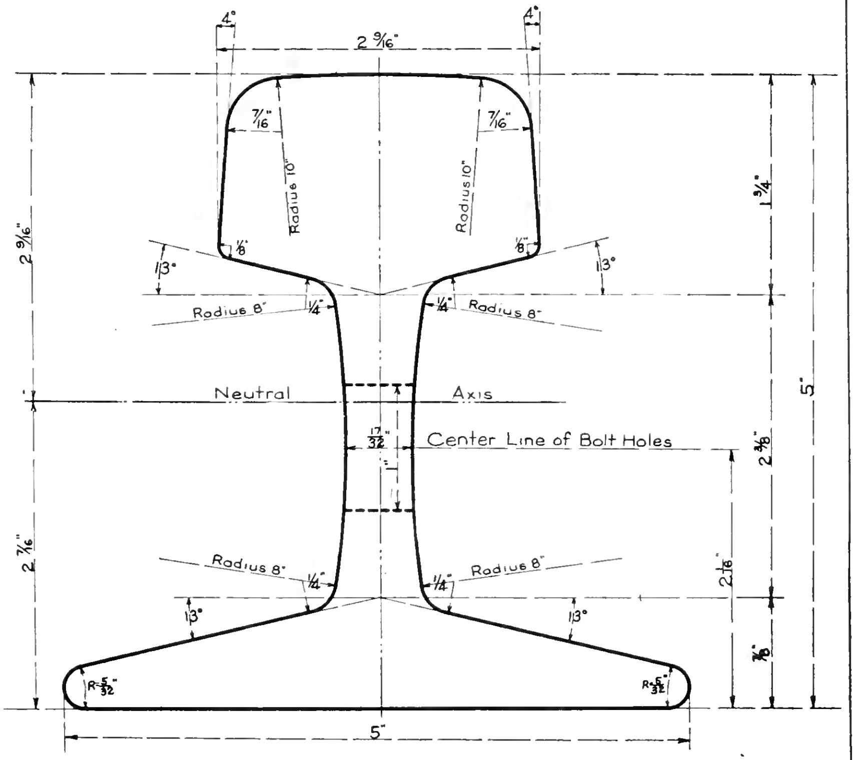
Moment of Inertia = 30.00

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

P.R.R. 85 lb.



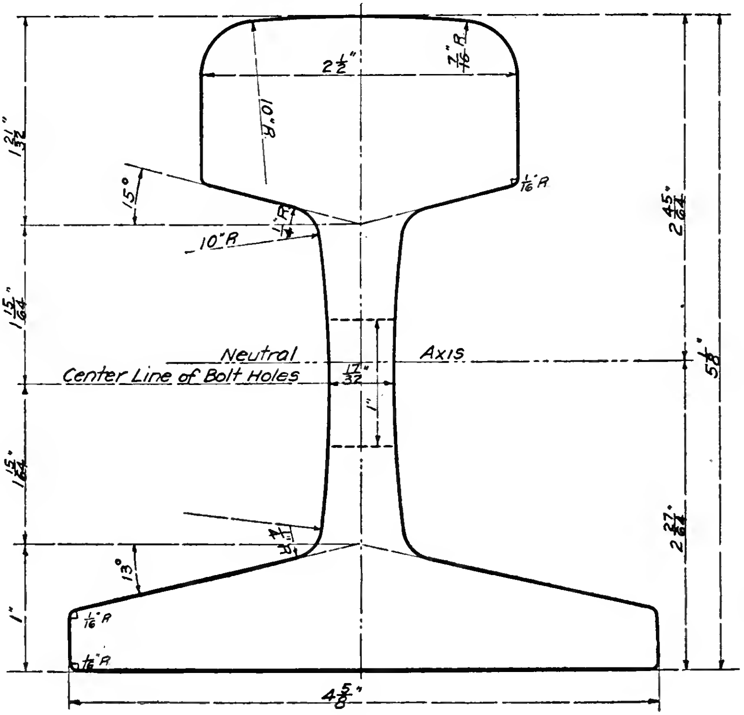
Area of Head	3.823 sq. in.	46.1 %
" Web	1.575 " "	19.0 %
" Base	2.894 " "	34.9 %
Total	8.292 " "	100.0 %

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

P. S. 85 LB.



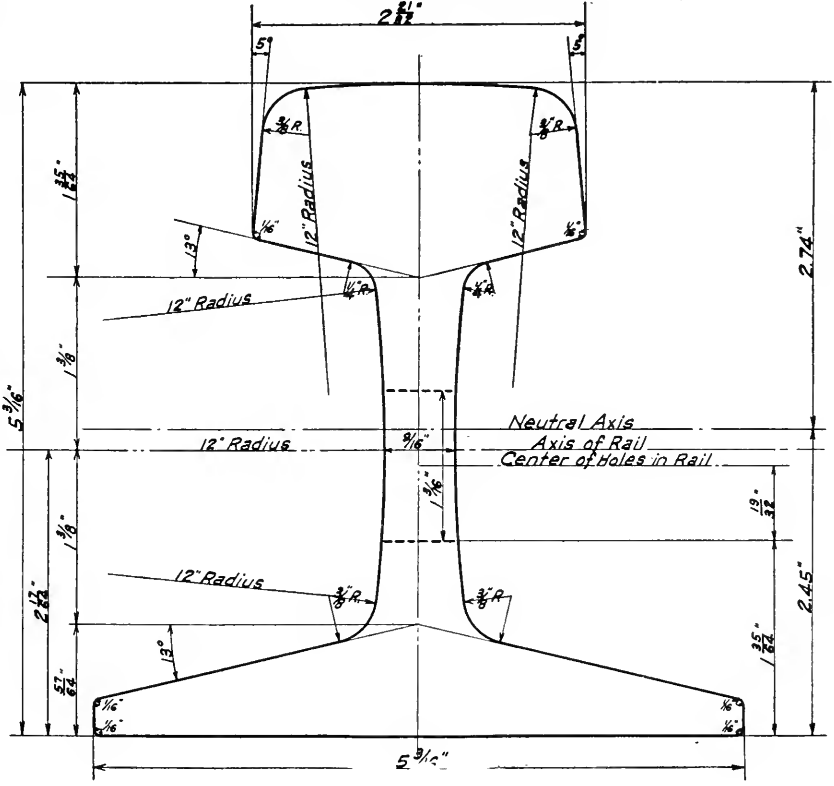
Area of Head	3.57	sq.in.	42.2 %
" " Web	1.51	" "	17.8
" " Base	3.39	" "	40.0
Total	8.47	" "	100.0 %

Moment of Inertia =

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

No. 85-N-85 Rolled by Carnegie Stee Co.
No. 8506
No. 852-85 Rolled by Colorado Fuel & Iron Co.



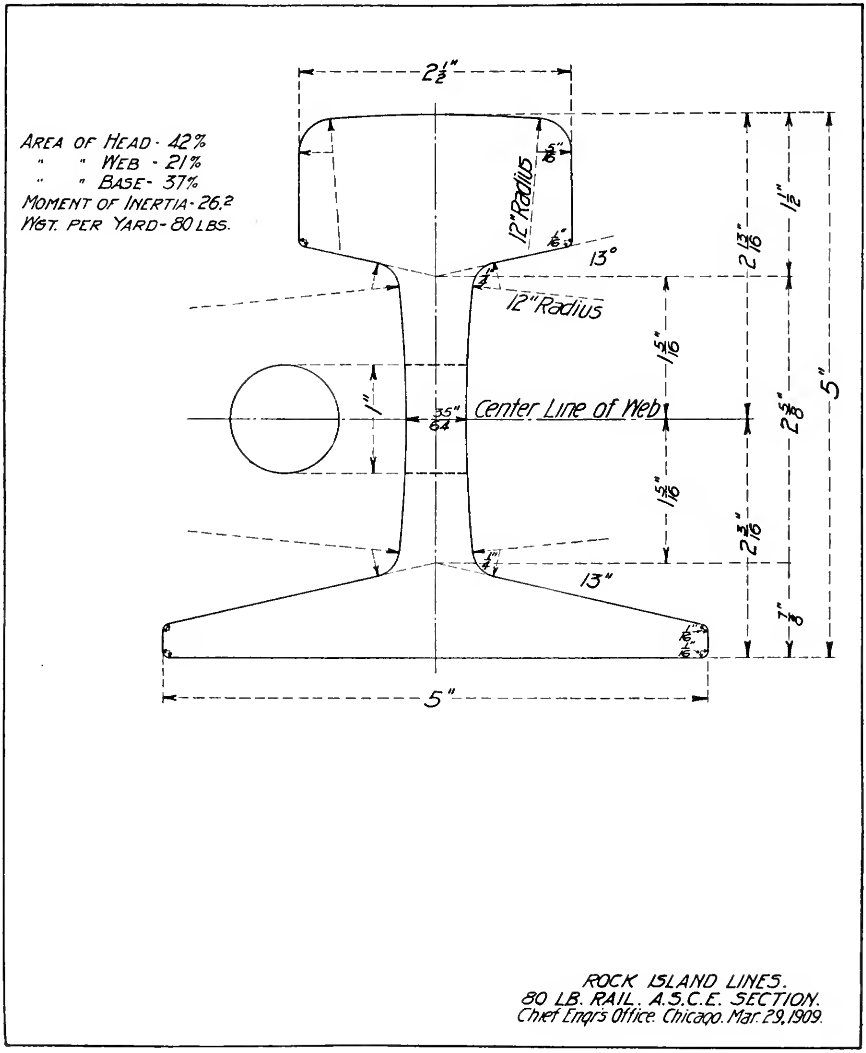
C.B&Q. 85lb. RAIL

Area of Head	3.49	sq. in	= 42 %
" " Web	1.74	" "	= 21 "
" " Base	3.07	" "	= 37 "
Total	8.30	sq. in.	= 100.0 %

Moment of Inertia 30.00

Section Modulus Comp. Side		10.93	(Head)
" " Tensile	"	12.23	(Base)

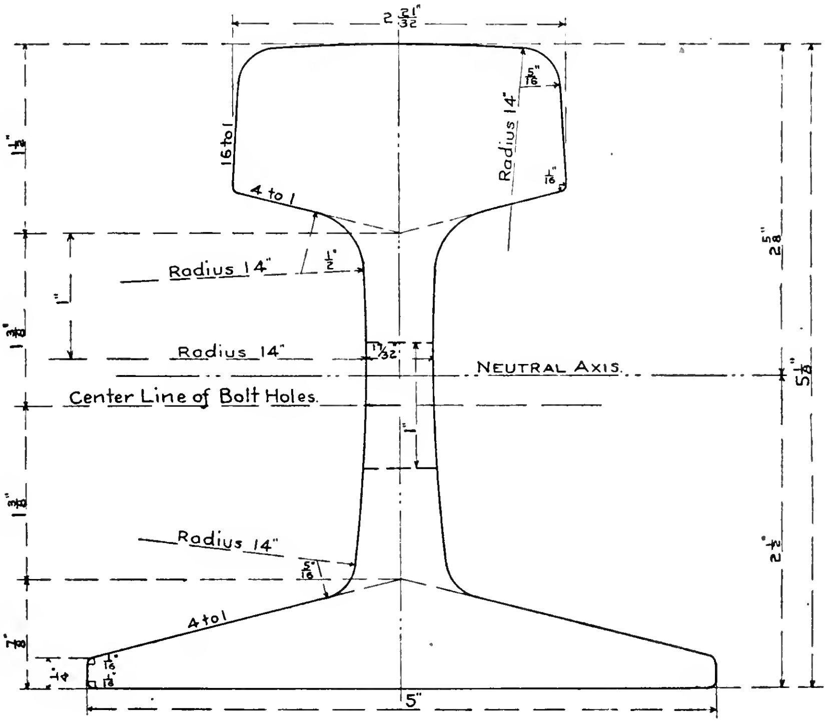
Office of Chief Engr. M. of W., South-West System
Pittsburgh, Pa. Sept. 14, 1909.



AREA OF HEAD - 42%
" " WEB - 21%
" " BASE - 37%
MOMENT OF INERTIA - 26.2
WGT. PER YARD - 80 LBS.

ROCK ISLAND LINES.
80 LB. RAIL. A.S.C.E. SECTION.
Chief Engr's Office. Chicago. Mar. 29, 1909.

NEW YORK CENTRAL_80 lb.

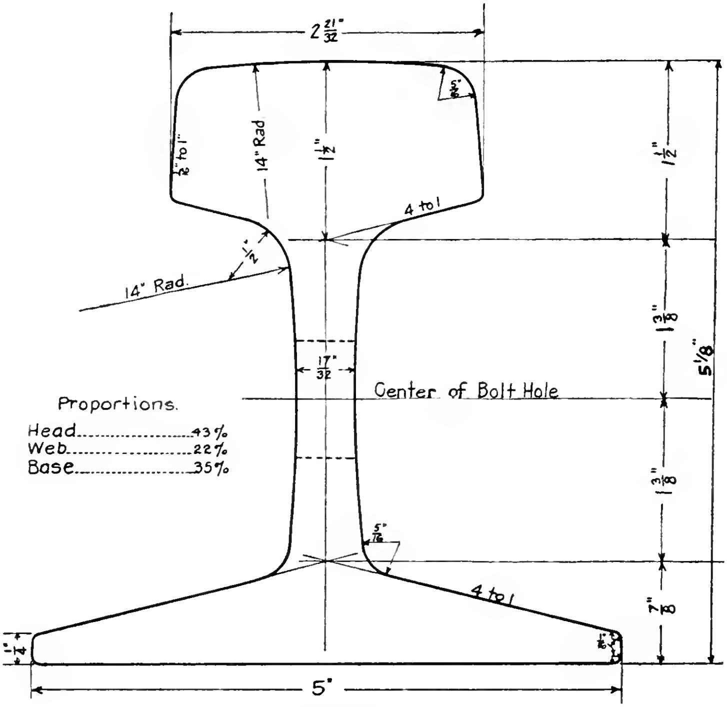


Area of Head	3.33 sq in.	42.5 %
" " Web	1.71 " "	21.8 "
" " Base	2.80 " "	35.7 "
Total	7.84 " "	100.0 %

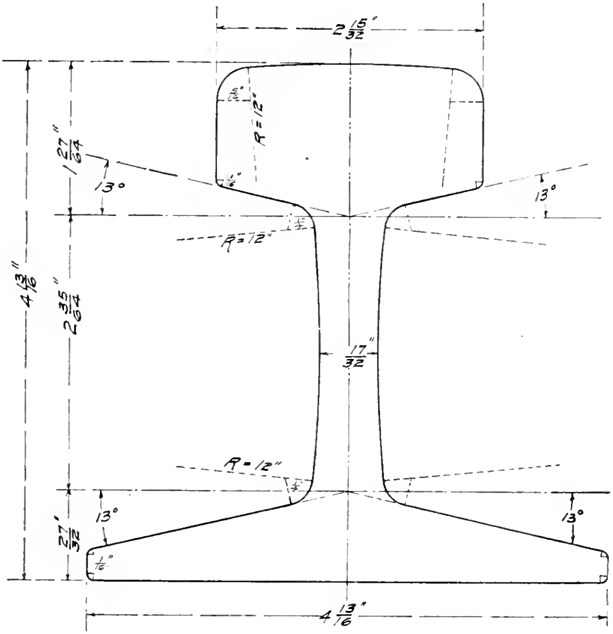
Moment of Inertia - 27.78

Section Modulus of Head = 10.58

" " " Base = 11.11



80 LB. RAIL
DUDLEY SECTION

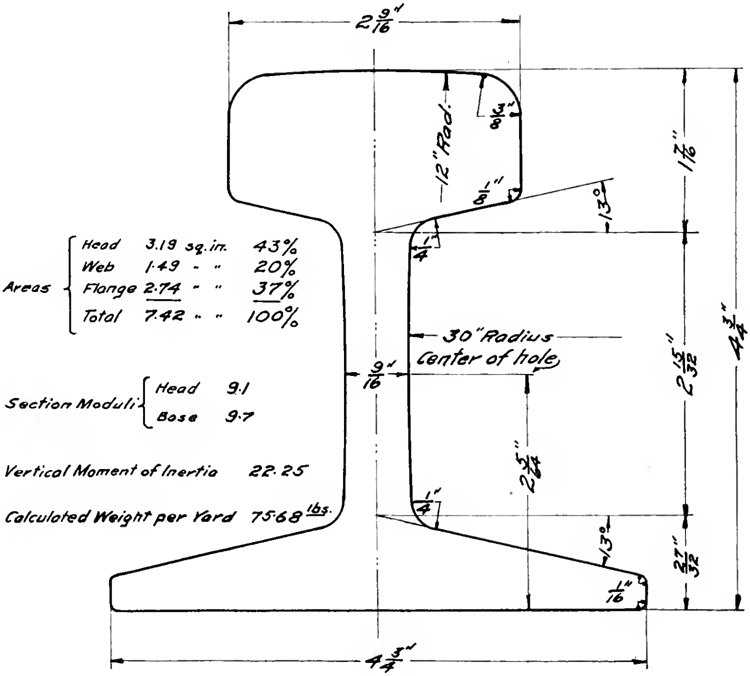


C.G.W.RY. STANDARD.

ILLINOIS STEEL CO'S. SECTION 7506.

Area of Head	3.107 sq. in.	Head...42%
Area of Web	1.548 sq. in.	Web....21%
Area of Base	2.717 sq. in.	Base....37%
Total	7.372 sq. in.	100%

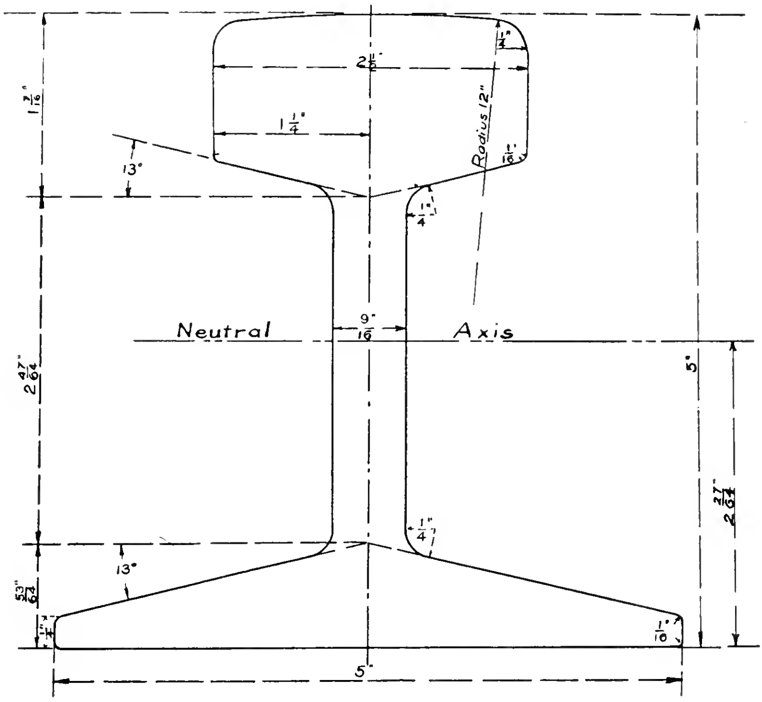
Moment of Inertia..................22.669
Section Modulus relative to Head... 8.907
Section Modulus relative to Base.... 9.997



Missouri Pacific Railway Co.
Standard 75 lb. Rail.

Boston & Maine R. R.

75 LB. RAIL

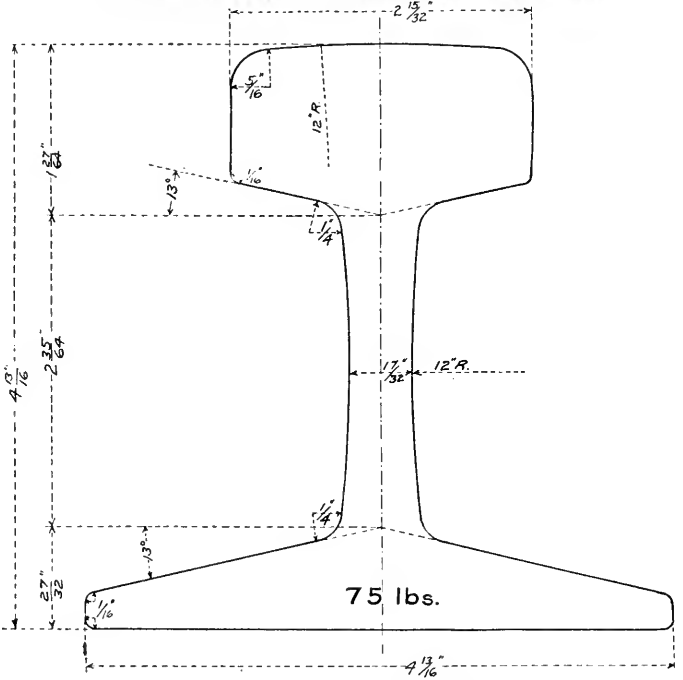


Area of Head	3.156 sq. in.		42.4%
" Web	1.605 "	"	21.5%
" Flange	2.693 "	"	36.1%
Total	7.454 "	"	100.0%

Moment of Inertia = 25.17

Section Modulus of Head = 9.75
" " " Base = 10.40

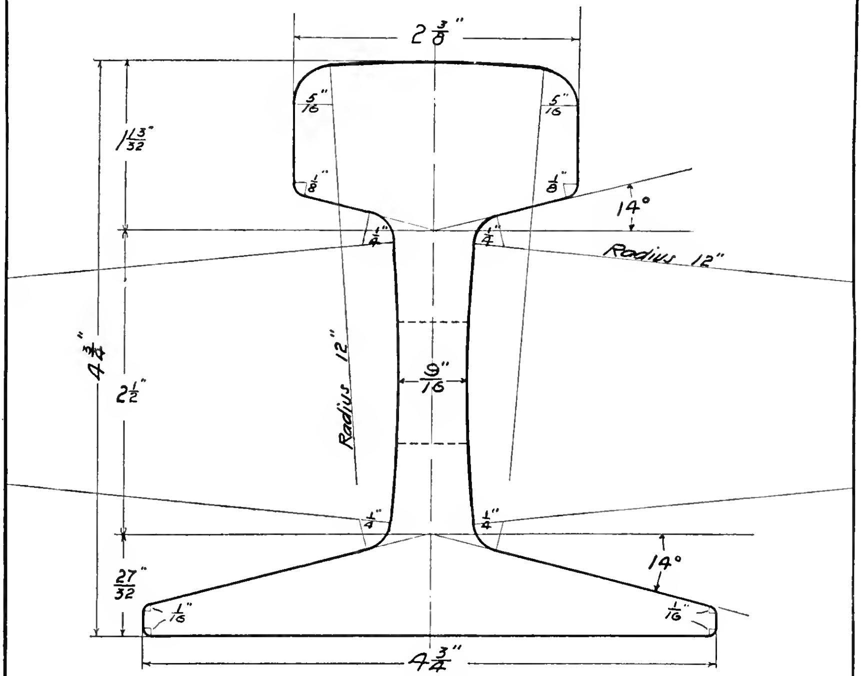
SECTION 7506. A.S.C.E.



Illinois Central R.R.

Area of Head	3.107 sq. in.	Head	42%
Area of Web	1.548 sq. in.	Web	21%
Area of Base	2.717 sq. in.	Base	37%
Total	7.372 sq. in.		100%

Moment of Inertia..................22.669
Section Modulus relative to Head... 8.907
Section Modulus relative to Base.... 9.997



72 lb. N.P Standard Rail.

Area of head	= 2.94	sq. in.	41.5%	Section Modulus Head = 8.68
" " web	= 1.56	" "	22.0%	" " Base = 9.64
" " base	= 2.60	" "	36.5%	
Total	7.10		100.0%	

Moment of Inertia = 21.69. Calculated weight = 72.4#

Summary by Weight and Section of Rail.

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet 1 of 2 Sheets

______ lb. ______ Sec ______ Steel. Rolled by ______ Steel Co. Record for Period of 6 months ending October 31 1909

~~Year~~ ~~Laid~~ Rail Section	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From May 1st To Oct 31st			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year......	Year......
189		100 lb. Rail - Bessemer											%																
													No.																
P.R.R. ~~189~~		"	"								294	214	%	23	11	2	6	5	7	11	10	15	7	2	1	16527	246.0		
													No.	115	54	9	31	27	34	57	53	77	37	9	5				
P.S ~~189~~		"	"									2	%													66	1.0		
													No.								2								
A.S.C.E.		"	"								156	215	%	3	5	0.3	0.7	13	27	13	20	2	5	10	1	12221	181.8		
													No.	12	19	1	2	48	98	51	74	7	18	37	4				
Dudley		"	"								3	18	%	10	24		14		5		28		14	5		693	10.3		
													No.	2	5		3		1		6		3	1					
Total		100 lb.	"								453	449	%	15	8	1	4	8	15	12	15	9	7	5	1	29507	439.1		
													No.	129	78	10	36	75	133	108	135	84	58	47	9				
B&A.		95 lb.	"	Bessemer							8	5	%		30	8		8			8	23		23		390	5.5		
													No.		4	1		1			1	3		3					
B&A.		95 lb	"	Open Hearth ?							3	1	%					25		50			25			120	1.7		
													No.					1		2			1						
A.S.C.E.		90 "	"	Bessemer							330	286	%	8	7	1	2	26	14	14	9	3	1	2	13	19608	262.6		
													No.	49	44	8	15	161	84	82	58	16	9	14	76				
A.S.C.E.		90 "	"	Open Hearth							6	8	%	29	29			7	7	7	14		7			459	6.2		
													No.	4	4			1	1	1	2		1						
P.R.R.		85 "	"	Bessemer							216	218	%	12	10	2	2	7	7	21	14	4	6	3	12	13709½	173.2		
													No.	50	44	8	10	31	30	93	59	19	24	15	51				
A.S.C.E.		" "	"	"							1001	1227	%	7	6	½	1	15	29	17	12	4	4	2	2½	74003	936.3		
													No.	162	135	11	21	326	656	381	276	78	81	42	59				
No9		" "	"	"							1		%													33	0.4		
													No.							1									
—		" "	"	"							16	18	%	15	29			9	12	14	9	3	3	6		1115	14.1		
													No.	5	10			3	4	5	3	1	1	2					
Total		85 "	"	Bessemer							1234	1463	%	8	7	8/10	1 2/10	13	26	18	12	4	4	2	4	88860½	1124.0		
													No.	217	189	19	31	360	690	480	338	98	106	59	110				
A.S.C.E.		85 "	"	Nickel							11	27	%	3	5	3	3	16	23	8	39					1226	15.5		
													No.	1	2	1	1	6	9	3	15								
—		85 "	"	Open Hearth								6	%		17								66		17	198	2.5		
													No.		1								4		1				
A.S.C.E.		85 "	"	Bessemer			A.T.& S.F. Ry.				Not Separated		%	39		41		16		4						2343	29.6		
											71		No.	28		29		11		3	Tang & Curve Not Separated								
Dudley	Sec.	80 "	"										%	3	7	1	11	9	44	3	12			4	6				
A.S.C.E.	"	90 "	"	Bessemer			Buffalo. Rochester & Pittsburgh				20	82	No.	3	7	1	11	9	45	3	13			4	6	3361	44.1		
Totals																													

Summary by Weight and Section of Rail

Sheet 2 of 2 Sheets

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

______lb. ______Sec. ______Steel. Rolled by ______ Steel Co Record for Period of 6 months ending October 31 1908

~~Year Laid~~ Rail Section	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From____ To____			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	B		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year____	Year____
~~100~~		80 lb	Rail	Bessemer									%																
													No.																
A.S.C.E. ~~100~~		" "	"		"						105	54	%	41	16 3/10	6/10		2½	9	16	7 4/10	3	6/10	3	6/10	4802	56.34		
													No.	65	26	1		4	14	25	12	5	1	5	1				
Dudley ~~100~~		" "	"		"							1	%													33	0.40		
													No.								1								
—		" "	"		"						5	3	%	12½	12½					50	25					240	2.85		
													No.	1	1					4	2								
Total		80 lb	Rail	Bessemer							110	58	%	39	16	½		2½	9	17	9	3	½	3	½	5075	59.59		
													No.	66	27	1		4	14	29	15	5	1	5	1				
		80 lb	Rail	Bessemer							Not Separated 27		%													818	9.74		
													No.	Records do not show Kind of Failures															
		80 "	"	Open Hearth							4	3	%		14						14			57	15	225	2.71		
													No.		1						1			4	1				
A.S.C.E.		80 "	"	Open Hearth							Not Separated 80		%	21		25		1		32		15		6		2609	31.1		
													No.	17		20		1		25		12		5					
P.R.R.		75 "	"	Bessemer							1		%													24	0.27		
													No.	1															
A.S.C.E.		" "	"		"						20	13	%	9	13	6	3	24	15	9	3	9	6	3		1160	13.00		
													No.	3	4	2	1	8	5	3	1	3	2	1					
7506		" "	"		"						25	11	%	46	17	6				17	.8		6			1075	12.00		
													No.	17	6	2				6	3		2						
753		" "	"		"						1		%													30	0.33		
													No.			1													
Mo.P.		" "	"		"						9	10	%	16				16	21	16	31					570	6.36		
													No.	3				3	4	3	6								
—		" "	"		"						8	6	%	29	29					21	14	7				420	4.69		
													No.	4	4					3	2	1							
Total											64	40	%	27	13	5	1	11	9	14	11	4	4	1		3279	36.65		
													No.	28	14	5	1	11	9	15	12	4	4	1					
A.S.C.E.		72 "	"		"						11	5	%	25	6			13	6	13	13		6	18		477	6.3		
													No.	4	1			2	1	2	2		1	3					
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

Sheet 1, of 15 Sheets.
See Supplement Sheet No 16
See Summary 2 Sheets.

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

100 lb P.R.R. P.S. Sec Bessemer Steel. Rolled by Various Steel Co's. Record for Period of 6 months ending October 31st 1908.

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From May 1st To Oct. 31st			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1907	Year 1908
													%																
189		P.R.R. Sec.						Maryland.					No.	Cumberland Valley															
													%							50	25	25							
1903 1904 189	3242							46000	50400		3	1	No.							2	1	1				132	1.96		0 06
													%																
189		P.R.R. Sec.						Maryland					No.	Pennsylvania R.R.															
													%	25	11	1	1	8	5	9	5	24	5	4	2				
1900 1907		0.50	0.08	1.00	0.13						75	30	No.	27	12	1	1	8	5	9	5	26	5	4	2	3338	49.68		
													%	25	17					8		25	17		8				
1908	516	"	"	"	"						7	5	No.	3	2					1		3	2		1	388	5.77		1.10
													%	26	12	1	1	7	4	9	4	25	6	3	2				
Total											82	35	No.	30	14	1	1	8	5	10	5	29	7	4	3	3726	5545		
													%																
		P.R.R. Sec.						Carnegie					No.	Pennsylvania R.R.															
												56	%	22	11	2	6	6	11	10	16	11	4	1					
1892 1907		0.50	0 08	1.00	0.13	specifications of 1900					59	56	No.	25	13	2	7	7	13	11	18	13	5	1		3708	55.16		
													%		50						50								
1908	1889	"	"	"	"							2	No.		1						1					63	094		0.05
													%	21	12	2	6	6	11	10	16	11	4	1					
Total											59	58	No.	25	14	2	7	7	13	11	19	13	5	1		3771	56.10		
													%																
		P.R.R. Sec.						Cambria					No.	Pennsylvania R.R.															
													%	22	[illegible]	3	9	5	6	14	10	12	8	12	08				
1900 1907		0 50	0 08	1.00	0.13						124	95	No.	46	19	6	20	12	13	30	23	27	18	3	2	7084	10545		
													%	12	12		18		18		23		17						
1908	1973	"	"	"	"						2	15	No.	2	2		3		3		4		3			558	830		0.40
													%	20	9	3	10	5	7	13	11	11	9	12	08				
Total											126	110	No.	48	21	6	23	12	16	30	27	27	21	3	2	7642	113.75		
													%																
		P.R.R. Sec.						Pennsylvania					No.	Pennsylvania R.R.															
													%	35	15					12	3	20	12	3					
1896 1906		0.50	0 08	1.00	0.13	Specifications 1900					24	10	No.	12	5					4	1	7	4	1		1256	18.80		
													%																
		P.S. Sec.						Cambria					No.	Pennsylvania R.R.															
													%								100								
1908	1440	0.50	0.08	1.00	0.13							2	No.								2					66	0 98		0.10
													%																
													No.																
Totals																													

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet 2 of 15 sheets

100 lb A.S.C.E. Dudley Sec. Bessemer Steel. Rolled by Various Steel Co s. Record for Period of 6 months ending October 31st 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From____ To____			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1907	Year 1908
													%																
189		A.S.C.E. Sec.						Maryland					No.	Baltimore & Ohio R.R.															
1901 1907										3 mill. to			%	4	4			12	9	13	5	1	3	48	1				
189	45295	.508	073			.066		40000	49000	10 5 mill	60	17	No.	3	3			9	7	10	4	1	2	37	1	2533	3781	0.22	0 08
													%																
189													No.																
													%																
		A.S.C.E. Sec.						Cambria					No.	Baltimore & Ohio R.R.															
1905										7 75 mill to			%	3	4			17	35	12	20	2	6		1				
1907	20927	.501	.098			.059		23.237	25083	10 5 mill	61	116	No.	5	8			30	62	23	35	3	10		1	5832	8678	0 86	0 42
													%																
													No.																
													%																
		A.S.C.E. Sec.						Illinois					No.	Chicago Rock Island & Pacific Ry.															
													%						11	67	22								
1907	707							45 575	53.550		6	3	No.						1	6	2					291	4 33		0.61
													%																
													No.																
													%																
		A.S.C.E. Sec.						Carnegie					No.	Pennsylvania Lines West N W System															
1901		0.40-0.55	over 0.07				Min	23.300	30800				%		10	2	4	16	31	12	19	2	2		2				
1908	20138	0.45-0.60	under 0.07	1.20			Max	51 500	61.800		16	33	No.		5	1	2	8	15	6	9	1	1		1	1626½	20 79	0.05	0 10
													%																
													No.																
													%																
		A.S.C.E. Sec.						Carnegie					No.	Pennsylvania Lines West S.W. System															
1902		0.40-0.55	over 0.07					48000	60000				%	7	5			2	23	10	40	3	8		2				
1908	17381	0.45-0.60	under 0.07	1.20				58800	61600		13	46	No.	4	3			1	13	6	24	2	5		1	1938½	28 80	0.14	0.16
													%																
													No.																
													%																
		Dudley Sec.						Lackawanna (Buffalo)					No.	Boston & Albany R.R.															
1904										44 mill. to			%	10	24		14		5		28		14	5					
1908	24308	0.50	0 096	1 00	0.13	0 08		54200	52500	106 2 mill	3	18	No.	2	5		3		1		6		3	1		693	10.30		0 04
													%																
													No.																
													%																
													No.																
Totals																													

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet 3 of 15 Sheets

95 & 90 lb. B & A / A S C E Sec 8 - Bessemer / 1 - Open Hearth Steel. Rolled by Various Steel Cos. Record for Period of 6 months ending October 31st 1908.

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From ~ To			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1907	Year 1908
													%																
189		95 lb. B & A. sec.						Lackawanna (Scranton)					No.	Boston & Albany R.R.															
1894 1904													%		30	8		8			8	23		23					
189	32678	0 60	0.06	0 90	0 15	0.07		41.750	52 500	1063M.	8	5	No.		4	1		1			1	3		3		390	5 51		0.01
													%																
189		95 lb. B & A sec. Open Hearth?						Bethlehem					No.	Boston & Albany R.R.															
1891					0.16 to								%					25		50			25						
1892	11000	0.60	0 06	0 90	0.15	0.08		34 834	30 750		3	1	No.					1		2			1			120	1.69		0.02
													%																
		90 lb. A.S.C.E. sec.						Maryland					No.	Central R.R. of New Jersey															
1903		0.45 to	under	0 80 to	under								%	25	14			22	12	7	7	3	7	1½	1½				
1908	26714	0 63	0 10	1.20	0.20			54000	58000		35	24	No.	15	8			13	7	4	4	2	4	1	1	1947	2607	0 10	0.10
													%																
		90 lb. A S C E sec						Maryland					No.	Delaware & Hudson Co.															
1906													%	15	20	7½	10	7½		17½	20			2½					
1907	18604							55500	43830		20	20	No.	6	8	3	4	3		7	8			1		1200	16.1		0.09
													%																
		90 lb. A.S.C.E. sec.						Maryland					No.	Lehigh Valley R.R.															
1902										mill.			%	19	6		25	13	6	6	6	6	13						
1908								23.88	25.57	170 76	7	9	No.	3	1		4	2	1	1	1	1	2			504	612		
													%																
		90 lb. A.S.C.E. Sec						Lackawanna					No.	Central R.R. of New Jersey															
1904		0 54	under	0 90	under								%	8	11		3	20	36	6	12		1		3				
1807	18835	0.65	0.10	1.15	0 20			54000	58000		24	46	No.	6	8		2	14	25	4	8		1		2	2310	3094	0.11	0.11
													%																
		90 lb. A.S.C.E. Sec.						Lackawanna					No.	Delaware & Hudson Co.															
													%	20				20		40	20								
1905	8367							55500	43830		4	1	No.	1				1		2	1					150	200		0 02
													%																
		90 lb. A.S.C.E. Sec.						Lackawanna					No.	Lehigh Valley R.R.															
1900										mill.			%	4	2	07	1.1	41	12	7	4	0.7		2½	25				
1908								23.88	25 57	170 76	151	118	No.	11	6	2	3	109	31	20	11	.2		7	67	8480	113.58		
													%																
		90 lb. A.S.C.E. Sec. Open Hearth							Bethlehem				No.	Central R.R. of New Jersey															
													%	50	12½			12½		12½			12½						
1908	5502	0 57	.031	0 82		0.43		54000	58000		6	2	No.	4	1			1		1			1			264	3.54		0.06
													%																
													No.																
Totals																													

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Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

90 lb. A.S.C.E. Sec. Bessemer / Open Hearth Steel. Rolled by Various Steel Cos. Record for Period of 6 months ending October 31st 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From________ To________			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1907	Year 1908
													%																
189								Cambria					No.	Central R.R. of New Jersey															
1907		0 54	under	0 90	under								%		29				14	14	29				14				
189	2204	0.58	0.10	1.00	0.20			54000	58000		1	6	No.		2				1	1	2				1	231	3.05	0.26	0.14
													%																
189													No.																
													%																
								Cambria					No.	Lehigh Valley R.R.															
1899										mill.			%	10	5		5	5	16	22	10	27							
1907								23.88	25.57	17076	12	7	No.	2	1		1	1	3	4	2	5				618	8.28		
													%																
													No.																
													%																
								Carnegie					No.	Central R.R. of New Jersey															
		0.54	under	Av.	under								%	100															
1906	3210	0.58	0.10	1.15	0.20			54000	58000		1		No.	1												33	0.44		0.01
													%																
													No.																
													%																
								Carnegie					No.	Lehigh Valley R.R.															
1900										mill			%	3	8	2	1	15	11	28	17	5	2	4	4				
1908								23 88	25.57	170 76	69	53	No.	4	10	2	1	18	14	34	21	6	2	5	5	3925	52.57		
													%																
													No.																
													%																
			Open Hearth					Bethlehem					No.	Lehigh Valley R.R.															
1907				0.80						mill.			%		50				17		33								
1908		0 75	.040	1.05				23 88	25.57	170 76		6.	No.		3				1		2					195	2.62		
													%																
													No.																
													%																
								Pennsylvania					No.	Lehigh Valley R.R.															
1902										mill.			%			12			25	63									
1903								23 88	25.57	170 76	6	2	No.			1			2	5						243	325		
													%																
													No.																
													%																
													No.																
Totals																													

Sheet 5 of 15 Sheets

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

85 to P.R.R. Sec Bessemer Steel. Rolled by Various Steel Cos: Record for Period of 6 months ending October 31st 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From ---- To ----			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1907	Year 1908
													%																
189								Cambria					No.	Baltimore Chesapeake & Atlantic Ry.															
													%																
1906 1908 189	538	0.54	.098	0 93	.057	.073		48 Tons	48 Tons		None		No.																
													%																
189													No.																
													%																
								Cambria					No.	Pennsylvania R.R.															
1899													%	24	21	3½			10½	10½	3½	10	10	3½	3½				
1907		0.50	0.08	1.00	0.13	Specifications 1902					15	14	No.	7	6	1			3	3	1	3	3	1	1	910	11.56		
													%		17				17				33		33				
1908	44	″	″	″	″							6	No.		1				1				2		2	189	2.39		5.5
													%	20	20	3			11	9	3	9	14	2	9				
Total											15	20	No.	7	7	1			4	3	1	3	5	1	3	1099	13.95		
													%																
													No.																
													%																
								Carnegie					No.	Pennsylvania Lines West N.W. System.															
1892		0.30					Min.	23300	30800				%	18				25	2	27	24	4							
1898	55369	0.50					Max.	51500	61800		33	12	No.	8				11	1	12	11	2				1465	18.44	0.03	0.03
													%																
													No.																
													%																
								Carnegie					No.	Pennsylvania Lines West S.W. System															
1895													%			3		12		79	2	2			2				
1898	38396							58800	61600		40	2	No.			1		5		33	1	1			1	1285	16:30	0.003	0.04
													%																
													No.																
													%																
								Carnegie					No.	Pennsylvania R.R.															
1891													%	12	19	3	4	4	3	19	17	3	7	1	8				
1907		0.50	0.08	1.00	0.13	Specifications 1900					56	75	No.	16	25	4	6	6	4	25	21	4	9	1	10	4093	50.88		
													%	12½			12½		25	12½	25			12½					
1908	556	″	″	″	″						3	5	No.	1			1		2	1	2			1		264	3.35		0.60
													%	12	18	3	5	4	4	19	17	3	6	2	7				
Total											59	80	No.	17	25	4	7	6	6	26	23	4	9	2	10	4357	54.23		
													%																
													No.																
Totals																													

Sheet 6 of 15 sheets.

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

85 lb P.R.R. Sec. Bessemer Steel. Rolled by Various Steel Cos. Racord for Period of 6 months ending October 31st 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From To			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curva	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1907	Year 1908
													%																
189								Illinois					No.	Pennsylvania Lines West, N.W. System															
1892 1898		030					Min	23300	30800				%	100															
189	21060	0.50					Max.	51500	61800		3		No.	3												117½	1.46	0.002	0.007
													%																
189													No.																
													%																
								Illinois					No.	Pennsylvania Lines West, S.W. System															
1895													%	100															
1898	10627							58800	61600		2		No.	2												60	0.80	0.007	0.008
													%																
													No.																
													%																
								Lackawanna					No.	Pennsylvania R.R.															
1901													%	3	8	1½	1½	12	5	14	12	3	3	9	28				
1907		0 50	0 08	1 00	0 13						28	37	No.	2	5	1	1	8	3	9	8	2	2	6	18	2084	26.47		
													%																
													No.																
													%																
								Pennsylvania					No.	Pennsylvania R.R.															
1889													%	15	10				10	20	15	15	10		5				
1906		0.50	0.08	1.00	0.13	Specifications 1900					10	10	No.	3	2				2	4	3	3	2		1	574	7.28		
													%																
													No.																
													%																
								Maryland					No.	Cumberland Valley R.R.															
1898													%	33	11				23	33									
1902	6006							46000	50400		6	3	No.	3	1				2	3						297	375		0.06
													%																
													No.																
													%																
								Maryland					No.	Pennsylvania R.R.															
1900													%	6	4½	1½	1½	1½	17	4½	17	6	6½	8	26				
1907		0.50	0.08	1.00	0.13						18	47	No.	4	3	1	1	1	11	3	11	4	4	5	17	2077	26.39		
													%	11	11		11		11		12		22	11	11				
1908	367	"	"	"	"						2	7	No.	1	1		1		1		1		2	1	1	294	374		1.00
													%	7	6	1	3	1	16	4	16	6	8	8	24				
Total											20	54	No.	5	4	1	2	1	12	3	12	4	6	6	18	2371	30.13		
Totals																													

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet, 7 of 15 Sheets

85 lb. A.S.C.E. Sec. Bessemer Steel. Rolled by Various Steel Co-s Record for Period of 6 months ending October 31st 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From---- To----			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length In Feet	Total Weight In Tons	Failures In Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1907	Year 1908
													%																
189								Cambria					No.	Baltimore & Ohio R.R.															
1898 1907										3.4 mill.			%	3	6			15	37	10	14	2	7	1	5				
189	71926	.502	098			.059		23237	25083	7.75	93	207	No.	8	17			46	111	31	43	5	20	3	16	11033	139.37	0.38	0.19
													%																
189								Cambria					No.	Grand Rapids & Indiana R.R.															
1903		0 40								1010 Mill.			%	7				13	27			7		13	33				
1907	10592	0 55	0.10	1.20				49000	44000	3030 Mill.	6	9	No.	1				2	4			1		2	5	522½	6.61		0.06
													%																
								Cambria					No.	Pennsylvania Lines West N.W. System.															
1900		0.40-0.55	over 0.07				Min.	23300	30800				%		20				30	20	20		10						
1906	12149	0.45-0.60	under 0.07	1.20			Max.	51500	61800		2	8	No.		2				3	2	2		1			330	4.12	0.03	0.03
													%																
								Cambria					No.	Pennsylvania Lines West - S.W. System															
1900		0.40-0.55	over 0.07										%		50						50								
1906	5055	0.45-0.60	under 0.07	1.20				58800	61600		1	1	No.		1						1					66	0.80		0.16
													%																
								Cambria					No.	Vandalia R.R. St Louis Division															
1901		0.40-0.55	over 0.07							Mill.			%	8				25	17	25				17	8				
1907	6983	0.45-0.60	under 0.07	1.20				57500	55500	875	9	3	No.	1				3	2	3				2	1	396	4.99		0.07
													%																
								Carnegie					No.	Baltimore & Ohio R.R.															
1897										1.1 Mill.			%	3	4		½	19	30	14	16	4½	6	1	2				
1908	238202	.477	.0893				0477	29542	.27375	5.6.	290	409	No.	19	30		3	131	208	98	109	33	44	9	15	22934	290.32	0.11	0.12
													%																
								Carnegie					No.	Pennsylvania Lines West N.W. System															
1899		0.40-0.55	over 0.07				Min.	23300	30800				%	12	9	0.4	1.1	11	6.4	35	17	5	2	0.7	0.4				
1908	167405	0.45-0.60	under 0.07	1.20			Max.	51500	61800		183	100	No.	34	26	1	3	32	18	100	47	14	5	2	1	9839	124.44	0.10	0.08
													%																
								Carnegie					No.	Pennsylvania Lines West S.W. System															
1899		0.40-0.55	over 0.07										%	7	4	3	0.4	19	5	39	11	5	2	1	36				
1908	200242	0.45-0.60	under 0.07	1.20				58800	61600		166	61	No.	15	10	6	1	43	12	89	26	11	4	2	8	7339	92.8	0.05	0.05
													%																
								Carnegie					No.	Vandalia R.R. St Louis Division															
1900		0.40-0.55	over 0.07										%	21	7			36	14	4	10	4	4						
1907	12801	0.45-0.60	under 0.07	1.20				57500	55500	8.75 Mill.	18	10	No.	6	2			10	4	1	3	1	1			918	11.60		0.09
													%																
													No.																
Totals																													

Sheet 8 of 15 sheets.

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

85 lb. A.S.C.E. Sec. Nickel Bessemer Steel. Rolled by Various Steel Co. Record for Period of 6 months ending October 31st 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From____ To____			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Bolt Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1907	Year 1908
													%																
189				Nickel Steel				Carnegie					No.	Pennsylvania Lines West N.W. System															
1903 1907								23300	30800				%	3	5	3	3	16	23	8	39								
189	1639	0.44	0.09	0.80	0.10	0.03	3.42	51500	61800		11	27	No.	1	2	1	1	6	9	3	15					1226	15.45	1.02	0.95
													%																
189								Colorado Fuel & Iron					No.	Atchison Topeka & Santa Fe Ry. Coast Lines															
1903													%	50		7			7	36									
1908	14.871										13	1	No.	7		1			1	5						495	6.26		0.04
													%																
								Illinois					No.	Baltimore & Ohio R.R.															
										Mill.			%	20				20		60									
1901	12.550							23237	25083	2.45	5		No.	1				1		3						162	2.02		0.02
													%																
								Illinois					No.	Chicago Great Western Ry - Eastern Division															
1905								48500		Mill.			%	38	13	12				25	12								
1907	7410	Illinois Steel Co.s Spec.					12.10	-04	43700	3.57	6	2	No.	3	1	1				2	1					264	334		0.045
													%																
								Illinois					No.	Chicago Rock Island & Pacific Ry.															
1905													%	31	15			8	15	23	8								
1906	68911							45575	53550		8	5	No.	4	2			1	2	3	1					429	543		0.008
													%																
								Illinois					No.	Illinois Central R.R.															
1899		0.43		0.80									%	28	5		1	10	25	10	7	5	1	7	1				
1908	249653	0.53	0.10	1.10	0.20			48500	46000		49	33	No.	23	4		1	8	20	8	6	4	1	6	1	2566	32.45		0.01
													%																
								Illinois					No.	Pennsylvania Lines West N.W. System															
1899		0.40-0.55	over 0.07				Min	23300	30800				%					50	50										
1905	11207	0.45-0.60	under 0.07	120			Max	51500	61800		1	1	No.					1	1							60	0.75	0.003	0.006
													%																
								Illinois					No.	Pennsylvania Lines West S.W. System.															
1899		0.40-0.55	over 0.07										%	19	12		50			19									
1906	15.322	0.45-0.60	under 0.07	1.20				58800	61600		6	10	No.	3	2		8			3						514	6.50	0.003	0.04
													%																
								Illinois					No.	Vandalia R.R.															
1900		0.40-0.55	over 0.07							Mill.			%																
1905	3398	0.45-0.60	under 0.07	1.20				57500	55500	8.75	None		No.																
													%																
													No.																
Totals																													

Sheet 9 of 15 sheets.

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

85 lb. Sec Bessemer Steel. Rolled by Various Steel Co s. Record for Period of 6 months ending October 31st 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From____ To____		Kind of Failure													Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year....	Year....
													%																
189		85 lb	9	sec.					Lackawanna				No.	Atchison Topeka & Santa Fe Ry. Coast Lines Valley Division															
1907													%																
189	12544										1		No.							1						33	0.38		
													%																
189		85 lb. Not stated section						Colorado Fuel & Iron					No.	Atchison Topeka & Santa Fe Ry. Albuquerque Division															
1903													%	16	36			4	12	12	8		4	8					
1905	21033							53960	56850		10	15	No.	4	9			1	3	3	2		1	2		852	10.77		0.05
													%																
		85 lb. Not stated. section						Lackawanna (Buffalo)					No.	Atchison Topeka & Santa Fe Ry. Albuquerque Division															
													%	11	11			22	11	23	11	11							
1904	3584							53960	56850		6	3	No.	1	1			2	1	2	1	1				263	3.33		0.09
													%																
		85 lb. A.S.C.E. section						Not stated, Manufacturer					No.	Atchison Topeka & Santa Fe Ry. Arizona Division															
1903											Both T. & C.		%	39		41		16		4									
1906	13122							53960	52900		71		No.	28		29		11		3	Tang & Curve not separated					2343	2962	0.10	0.25
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
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													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

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Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

85 lb A.S.C.E. Sec. ~~Bessemer~~ Open Hearth Steel. Rolled by Various Steel Co. Record for Period of 6 months ending October 31st 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From To			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1907	Year 1908
													%																
189								Lorain					No.	Chicago Rock Island & Pacific Ry.															
1906													%	100															
189	1456							45.575	53.550		1		No.	1												33	0.42		0.03
													%																
189								Lorain					No.	Pennsylvania Lines West N.W. System															
1899		0.40-0.55	over 0.07				Mim.	23300	30800				%		32			17		17			17	17					
1903	8324	0.45-0.60	under 0.07	1.20			Max.	51 500	61800		3	3	No.		2			1		1			1	1		180	2.25		0.08
													%																
								Maryland					No.	Baltimore & Ohio R.R.															
1899										3 Mill to 9.41 Mill			%	1	4			22	32	13	15	4	2	3	4				
1908	84.452	.516	.074			.064		23237	25083		73	108	No.	2	7			38	66	22	26	6	3	5	6	5939	75.17	0.15	0.09
													%																
								National					No.	Baltimore & Ohio R.R.															
1900										1.71 Mill. to 5.56 Mill.			%	25				25	25	12½		12½							
1901	13125							23 237	25083		6	2	No.	2				2	2	1		1				259	3.27	0.05	0.02
													%																
								National					No.	Pennsylvania Lines West N.W. System															
1901		0.40-0.55	over 0.07				Mim.	23300	30.800				%		50			25	25										
1904	12014	0.45-0.60	under 0.07	1.20			Max.	51500	61.800		1	3	No.		2			1	1							117½	1.48	0.01	0.01
													%																
								Pennsylvania					No.	Pennsylvania R.R.															
													%									50	50						
1906		0.50	0.08	1.00	0.13						1	1	No.									1	1			66	0.84		
													%																
								Republic					No.	Pennsylvania Lines West N.W. System															
1905		0.40-0.55	over 0.07				Mim.	23300	30.800				%	14			44	14	14		14								
1906	1758	0.45-0.60	under 0.07	1.20			Max.	51.500	61.800		2	5	No.	1			3	1	1		1					231	2.89	0.09	0.16
													%																
				Open Hearth				Tennesee Coal & Iron					No.	Baltimore & Ohio R.R.															
										Mill			%		17								66		17				
1906	200	0.61	0.05	.087	.008	.041		23237	25083	2.72		6	No.		1								4		1	198	2.50		1.25
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

Sheet 11 of 15 Sheets

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

80 lb. A.S.C.E Sec. Bessemer Steel. Rolled by Various Steel Co's Record for Period of 6 months ending October 31st 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From........ To........			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1907	Year 1908
													%																
189								Cambria					No.	Pennsylvania R.R.															
1901													%					100											
189		0.50	0 08	1.00	0.13						1		No.					1								30	0.36		
													%																
189								Carnegie					No.	Delaware & Hudson Co.															
													%	13	20				13	47	7								
1903	11954							55500	43830		9	6	No.	2	3				2	7	1					450	5.4		0.05
													%																
								Illinois					No.	Chicago & Alton R.R. Western Division															
1899											Not divided		%																
1905											27		No.	Records do not show kind of failures												818	9.74		
													%																
								Illinois					No.	Chicago & Alton R.R. Eastern Division															
1899													%	81		2				15		2							
1907											42		No.	34		1				6		1				1267	1500		
													%																
								Illinois					No.	Chicago Rock Island & Pacific Ry.															
1894													%	46	25			2	2	2	4	7	2	8	2				
1904	276447							45575	53550		34	18	No.	24	13			1	1	1	2	4	1	4	1	1583	1884		0.007
													%																
								Illinois					No.	Lake Superior & Ishpeming Ry.															
1904													%																
1906	2500	0.48	0.90	0.92	0 094			48250	32600	82800	None		No.																
													%																
								Illinois					No.	Lake Superior & Ishpeming Ry. Munising Ry.															
													%																
1906	629	0.48	0.39	0.92	0.94	2nd Quality		48250	32600	207000	None		No.																
													%																
								Lackawanna					No.	Delaware & Hudson Co.															
1896													%	11	16			5	5	26	37								
1904	23091							55500	43830		8	11	No.	2	3			1	1	5	7					570	6.80		0.03
													%																
								Lackawanna					No.	Lake Superior & Ishpeming Ry Munising															
		0.48		0.80									%																
1906	1454	0.58	0.10	1.10	0.20	2nd Quality		48250	32600	207000	None		No.																
													%																
													No.																
Totals																													

Sheet 12 of 15 Sheets

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

80 lb A.S.C.E Unknown Sec. Bessemer Open Hearth Steel. Rolled by Various Steel Cos. Record for Period of 6 months ending October 31st 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From------- To-------			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year.....	Year.....
													%																
189								Lackawanna					No.	Marquette & southeastern Ry.															
1907		0 40		075		1st & 2nd							%																
1908 189	1941	0.50	0.10	1.05	0.20	Quality		48250	32600	305000	None		No.																
													%.																
189								Maryland					No.	Chicago Rock Island & Pacific Ry.															
1903													%	11				11	33	34	11								
1904	13078							45575	53550		5	4	No.	1				1	3	3	1					268	3.19		0.024
													%																
								Maryland					No.	Delaware & Hudson Co.															
													%		31				53		8			8					
1907	2176							55500	43830		1	12	No.		4				7		1			1		390	4.6		021
													%																
								National					No.	Chicago Rock Island & Pacific Ry.															
1901													%	100															
1902	5408							45575	53550		2		No.	2												66	0.79		0.014
													%																
								Pennsylvania					No.	Chicago Rock Island & Pacific Ry.															
1904													%		50					50									
1905	3932							45575	53550		2	2	No.		2					2						118	1.38		0.35
													%																
								Pennsylvania					No.	Delaware & Hudson Co.															
													%		50					50									
1903	8908							55500	43830		1	1	No.		1					1						60	0.8		0 01
													%																
		Open Hearth						Tennessee Coal & Iron					No.	Chicago Rock Island & Pacific Ry															
													%		50						50								
1903	100							45575	53550			2	No.		1						1					60	0.71		0.71
													%																
		Open Hearth						Tennessee Coal & Iron					No.	Georgia R.R.															
1907													%											80	20				
1908	10000	0 59	.045	0.88	.008	.043		42317	42317		4	1	No.											4	1	165	2.00		0.02
													%																
		Not stated, Sec. Bessemer						Carnegie					No.	Central Vermont															
1900		0.40		0.70						Mill.			%	12½	12½					50	25								
1904		0.50	0.10	0 90		0.05		$101\frac{500}{2000}$	$77\frac{500}{2000}$	2.5	5	3	No.	1	1					4	2					240	2.85		
													%																
													No.																
Totals																													

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet 13 of 15 Sheets

75 lb. Various Sec Bessemer Steel. Rolled by Various Steel Co.s. Record for Period of 6 months ending October 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From ___ To ___			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length In Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1907	Year 1908
													%																
189		P.R.R. Sec.						Cambria					No.	Pennsylvania R.R.															
1906													%	100															
189		0.50	0.08	1.00	0.13						1		No.	1												24	0.27		
													%																
189		Sec. not stated						Carnegie					No.	Central Vermont R.R.															
1890		0.40		0.70									%	29	29					21	14	7							
1899		0.50	0.10	0.90		0.05		68 $\frac{500}{2000}$	57 $\frac{600}{2000}$		8	6	No.	4	4					3	2	1				420	4.69		
													%																
		A.S.C.E. Sec.						Carnegie & Lorain					No.	Chicago & Alton (Toledo St. Louis & Western)															
1905													%		10	9	5	36	18	4		3	9						
1907	28406										13	9	No.		2	2	1	8	4	1		2	2			714	8.00		0.03
													%																
		A.S.C.E. Sec.						Illinois					No.	Illinois Central R.R.															
1893		0.40		0.75									%	$16\frac{2}{3}$	$16\frac{2}{3}$				$16\frac{2}{3}$	$16\frac{2}{3}$		$16\frac{2}{3}$		$16\frac{2}{5}$					
1898	85309	0.50	0 10	1.05	0.20			48500	46000		4	2	No.	1	1				1	1		1		1		176	2.00		
													%																
		A.S.C.E. Sec.						Pennsylvania					No.	Chicago Great Western Ry. Eastern Division															
		0.45		0.80	0.10	Max 06				Mill.			%	40	20					20	20								
1899	3470	0.55	0.75	1.00	0.20	Av. 055		48.500	43.700	3.57	3	2	No.	2	1					1	1					270	3.01		0.05
													%																
		7506 Sec.						Illinois					No.	Chicago Great Western Ry. Eastern & N.W. Divisions															
1895										Mill.			%	47	17	6				17	8		5						
1906	34840	Illinois Steel Co. Spec.						48500	43700	2.0 3.6	25	11	No.	17	6	2				6	3		2			1075	12.00		0.035
													%																
		753 Sec.						Colorado Fuel & Iron					No.	El Paso & South Western R.R.															
													%			100													
1905	10.000										1		No.			1										30	0.33		0.03
													%																
		M.O.P. Sec.						Illinois					No.	International & Great Northern R.R.															
1898								Per	Axle				%	16				16	21	16	31								
1900	5475							22 Tons	22 Tons	65	9	10	No.	3				3	4	3	6					570	6.36		0.12
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

Philadelphia & Reading Ry. RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet 14 of 15 sheets

Not stated lb Sec Steel. Rolled by Various Steel Co.s Record for Period of ending During 1908

Year Laid	Tons of New Rail ~~Laid~~ Rolled	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From To		Kind of Failure													Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan. & Curve	~~Curve~~		Broken		~~Flow of Metal~~		~~Crushed Head~~		Split Head		~~Split Web~~		Broken Base		Total Length in Feet	Total Weight in Tons	~~Failures in Percentage of Tons of Rail Laid~~	
														~~Tan.~~	~~Curve~~	~~Tan.~~	~~Curve~~	~~Tan.~~	~~Curve~~	~~Tan.~~	~~Curve~~	~~Tan.~~	~~Curve~~	~~Tan.~~	~~Curve~~			~~Year~~	~~Year~~ 1908
								Bethlehem					%			Crushed						Broken						Proportion removed	
189													No.			or Flowed						Base						per 1000 Tons Rolled	
1882 1897													%	70		5				25									
189											20		No.	14		1				5									
								Cambria					%																
189													No.																
													%	21		7				68		4							
1905	3450										28		No.	6		2				19		1							8.09
								Carnegie					%																
													No.																
													%	13						67		20							
1905	6852										15		No.	2						10		3							2.18
								Lackawanna					%																
													No.																
1898													%	67						33									
1900											6		No.	4						2									
													%	7		47				32		14							
1905	1504										28		No.	2		13				9		4							186
													%																
1906	4165										None		No.																
													%																
								Maryland					No.																
													%	50						50									
1902											2		No.	1						1									
1903													%	16		48				30		6							
1908	108611										252		No.	41		119				77		15							232
													%																
								Pennsylvania					No.																
1890													%	69		5				26									
1902											19		No.	13		1				5									
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

Philadelphia & Reading Ry. RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet 15 of 15 Sheets

lb Not stated Sec. Steel. Rolled by Various Steel Co's. Record for Period of ending During 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From ------- To -------		Kind of Failure													Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan. & Curve	~~Curve~~		Tan. & Curve	~~Curve~~	~~Tan.~~	~~Curve~~	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan. & Curve	~~Curve~~			Year 1907	Year
													%	Other breaks															
189								Bethlehem					No.																
1886 1897 189													%	100															
											14		No.	14															
													%																
189								Cambria					No.																
													%	86										14					
1905											7		No.	6										1					
													%																
								Carnegie					No.																
													%	40										60					
1905											5		No.	2										3					
													%																
								Lackawanna					No.																
1898													%	60										40					
1905											10		No.	6										4					
													%																
								Maryland					No.																
1902													%	74										26					
1907											57		No.	42										15					
													%																
								Pennsylvania					No.																
1890													%	100															
1902											13		No.	13															
													%																
													No.	Tang	Curve	Tang	Curve	Tang.	Curve	Tang	Curve	Tang.	Curve	Tang.	Curve				
													%																
	85 lb. A.S.C.E. Sec. Bessemer steel. Illinois.												No.	Chicago Milwaukee & St. Paul R.R. Failures for 6 months ending Oct 31.1907															
1899													%	1½	2			2	95			1½							
1907	161460	0.53	0.10	0.95	0.20			50700	46000		7	200	No.	3	4			3	196			1				6216	78.60	0.05	
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

Supplement, Sheet 16.

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Various lb Various Sec. Bessemer & Open Hearth Steel. Rolled by Various Steel Co Record for Period of 6 months ending October 31 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From ---- To ----			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1907	Year 1908
	80 lb.	Dudley Sec											%																
189	90 "	A.S.C.E "		Bessemer				Carnegie					No.	Buffalo Rochester & Pittsburgh R.R.															
1900 1907		0 48	Max	0 80	Max					Per Anum 12 to 37 Mill			%		4		7	13	52	3	14				7				
189	28300	0 58	0 10	1.10	0 20			41000	53000		11	59	No.		3		5	9	36	2	10				5	2310	303		0.107
	80 lb	Dudley	Sec										%																
189	90 "	A.S.C.E	"	Bessemer				Lackawanna					No.	Buffalo Rochester & Pittsburgh R.R.															
1895		0 48	Max	0 80	Max					Per Anum 12 to 47 Mill			%	3	13	3	19		28	3	9			13	3				
1907	27400	0 58	0 10	1.10	0 20			41000	53000		9	23	No.	3	4	1	6		9	1	3			4	1	1051	13.8		0 05.
													%																
	80 lb. Dudley Sec Bessemer							Bethlehem					No.	Buffalo Rochester & Pittsburgh R.R.															
		0.48	Max	0 80	Max.								%																
1895	2100	0 58	0 10	1 10	0 20			41000	53000	47 Mill		1	No.								1					33	0.4		0 02
													%																
	85 lb A.S.C.E sec Bessemer							Illinois					No.	Northern Pacific R.R.															
1903		0 43	Max	0 80	Max.								%	30	26	1	2	2	5	7	11			11	5				
1908	110.410	0 53	0 10	1.10	0 20			54730	52300		45	43	No.	26	23	1	2	2	4	.6	10			10	4	2869	363		0.03
													%																
	85 lb A.S.C.E Sec Bessemer							Lackawanna					No.	Northern Pacific R.R.															
1903		0 43	Max	0 80	Max								%	25		13				37					25				
1907	4736	0 53	0 10	1 10	0 20			51750	52300		6	2	No.	2		1				3					2	258	33		0 06
													%																
	72 lb	A.S.C.E Sec Bessemer						Illinois					No.	Northern Pacific R.R.															
1889		Prev to 1900 Steel Co's spec											%	25	8			8	8	8	9		9	25					
1902	6951	0 40-0 50	Max 0.10	0 75-1 05	Max 0 20	Year 1900-1902		51750	52300		8	4	No.	3	1			1	1	1	1		1	3		357	5.1		0 05
													%																
	72 lb.	A.S.C.E Sec Bessemer						Lackawanna					No.	Northern Pacific R.R.															
1899													%	25				25		25	25								
1900	12168	As above						51750	52300		3	1	No.	1				1		1	1					120	12		0 01
													%																
	80 lb	A S C E Sec Open Hearth						Tennessee Coal & Iron R R Co.					No.	Louisville & Nashville R.R. (All Divisions)															
		0 55	Max	0 80	Max			30900 to	26500	5.93 M.	Not separated		%	42		21				15		11		11					
1905	40772	0 68	0 06	1 10	0 20			43000	42400	37.26 "	19		No.	8		4				3		2		2		621	7.4		0 02
									33000	217 M			%	12½		42				25		12½		8					
1906	23349	"	"	"	"			"	42400	2606 "	24		No.	3		10				6		3		2		783	9.3		0 04
								32400 to		109 M			%	15		15		3		43		21		3					
1907	29620	"	"	"	"			43000	"	1404 "	33		No.	5		5		1		14		7		1		1073	12.8		0.04
								30900 to		0 23 M			%	25		25				50									
1908	26054	"	"	"	"			43000	"	361 "	4		No.	1		1				2						132	1.6		0 006
Totals	119795												%	21		25		1		32		15		6					
											80		No	17.		20		1		25		12		5		2609	31.1		0.026

The Baltimore and Ohio RAILROAD

Position in Ingot of Steel Rails which Failed, for Period of 6 mos. ending October 31, 1908.

A.S.C.E. TYPE OF RAIL SECTION

Sheet No 1

of Sheets

Kind of Failure	Maryland Steel Co								Sparrow's Point Mill								National Steel Co								Mill							
	100 lb.								85 lb.								100 lb.								85 lb.							
	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken	2	2					2	6							9	9															2	2
Flow of Metal																																
Crushed Head	9			1			6	16							104	104															4	4
Split Head	10						4	14							48	48															1	1
Split Web	1						2	3							9	9															1	1
Broken Base	3	8	11	11	4		1	38							11	11																
Totals	25	10	11	12	4		15	77							181	181															8	8
	Cambria Steel Co.								Johnstown Mill								Illinois Steel Co.								Mill							
Broken							13	13							25	25															1	1
Flow of Metal																																
Crushed Head							92	92							157	157															1	1
Split Head							58	58							74	74															3	3
Split Web							12	12							25	25																
Broken Base							1	1							19	19																
Totals							177	177							300	300															5	5
	Carnegie Steel Co.								Edgar Thompson Mill								Tennessee Steel Co.								Mill							
Broken															49	49															1	1
Flow of Metal															3	3																
Crushed Head															339	339																
Split Head															207	207																
Split Web															77	77															4	4
Broken Base															24	24															1	1
Totals															699	699															6	6

Boston and Albany RAILROAD

Position in Ingot of Steel Rails which Failed, for Period of 2 mos. **ending** March 31 19 08.

Sheet No. 1
of 1 Sheets

TYPE OF RAIL SECTION

	Kind of Failure	Lackawanna Steel Co. Buffalo Mill																Co. Mill															
		100 lb.								85 lb.								100 lb.								85 lb.							
		A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
February '08.	Broken	3	4	2	1																												
	Flow of Metal				1																												
	Crushed Head																																
	Split Head	3	2		1																												
	Split Web																																
	Broken Base																																
	Totals																																
		Lackawanna Steel Co. Buffalo Mill																Co. Mill															
March '08	Broken	3	2	8	2																												
	Flow of Metal																																
	Crushed Head																																
	Split Head	2	3	2	2																												
	Split Web	4		1																													
	Broken Base																																
	Totals																																
		Co. Mill																Co. Mill															
	Broken																																
	Flow of Metal																																
	Crushed Head																																
	Split Head																																
	Split Web																																
	Broken Base																																
	Totals																																

Northern Pacific RAILROAD

Position in Ingot of Steel Rails which Failed, for Period of 6 mos. **ending** October 31, 1908

A.S.C.E. TYPE OF RAIL SECTION

Sheet No.______ of______ Sheets

Kind of Failure	Illinois Steel Co.								South Works, Chicago, Ill. Mill								Lackawanna Steel Co.								Buffalo, N.Y. Mill							
	72 lb.								85 lb.								72 lb.								85 lb.							
	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken							4	4	1	1		1			46	49															2	2
Flow of Metal															3	3															1	1
Crushed Head							2	2							6	6																
Split Head							2	2							16	16															3	3
Split Web							1	1																								
Broken Base							3	3							14	14															2	2
Totals							12	12							85	88															8	8
	Co.								Mill								Lackawanna Steel Co.								Scranton, Pa. Mill							
Broken																							2	2								
Flow of Metal																																
Crushed Head																																
Split Head																							2	2								
Split Web																																
Broken Base																																
Totals																							4	4								
	Co.								Mill								Co.								Mill							
Broken																																
Flow of Metal																																
Crushed Head																																
Split Head																																
Split Web																																
Broken Base																																
Totals																																

Toledo St. Louis and Western RAILROAD

Position in Ingot of Steel Rails which Failed, for Period of 6 mos. ending October 31, 1908.

A.S.C.E. TYPE OF RAIL SECTION

Sheet No.______

of______Sheets

Kind of Failure	Carnegie Steel Co.								Edgar Thompson Mill							
	75 lb.								85 lb.							
	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken																
Flow of Metal																
Crushed Head			4					4								
Split Head																
Split Web					1			1								
Broken Base																
Totals								5								
	Lorain Steel Co.								Mill							
Broken																
Flow of Metal																
Crushed Head																
Split Head																
Split Web					1			1								
Broken Base																
Totals								1								
	Co.								Mill							
Broken																
Flow of Metal																
Crushed Head																
Split Head																
Split Web																
Broken Base																
Totals																

Kind of Failure	Carnegie Steel Co.								Ohio Works Mill							
	75 lb.								85 lb.							
	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken	1							1								
Flow of Metal		3						3								
Crushed Head			7					7								
Split Head				1				1								
Split Web					2			2								
Broken Base																
Totals								14								
	Illinois Steel Co.								South Works Mill							
Broken	1							1								
Flow of Metal																
Crushed Head			1					1								
Split Head																
Split Web																
Broken Base																
Totals								2								
	Co.								Mill							
Broken																
Flow of Metal																
Crushed Head																
Split Head																
Split Web																
Broken Base																
Totals																

Boston and Albany RAILROAD

Record of Comparative Wear of Special Rail

Date of Report October 31 19 08

Special Rail Marked "Diagonal"													Chemical Composition of .... Rail of .... Section with which Special Rail was Compared							Special and Comparative Rails						
Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Chemical Composition														Date Laid	Date Removed	Length of Service at date of Report	Average Area Abraded of all the Sections taken			
																							Special		Comparative	
						C	P	Mn	Si	S			C	P	Mn	Si	S						Sq. In. abraded	% of area of Head	Sq. In. abraded	% of area of Head
	East Brookfield		100	Dudley	L. S. Co.	0.48	0.096	1.00	0.13	0.06			0.45	0.096	1.00	0.13	0.06			Oct. 1, 08		1 month	No record		taken	to date
	Chatham Center.		100	Dudley	L. S. Co.	0.48	0.096	1.00	0.13	0.06																
													0.45	0.096	1.00	0.13	0.06			Oct. 1, 08.		1 month	"	"	"	" "

Pennsylvania (*Lines East*) RAILROAD

Sheet No. 1 of 3 Sheets.

Record of Comparative Wear of Special Rail

Date of Report *October 31*, 19*08*

Special Rail													Chemical Composition of *Cambria Bessemer* Rail of *P.R.R.* Section with which Special Rail was Compared							Special and Comparative Rails						
Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Chemical Composition														Date Laid	Date Removed	Length of Service at date of Report	Average Area Abraded of all the Sections taken			
						C	P	Mn	Si	S	*N*	*Ch.*	C	P	Mn	Si	S						Special		Comparative	
																							Sq. In. abraded	% of area of Head	Sq. In. abraded	% of area of Head
	New York Div.																									
Nickel	*Meadows-E.B.F.*	*22.32*	*100*	*P.R.R.*	*Carnegie*	*.51*	*.092*	*.84*	*.11*	*.046*	*3.25*									*3.-06*	*3.27.07*	*1y-1m*	*0.49*	*10.8*		
"	*Philada. Div.*																									
Nickel	*Bradford Hills-E.B.F.*	*145.48*	*100*	*P.R.R.*	*Carnegie*	*.51*	*.092*	*.84*	*.11*	*.046*	*3.25*									*9.-03*	*4.-06*	*2y-7m*	*0.88*	*19.5*		
"	*Pomeroy* "	*179.61*	"	"	"	"	"	"	"	"	"									*9.-03*	*4.-06*	*2y-7m.*	*0.57*	*12.6*		
"	*Christiana* "	*59.32*	"	"	"	"	"	"	"	"	"									*7-03*	*4.-06*	*2" 9"*	*0.68*	*15.1*		
"	*Gap* "	*72.47*	"	"	"	"	"	"	"	"	"									*8.-03*	*9.-05*	*2" 1"*	*0.79*	*17.5*		
"	*Kinzer* "	*69.67*	"	"	"	"	"	"	"	"	"									*7.-03*	*4.-06*	*2" 9"*	*0.73*	*16.1*		
"	*Ronk* "	*90.21*	"	"	"	"	"	"	"	"	"									*7.-03*	*4.-06*	*2" 9"*	*0.62*	*13.8*		
"	*Columbia* "	*23.75*	"	"	"	"	"	"	"	"	"									*7-03*	*1.-05*	*1" 6"*	*1.53*	*33.9*		
"	*Rockville* "	*38.42*	"	"	"	"	"	"	"	"	"									*7-03*	*12.-04*	*1" 5"*	*0.54*	*11.9*		
Mayari	*Safe Harbor* "	*15.48*	"	"	*Maryland*	*.516*	*.026*	*.87*				*.17*								*8.-07*	*10-08*	*1" 3"*	*0.91*	*20.1*		
	Middle Div.																									
Bessemer	*Schoenberger*	*58.36*	*100*	*P.R.R.*	*Lackawanna*	*.50*	*.08*	*1.0*	*.13*				*.50*	*.07*	*1.0*	*.13*				*7.-00*	*4.-02*	*1y 9m.*	*0.61*	*13.5*	*0.85*	*18.8*
"	*Pemberton*	*19.88*	"	"	"	"	"	"	"				"	"	"	"				*7.-00*	*4.-02*	*1" 9"*	*0.53*	*11.7*	*0.80*	*17.7*
"	*Tyrone Forge*	*18.33*	"	"	"	"	"	"	"				"	"	"	"				*7.-00*	*4.-02*	*1" 9"*	*0.46*	*10.2*	*0.71*	*15.7*
"	*Union Furnace*	*16.31*	"	"	"	"	"	"	"				"	"	"	"				*8.-00*	*4.-02*	*1" 8"*	*0.32*	*7.1*	*0.59*	*13.1*
"	" "	*18.06*	"	"	"	"	"	"	"				"	"	"	"				*8.-00*	*4.-02*	*1" 8"*	*0.15*	*3.3*	*0.34*	*7.5*
"	*Schoenberger*	*32.74*	"	*A.S.C.E.*	*Carnegie*	"	"	"	"				"	"	"	"				*8.-02*	*10.-03*	*1" 2"*	*0.53*	*13.5*	*0.63*	*13.9*
"	"	*24.48*	"	"	"	"	"	"	"				"	"	"	"				*8.-02*	*11.-03*	*1" 3"*	*0.60*	*14.8*	*0.83*	*18.4*
"	*Tyrone Forge*	*38.30*	"	"	"	"	"	"	"				"	"	"	"				*9.-02*	*11.-03*	*1" 2"*	*0.77*	*19.0*	*0.39*	*8.6*
"	" "	*46.58*	"	"	"	"	"	"	"				"	"	"	"				*8.-02*	*4.-04*	*1" 8"*	*0.87*	*21.4*	*0.76*	*16.8*
"	*Mexico*	*32.86*	"	*P.R.R.*	*Lackawanna*	"	"	"	"				"	"	"	"				*7.-00*	*7.-05*	*5" 0"*	*0.65*	*14.4*	*0.74*	*16.4*
"	*Rockville*	*41.55*	"	"	*Carnegie*	"	"	"	"											*7.-03*	*10.-05*	*2" 3"*	*0.98*	*21.5*		
"	*Granville*	*89.14*	"	"	*Lackawanna*	"	"	"	"				*.50*	*.07*	*1.0*	*.13*				*7.-00*	*4.-06*	*5" 9"*	*0.81*	*17.9*	*0.88*	*19.5*

Pennsylvania *(Lines East)* RAILROAD

Sheet No. 2 of 3 Sheets

Record of Comparative Wear of Special Rail

Date of Report *October 31* 19*08.*

Special Rail													Chemical Composition of .... Rail of .... Section with which Special Rail was Compared							Special and Comparative Rails						
Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Chemical Composition														Date Laid	Date Removed	Length of Service at date of Report	Average Area Abraded of all the Sections taken			
																							Special		Comparative	
						C	P	Mn	Si	S	*N*		C	P	Mn	Si	S						Sq. In. abraded	% of area of Head	Sq. In. abraded	% of area of Head
	Middle Div. (Cont.)																									
Nickel	*Union Furnace*	*71.43*	*100*	*P.R.R.*	*Carnegie*	*.51*	*.092*	*.84*	*.11*	*.046*	*3.25*									*5.-03*	*8.-04*	*1 y 3 m*	*0.54*	*11.9*		
"	*Tyrone*	*53.87*	"	"	"	"	"	"	"	"	"									*6.-03*	*9.-04*	*1 " 3 "*	*0.46*	*10.2*		
"	*Mexico*	*56.97*	"	"	"	"	"	"	"	"	"									*8.-03*	*11.-04*	*1 " 3 "*	*0.60*	*13.3*		
"	*Spruce Creek*	*47.65*	"	"	"	"	"	"	"	"	"									*6.-03*	*12.-04*	*1 " 6 "*	*0.58*	*12.8*		
"	*Union Furnace*	*41.25*	"	"	"	"	"	"	"	"	"									*7.-03*	*12.-04*	*1 " 5 "*	*0.51*	*11.3*		
"	*Schoenberger*	*36.19*	"	"	"	"	"	"	"	"	"									*6.-03*	*12.-04*	*1 " 6 "*	*0.45*	*10.0*		
"	"	*26.97*	"	"	"	"	"	"	"	"	"									*11.-03*	*12.-04*	*1 " 1 "*	*0.35*	*7.7*		
"	*Birmingham*	*76.40*	"	"	"	"	"	"	"	"	"									*10.-03*	*12.-04*	*1 " 2 "*	*0.29*	*6.4*		
"	*Spruce Creek*	*56.73*	"	"	"	"	"	"	"	"	"									*5.-03*	*9.-05*	*2 " 4 "*	*0.50*	*11.1*		
"	*Birmingham*	*58.48*	"	"	"	"	"	"	"	"	"									*11.-03*	*9.-05*	*1 " 10 "*	*0.67*	*14.8*		
"	*Lewistown Junc.*	*79.94*	"	"	"	"	"	"	"	"	"									*10.-03*	*6.-06*	*2 " 8 "*	*1.09*	*24.1*		
"	" *-E.B.F.*	*89.70*	"	"	"	"	"	"	"	"	"									*10.-03*	*6.-06*	*2 " 8 "*	*0.80*	*17.7*		
" *2nd Class*	*Spruce Creek*	*27.95*	"	"	"	"	"	"	"	"	"									*7.-03*	*9.-05*	*2 " 2 "*	*0.50*	*11.1*		
" " "	*Warrior Ridge*	*107.83*	"	"	"	"	"	"	"	"	"									*8.-03*	*6.-06*	*2 " 10 "*	*0.34*	*7.5*		
" " "	" "	*131.10*	"	"	"	"	"	"	"	"	"									*7.-03*	*8.-07*	*4 " 1 "*	*0.31*	*6.9*		
" " "	" "	*50.92*	"	"	"	"	"	"	"	"	"									*7.-03*	*6.-07*	*3 " 11 "*	*0.35*	*7.7*		
" " "	*Lewistown Junc.*	*57.29*	"	"	"	"	"	"	"	"	"									*9.-03*	*8.-07*	*3 " 11 "*	*0.90*	*19.9*		
Open Hearth	*Union Furnace*	*21.43*	"	"	*Maryland*	*.85*	*.015*	*.68*	*.036*											*8.-04*	*1.-07*	*2 " 5 "*	*0.74*	*16.4*		
" "	*Tyrone Forge*	*30.66*	"	"	"	"	"	"	"											*9.-05*	*8.-07*	*1 " 11 "*	*0.70*	*15.5*		
" "	*Schoenberger*	*61.01*	"	"	"	"	"	"	"											*9.-05*	*9.-07*	*2 " 0 "*	*0.64*	*14.0*		
" "	*Pemberton*	*78.57*	"	"	"	"	"	"	"											*9.-05*	*9.-07*	*2 " 0 "*	*0.55*	*12.2*		
" "	*Birmingham*	*56.55*	"	"	"	"	"	"	"											*9.-05*	*9.-07*	*2 " 0 "*	*0.47*	*10.4*		
" "	*Spruce Creek*	*41.67*	"	"	"	"	"	"	"											*9.-05*	*5.-08*	*2 " 8 "*	*0.50*	*11.1*		

Pennsylvania (Lines East) RAILROAD

Sheet No. 3 of 3 Sheets

Record of Comparative Wear of Special Rail

Date of Report ______ 19__

Special Rail													Chemical Composition of Md. Cam. & Lack. Bessm'r. Rail of P.R.R. Section with which Special Rail was Compared							Special and Comparative Rails						
Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Chemical Composition														Date Laid	Date Removed	Length of Service at date of Report	Average Area Abraded of all the Sections taken			
						C	P	Mn	Si	S	N	Ch.	C	P	Mn	Si	S						Special		Comparative	
																							Sq. In. abraded	% of area of Head	Sq. In. abraded	% of area of Head
	Tyrone Div.																									
Bessemer	Gardner	2.28	85	P.R.R.	Carnegie	.50	.08	1.00	.13				.50	.08	1.00	.13				3.-02	6.-03	1y.3m.	0.37	9.6	0.65	16.9
													Cam. Car. & Lack. Bessemer													
Bessemer	Gardner	2.28	85	P.R.R.	Maryland	.50	.08	1.00	.13				.50	.08	1.00	.13				3.-02	6.-03	1y.3m.	0.39	10.1	0.64	16.6
													Car. Md. & Lack. Bessemer													
Bessemer	Gardner	2.28	85	P.R.R.	Cambria	.50	.08	1.00	.13				.50	.08	1.00	.13				3.-02	6.-03	1y.3m.	0.96	24.9	0.45	11.7
													Car. Md. & Cam. Bessemer													
Bessemer	Gardner	2.28	85	P.R.R.	Lackawanna	.50	.08	1.00	.13				.50	.08	1.00	.13				3.-02	6.-03	1y.3m.	0.60	15.6	0.57	14.8
													Carnegie Bessemer													
Mayari	Gardner	3.97	80	A.S.C.E.	Maryland	.51	.026	.87					.50	.08	1.00	.13				10.-07	10.-08	1y. 1m.	0.63	19.7	0.57	14.8
"	"	12.30	85	P.R.R.	"	"	"	"					"	"	"	"				10.-07	10.-08	" 1 "	0.53	13.7	0.57	14.8
	Pittsburgh Div.												Cambria Bessemer													
Chrome	Kittanning Point	2.68	100	P.R.R.	Maryland								.50	.08	1.00	.13				9.-02	9.-03	1y 0m.	1.10	24.3	1.07	23.7
Bessemer	" "	40.60	"	"	Cambria	.50	.08	1.00	.13				Cambria Bessemer							1.-03	9.-03	0 " 8 "	1.11	24.6		
"	Mineral "	100.00	"	"	Lackawanna	"	"	"	"				.50	.08	1.00	.13				5.-00	8.-05	5 " 3 "	0.83	18.4	0.81	17.9
Nickel	Kittanning "	2.92	"	"	Carnegie	.51	.092	.84	.11	.046	3.25		"	"	"	"				9.-03	7.-04	0 " 10 "	0.79	17.5	0.76	18.7
"	Pittsburgh	20.83	"	"	"	"	"	"	"	"	"									6.-03	6.-05	2 " 0 "	0.55	12.2		
"	Donohoe	50.09	"	"	"	"	"	"	"	"	"									8.-04	1.-06	1 " 5 "	0.63	13.9		
"	Kittanning Point		"	A.S.C.E.	"	.50	.094	1.00	—	—	3.22									1.-00	3.-06	6 " 2 "	1.21	29.8		
"	Sang Hollow	68.13	"	P.R.R.	"	.51	.092	.84	.H	.046	3.25									8.-03	6.-07	3 " 10 "	0.72	15.9		
"	Altoona	30.00	"	A.S.C.E.	"	.50	.094	1.00	—	—	3.22									1.-00	4.-07	7 " 3 "	1.12	27.6		
Johnston Hardened	Kittanning Point	12.23	"	P.R.R.	Johnston	.50	.08	1.00	.13											8.-05	1.-06	0 " 5 "	1.26	27.9		
Open Hearth	" "	14.73	"	"	Maryland	.85	.015	.68	.04				.50	.08	1.00	.13				8.-05	8.-06	1 " 0 "	1.30	28.8	1.50	33.2
Mayari	" "		"	"	"	.65	.019	.94				.23	.50	.096	.84	.104	.045			9.-07	3.-08	0 " 6 "	0.74	16.4	0.81	17.9

PENNSYLVANIA LINES WEST OF PITTSBURGH, INCLUDING C.& M.V. R.R.

Record of Comparative Wear of Special Rail

Date of Report October 19 08

Special Rail													Chemical Composition of Carnegie Bessemer 85 lb. Rail of A.S.C.E. Section with which Special Rail was Compared							Special and Comparative Rails						
Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Chemical Composition														Date Laid	Date Removed	Length of Service at date of Report	Average Area Abraded of all the Sections taken			
																							Special		Comparative	
						C	P	Mn	Si	S	Ni		C	P	Mn	Si	S						Sq. In. abraded	% of area of Head	Sq. In. abraded	% of area of Head
Nickel	Highland	454	85	A.S.C.E.	Carnegie Steel Co	0.44	0.09	0.80	0.10	0.03	3.42		0.48	0.09	0.88	0.10	0.04			1903		5½ Years	0.38	10.9	0.45	12.9
"	Massillon	506	"	"	" " "	"	"	"	"	"	"		"	"	"	"	"			"		"	0.24	6.8	0.39	11.1
"	Wooster	512	"	"	" " "	"	"	"	"	"	"		"	"	"	"	"			"		"	0.46	13.1	0.49	13.9
"	Oakdale to McDonald	363	"	"	" " "	"	"	"	"	"	3.40		"	"	"	"	"			"		5 Years	0.37	10.6	0.45	12.9
"	Manlin to Collier	736	"	"	" " "	"	"	"	"	—	3.42		0.49	"	0.87	"	"			"	Part 1906 " 1907	3 " 4 "	0.43	12.3	0.58	16.6
"	Wheeling Junction	104	"	"	" " "	"	"	"	"	"	3.45		0.48	"	0.88	"	"			"	1906	3 "	0.41	11.7	0.53	15.1
"	Cadiz Junction	109	"	"	" " "	"	"	"	"	"	3.39		0.49	"	0.85	"	"			"	*1907	4 "	0 47	13.4	0.80	22.8
"	BA Tower to Scio	168	"	"	" " "	"	"	"	"	"	3.41		0.48	"	0.88	"	"			"		5 "	0.40	11.4	0.41	11.7

* Bessemer removed in 1907; Nickel still in track

Appendix C.

RAIL FAILURE STATISTICS FOR PERIOD OF SIX MONTHS, OCTOBER 31, 1908, TO APRIL 30, 1909.

(Bulletin 116.)

Note.—The General Committee has accepted the following report at its meeting at Niagara Falls, October 4, 1909, as a progress report and has no conclusions to offer at the present time.

A tabulation of rail failure statistics, for the period of six months from October 31, 1908, to April 30, 1909, has been prepared and is submitted herewith.

Statistical information has been received from 42 railroad systems, some of them embracing several companies, and, while the reports are in better shape than the last ones, some of the information was not complete enough for use. It is to be hoped that the various companies will observe wherein their reports have been deficient, and will remedy them hereafter. The last column on the forms cannot be filled out unless the total tons laid are reported in the second column. On account of this omission, a number of important records, which could not be included for lack of information relative to the tonnage laid, have had to be excluded.

This report consists of the following divisions:

(1) A tabulation of the information received from each company, on sheets I to XXXVII, both inclusive.

(2) A summary of sheets I to XXXVII, by sections, weights and kinds of steel, on sheets XXXVIII to XLII, both inclusive.

(3) A tabulation for diagrams from 1 to 5, on sheets XLIII to XLIX, both inclusive.

(4) A report of failures classified according to the position in the ingot, on sheets L to LIX, both inclusive.

(5) A report on the comparative wear of special rail, on sheets LX and LXI.

(6) Diagrams 1, 2, 3, 4 and 5, showing a comparison of failures graphically, for different studies.

GENERAL SUMMARY (SHEETS I TO XXXVII).

The number of rail failures range from 0 to 1.43 (one and forty-three hundredths) per cent., or 143 failures per 10,000 tons of new rail laid.

Excluding rail laid during the present year, there were no failures reported for any of the following rail:

100 lb. A. S. C. E.,	Cambria,	Bessemer	1904	on Penna. Lines West.
100 lb. P. S.,	Maryland,	Bessemer	1908	on Penna. Lines West.
90 lb. A. R. A.,	Carnegie,	Bessemer	1908	on B. & O. S. W.
85 lb. A. S. C. E.,	Illinois,	Bessemer	1901	on B. & O. S. W.
85 lb. A. S. C. E.,	Maryland,	Bessemer	1906	on C. R. I. & P.

85 lb. A. S. C. E.,	National,	Bessemer	1901	on Norfolk & Western.
85 lb. A. S. C. E.,	Tenn. C. & I.,	Open-Hearth	1904	on N. & W. and Penna. Lines West.
85 lb. A. S. C. E.,	Carnegie,	Nickel	1902-3	on Penna. Lines West.
85 lb. A. S. C. E.,	Illinois,	Rerolled	1904-5	on Penna. Lines West.
85 lb. A. S. C. E.,	Lackawanna,	Bessemer	1900	on Penna. Lines West.
85 lb. A. S. C. E.,	National,	Bessemer	1900	on Penna. Lines West.
85 lb. P. S.,	Cambria,	Bessemer	1908	on Penna. Lines West.
85 lb. P. S.,	Maryland,	Bessemer	1908	on Penna. Lines West.
80 lb. A. S. C. E.,	Ill. and Lack.	Bessemer	1906	on Munising.
80 lb. A. S. C. E.,	Lackawanna,	Bessemer	1907-8	on Marquette & S-E.
80 lb. A. S. C. E.,	Col. F. & I.,	Bessemer	1907	on St. L. Rocky Mountain & Pac.
75 lb. B. & M.,	Lackawanna,	Bessemer	1907	on Maine Central.

In some of these cases the quantity of rail in the track is very small.

It should be borne in mind when considering the above, as well as what follows, that these records are for six months only, and in some cases the failures have not begun, while in others the poor rails have been pretty thoroughly weeded out.

There was but .4 failure per 10,000 tons of rail laid of 80-lb. A.S.C.E. section, Bessemer steel, from the Lorain Steel Company, on the Chicago, Rock Island & Pacific Railway, the chemical constituents being as follows:

Carbon	.43 to .53
Phosphorus	.10
Manganese	.80 to 1.10
Silicon	.20

The 143 failures per 10,000 tons laid were of 80-lb. A.S.C.E. Open-Hearth steel from the Tennessee Coal & Iron Company, on the Chicago, Rock Island & Pacific Railway, the chemical constituents being as follows:

Carbon	.56
Phosphorus	.04
Manganese	.82
Silicon	.006

These failures are, however, from a lot of only 123 tons of rail from which 2 failures are reported. On page XXII much larger lots of this rail of 85-lb. section show many fewer failures.

There were 120 failures per 10,000 tons laid of 100-lb. N. Y. N. H. & H. section Open-Hearth steel from the Bethlehem Steel Company, on the New York, New Haven & Hartford Railroad, the chemical constituents being:

Carbon	.70 to .79
Phosphorus	.02 to .03
Manganese	.70 to .90
Silicon	.10 to .20
Sulphur	.02 to .05

On the same road, in the case of the same weight and section of rail, but of Open-Hearth steel made by the Pennsylvania Steel Company, there were only 10 failures per 10,000 tons laid, the chemical composition being:

Carbon	.74 to .87
Phosphorus	.01
Manganese	.75 to .85
Sulphur	.02 to .05

the carbon in this case being considerably higher.

On the same road, with the same weight and section of rail, Maryland and Lackawanna Bessemer only gave 5 failures per 10,000 tons laid and Carnegie Bessemer only 4 failures per 10,000 tons laid.

There were 112 failures per 10,000 tons laid of 85-lb. A.S.C.E. section of nickel steel from the Carnegie Steel Company on Pennsylvania Lines, Northwest System, the chemical composition being:

Carbon	.44
Phosphorus	.09
Manganese	.80
Silicon	.10
Sulphur	.03
Nickel	3.42

The failures, 41 per 10,000 tons laid, of 90-lb. A.S.C.E. section Chrome Nickel steel from the Bethlehem Steel Company, on the Central Railroad of New Jersey, were quite high, compared with some of the others and were nearly all broken rails, only one having a split web. The chemical composition is not given.

Some of the roads have a larger proportion of broken rails than others, the failures in the latter cases being largely crushed and split heads. Some of the roads which have a large number of breakages are as follows:

Michigan Central, 100-lb. A.S.C.E.
Pennsylvania Railroad, 100-lb. P. R. R.
Lehigh Valley, 90-lb. A.S.C.E. Open-Hearth.
Minneapolis, St. Paul & Sault Ste. Marie, 85-lb. A.S.C.E.
Maine Central, 85-lb. A.S.C.E.
Northern Pacific, 85-lb. A.S.C.E.
Illinois Central, 85-lb. A.S.C.E.
Chicago, Rock Island & Pacific Railway, 80-lb. A.S.C.E.
Grand Trunk, 80-lb. A.S.C.E.
St. Louis & San Francisco, 75-lb. A.S.C.E.
Illinois Central, 75-lb. A.S.C.E.

Some of these roads are in the Northern climate, and the A.S.C.E. sections are known as stiff sections, while the Pennsylvania Railroad is in a more Southern climate, and the section is lower, with a heavy head.

Taking all of the reports together, the failures are divided up into broken, head failures, web failures and base failures, according to the following percentages:

Broken	failures,	25	per cent.
Head	failures,	59	per cent.
Web	failures,	7.5	per cent.
Base	failures,	8.5	per cent.

DIAGRAM I. COMPARISON BETWEEN DIFFERENT WEIGHTS OF RAIL, BESSEMER STEEL.

The information for this diagram is given on sheet XLIII. The most striking characteristic is the large proportion of head failures, compared with any other kind, except in the case of the 75-lb. rail, which has probably been long in service, and had the weak rails weeded out.

The head failures of the 90-lb. rail are the most numerous, the 85-lb. and the 100 being next and about the same in number. The head failures of the 80-lb. rail on tangent seem excessive, but it is probably due to lack of distribution between tangent and curve on the Grand Trunk. Sheet XLIII gives a list of the roads used in making up the statistics, and it is quite likely that they have a large proportion of tangent, such as the Chicago & Alton, Chicago, Rock Island, & Pacific, Evansville & Terre Haute, Michigan Central, Chicago & Eastern Illinois, etc. The head failures on tangent for 100-lb., 90-lb. and 85-lb. are only slightly more than on curve.

The breakages of 90-lb. rail are slightly more numerous than those of the 100, the breakages of the 100 slightly more numerous than those of the 85, and those of the 85 than of the 80 and 75-lb., which are about the same. It must be due to the fact that the lighter sections are older and the weak rails have been weeded out.

The web and base failures are quite insignificant, except in the case of the 90-lb.

The 90-lb. rail is mostly of A.S.C.E. section on the Central Railroad of New Jersey, Baltimore & Ohio, Pittsburg & Lake Erie and Western Allegheny.

The 100-lb. rail is mostly of A.S.C.E. section on the Pennsylvania Lines West, Baltimore & Ohio, Bessemer & Lake Erie, Grand Trunk and Michigan Central.

The 85-lb. rail is quite widely distributed, and largely of the A.S.C.E. section.

DIAGRAM 2. COMPARISON BETWEEN DIFFERENT WEIGHTS OF RAIL, OPEN-HEARTH STEEL AND VARIOUS ALLOYS.

When the next tabulation is made, a diagram for the alloys should be made separate from the diagram for Open-Hearth steel rail, as a number of companies are beginning to make experiments with rail metal of different alloys.

The information for this diagram is tabulated on sheet XLIV. Attention is at once called to the large number of web failures of 100-lb. rail on tangent. Reference to sheet XLIV shows that these failures are reported by three companies, the Grand Trunk, Michigan Central and New York, New Haven & Hartford. Reference to sheet V shows that they are mostly reported by the New York, New Haven & Hartford, for 100-lb. N. Y. N. H. & H. section, Open-Hearth, from the Bethlehem Steel Company, the chemical composition being:

Carbon	.70 to .79
Phosphorus	.02 to .03
Manganese	.70 to .90
Silicon	.10 to .20
Sulphur	.03 to .05

The head failures are largest for the 85 and 90-lb., and nearly as large for the 80-lb., the two former cases being on curve and the latter on tangent. The large number on tangent in the case of the 80-lb. is due, however, to lack of separation of failures as between tangent and curve on the Grand Trunk and Rock Island. The former are reported all tangent, and the latter all curve. The 85-lb. failures are mostly of Nickel steel, A.S.C.E. section, on the Pennsylvania Lines, Northwest System, sheet XXI, the composition being:

Carbon	.44
Phosphorus	.09
Manganese	.80
Silicon	.10
Sulphur	.03
Nickel	3.42

The 90-lb. rail is on the Central Railroad of New Jersey and Baltimore & Ohio, about one-third being Chrome Nickel steel of A.S.C.E. section on the Central Railroad of New Jersey, and a large portion of the remainder of Open-Hearth steel, A. R. A. "B" section, from the Bethlehem Steel Company. The breakages are nearly all reported by the Central Railroad of New Jersey, and the head failures by the Baltimore & Ohio.

The web failures of 100-lb. rail on tangent are very large. (Explanation under Diagram 4.)

DIAGRAM 3. COMPARISON BETWEEN DIFFERENT SECTIONS OF RAIL.

BESSEMER STEEL.

The information for this diagram is tabulated on sheets XLV, XLVI and XLVII.

The most striking characteristic of the diagram is the comparatively large number of head failures of 85-N. 85, both on tangent, 36.1 failures per 10,000 tons, and on curve, 27.7 failures per 10,000 tons laid. The legend on the diagram explains that this is a Chicago, Burlington & Quincy section, and it is possible that the drawing of the section, when received, may offer an explanation. It can hardly be said that the carbon is excessively high, although pretty high, unless it is badly segregated, the chemical constituents being:

Carbon	.48 to .58
Phosphorus	.10
Manganese	.80 to 1.10
Silicon	.20

Section 852, 85-lb., also a Chicago, Burlington & Quincy section, has the same composition, but the failures are not so numerous.

Carbon	.58
Phosphorus	.10
Manganese	.80 to 1.10
Silicon	.20

The next most numerous head failures are in the A.S.C.E. 90-lb. on tangent, 15½ failures per 10,000 tons, and on curve, 12½ failures per 10,000 tons laid. The P. R. R. 100-lb. head failures are 12.8 per 10,000 tons laid, while the head failures on tangent are small, and the head failures of the New York Central 80-lb. are about as large, both on tangent and curve, 11.4 per 10,000 tons laid. The A.S.C.E 80-lb. on tangent, the P. R. R. 85-lb. on tangent, and the A.S.C.E. 85-lb. on tangent and curve, have had the same number of head failures as the New York Central 80-lb. The A.S.C.E. 100-lb. on tangent and curve comes next, and then 852, 85-lb. on curve, while the rest were all less than 5 failures per 10,000 tons laid.

The breakages are most numerous in 85N 85-lb. on tangent, 9.6 per 10,000 tons laid, and next of 852, 85-lb. on tangent, with the A.S.C.E. 90-lb. on tangent and the Dudley 80-lb. on curve, both the same, following closely. Next comes the New York Central 80-lb. and 852 85-lb. on curve and the Boston & Maine 75-lb. on tangent, all the same, and then A.S.C.E. 100 and 85-lb. on tangent. The breakages of the others are less than 4 per 10,000 tons laid.

It will be observed that the breakages of so-called stiff sections are more numerous than those of the lower sections with the heavier head. Sufficient time has not elapsed to enable a comparison to be made of the newer sections, such as P. S. and A. R. A.

The carbon is generally higher in the C. B. & Q. sections than in the A.S.C.E. and P. R. R. sections.

The web and base failures are less than 4 per 10,000 tons laid.

DIAGRAM 4. COMPARISON BETWEEN DIFFERENT SECTIONS OF RAIL, OPEN-HEARTH AND VARIOUS ALLOYS.

The information for this diagram is tabulated on sheet XLVIII.

The most striking characteristic of the diagram is the head failures of the A. R. A. "B" 90-lb. section, numbering 34 on curve per 10,000 tons laid. This is reported by the B. & O. The next most numerous head failures are of A.S.C.E. 85-lb. on curve. The A.S.C.E. 80-lb. has not been properly divided as between tangent and curve. Except the A.S.C.E. 100-lb., the rest of the head failures are below 5 per 10,000 tons laid.

The broken rails are the most numerous in the case of the A.S.C.E. 90-lb., being 17½ per 10,000 tons laid on tangent, and 16.2 on curve, per 10,000 tons laid. Half the breakages on tangent and three-quarters of them on curve are of Chrome Nickel steel, and the rest Open-Hearth, all on the Central Railroad of New Jersey.

The web failures are large only in the case of the N. Y. N. H. & H. 100-lb., on the New York, New Haven & Hartford. The chemical composition of this rail has already been mentioned.

DIAGRAM 5. COMPARISON OF FAILURES FOR DIFFERENT LENGTHS OF SERVICE.

The information for this diagram is tabulated on sheet XLIX.

The failures of P. R. R. rail have occurred mostly when less than one year old.

The failures of A.S.C.E. 90-lb. are pretty large in all years after two years, except between the periods between six and seven years and after nine years.

The failures of N. Y. N. H. & H 100-lb., are all in one year and less.

FAILURES WITH RESPECT TO POSITION IN THE INGOT.

This information, on sheets L to LIX, both inclusive, is still quite incomplete. as will be observed by the large percentage of "unknown." In general, as is already known, the largest number of failures occur in the "A" or top rail, but, nevertheless, some of the reports clearly show that a considerable number of failures occur down as low as the "D" and "E" rails, and even in the "F" rails. It is pretty clear, though, that the elimination of the "A" rails would reduce the number of failures very considerably.

REPORT OF COMPARATIVE WEAR OF SPECIAL RAIL.

The progress report of the B. & O. shows that the Titanium rail with .70 carbon on Kessler's curve is only wearing one-third as fast as the Bessemer steel with .50 carbon, with which it is compared.

The special Bessemer rail furnished by the Pennsylvania Steel Company for the same road is wearing faster than the Cambria and Carnegie Bessemer steel with which it is compared. It is provided with .21 per cent. chromium, very low phosphorus, and low carbon.

The Mayari steel at Gardner, reported by the Pennsylvania Railroad, is wearing somewhat faster than the Carnegie-Bessemer with which it is compared, while at Kittanning Point it is not wearing as fast as the Cambria-Bessemer with which it is compared. At the latter place it has .65 per cent. carbon, compared with .51 per cent. at the former, which might partly account for the difference.

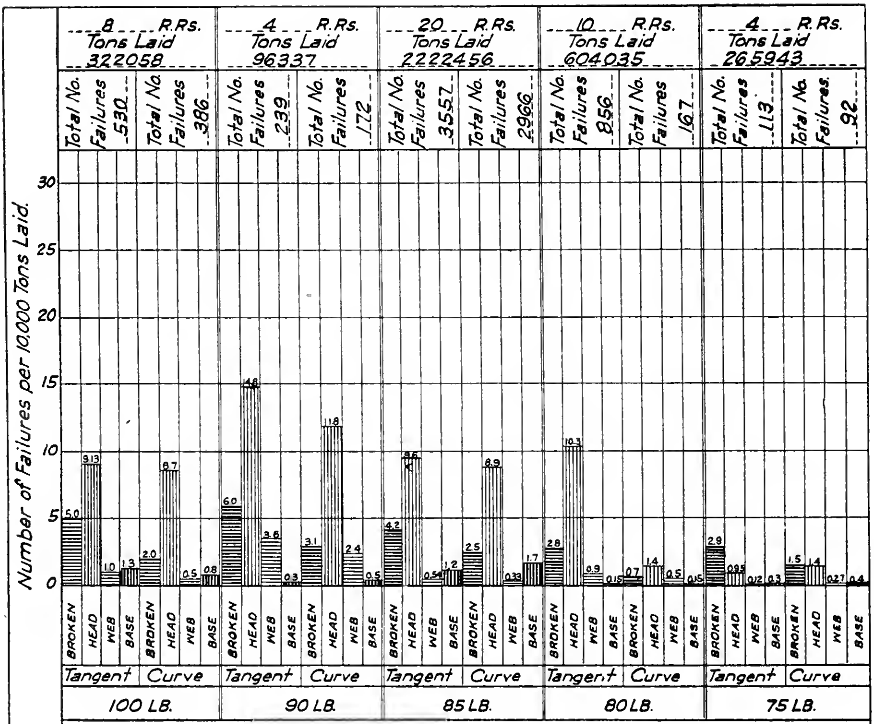
As the Nickel rail has not been compared with any, it is difficult to draw conclusions.

GENERAL REMARKS.

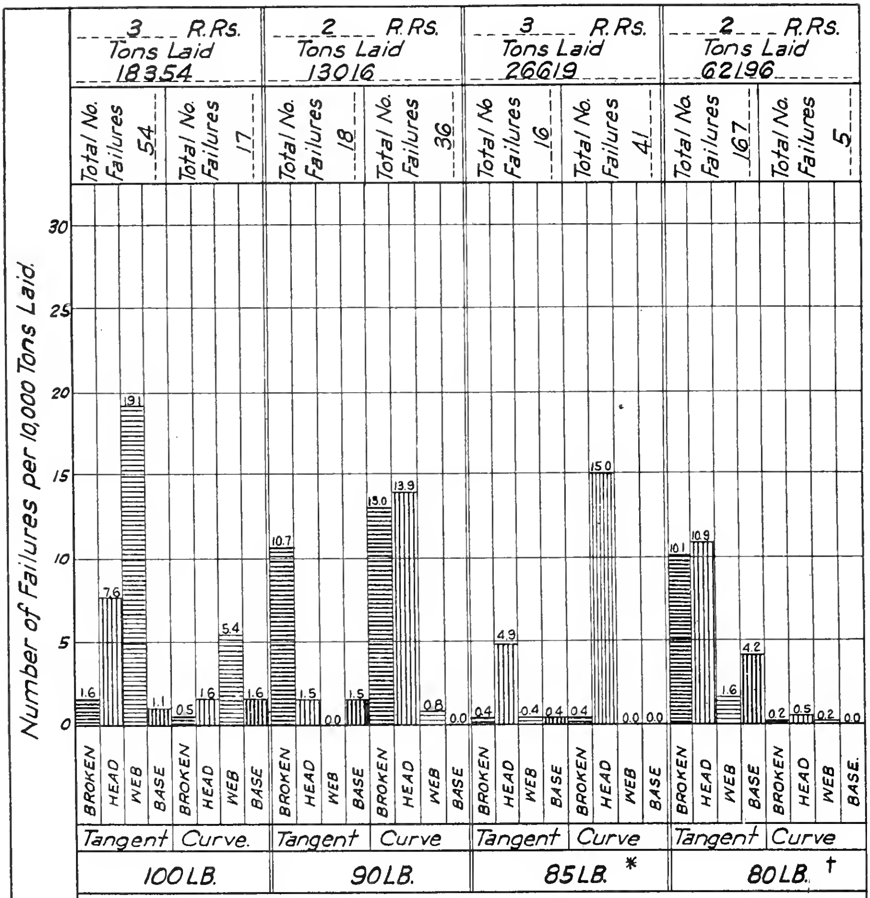
The new sections of rail have not been sufficiently long in service to afford any valuable information.

The statistics do show, however, that the difference in section can be entirely annihilated by difference in chemical composition, by treatment at the mill, or both.

The record of the Chrome Nickel on the Central Railroad of New Jersey, and of the plain Nickel on the Pennsylvania Lines, North West System, is not very good.



CLASSIFIED RAIL FAILURES DIAGRAM I.
Comparison between different WEIGHTS OF RAIL.
BESSEMER STEEL
Period of 6 Months from Oct. 31, 1908 to April 30, 1909.
Report from number of Railroads as shown above.



CLASSIFIED RAIL FAILURES DIAGRAM 2.

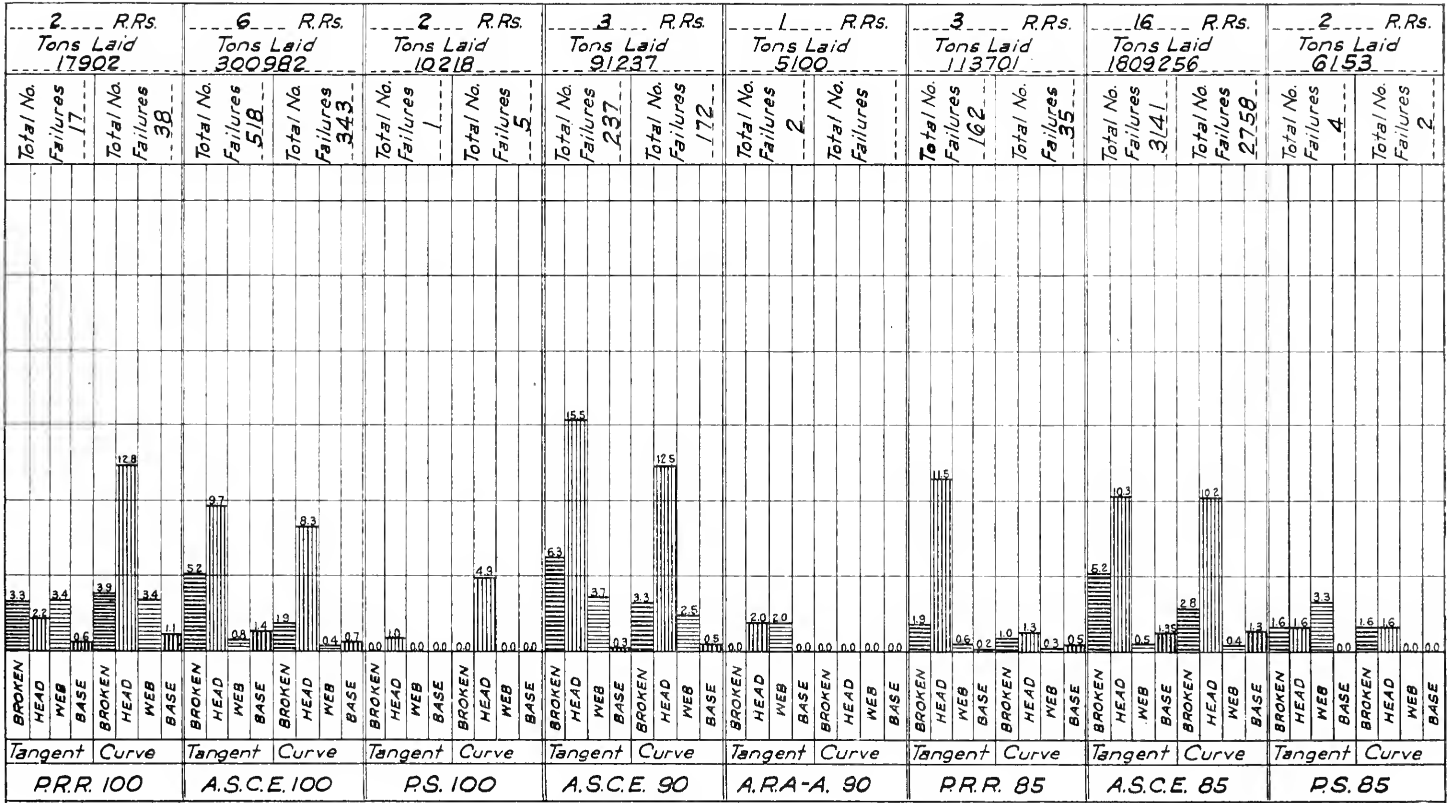
Comparison between different WEIGHTS OF RAIL.

OPEN HEARTH STEEL AND VARIOUS ALLOYS.

Period of 6 Months from Oct. 31, 1908 to April 30, 1909.

Report from number of Railroads as shown above.

*Mostly Nickel Steel. † Not correctly seperated for tangent & curve



LEGEND

P.R.R. = Pennsylvania R.R.
A.S.C.E. = Amer. Society of Civil Eng'rs.
P.S. = Pennsylvania System (New, 1908)
A.R.A-A = Amer. Ry. Association. "Type A."
85 N = Chgo. Burlington & Quincy R.R.
8506 = Chgo. Burlington & Quincy R.R.
852 = " " " "
Dudley = P.H. Dudley
N.Y.C. = New York Central R.R.
B&M. = Boston & Maine.

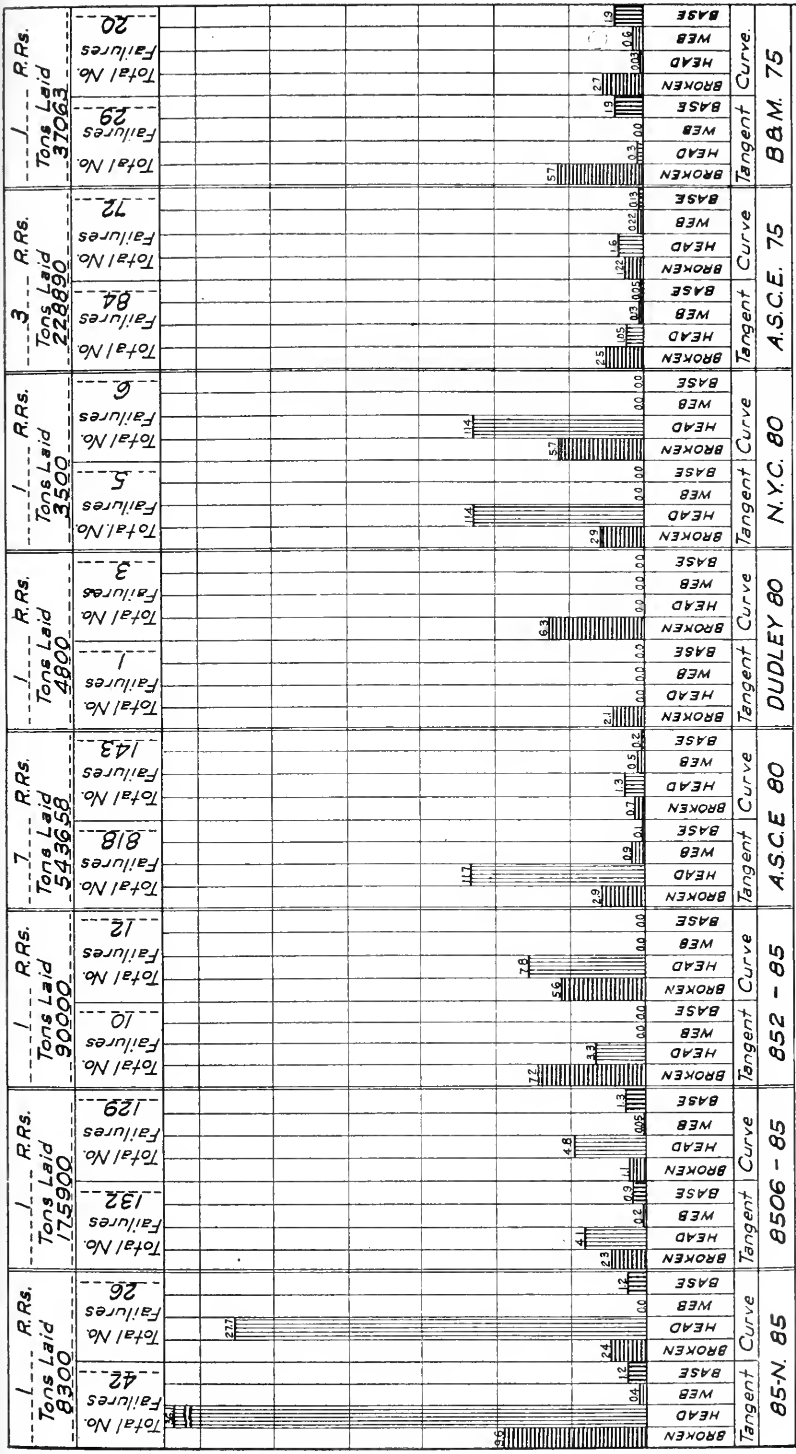


DIAGRAM 3

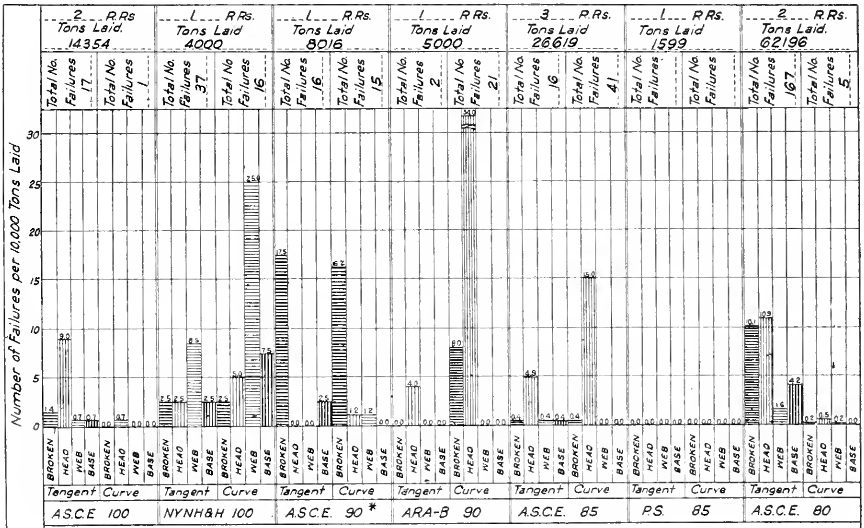
CLASSIFIED RAIL FAILURES.

Comparison between different SECTIONS OF RAIL.

BESSEMER STEEL.

Period of 6 Months from Oct. 31, 1908 to April 30, 1909.

Report from Number of Railroads as shown above.



CLASSIFIED RAIL FAILURES. DIAGRAM 4

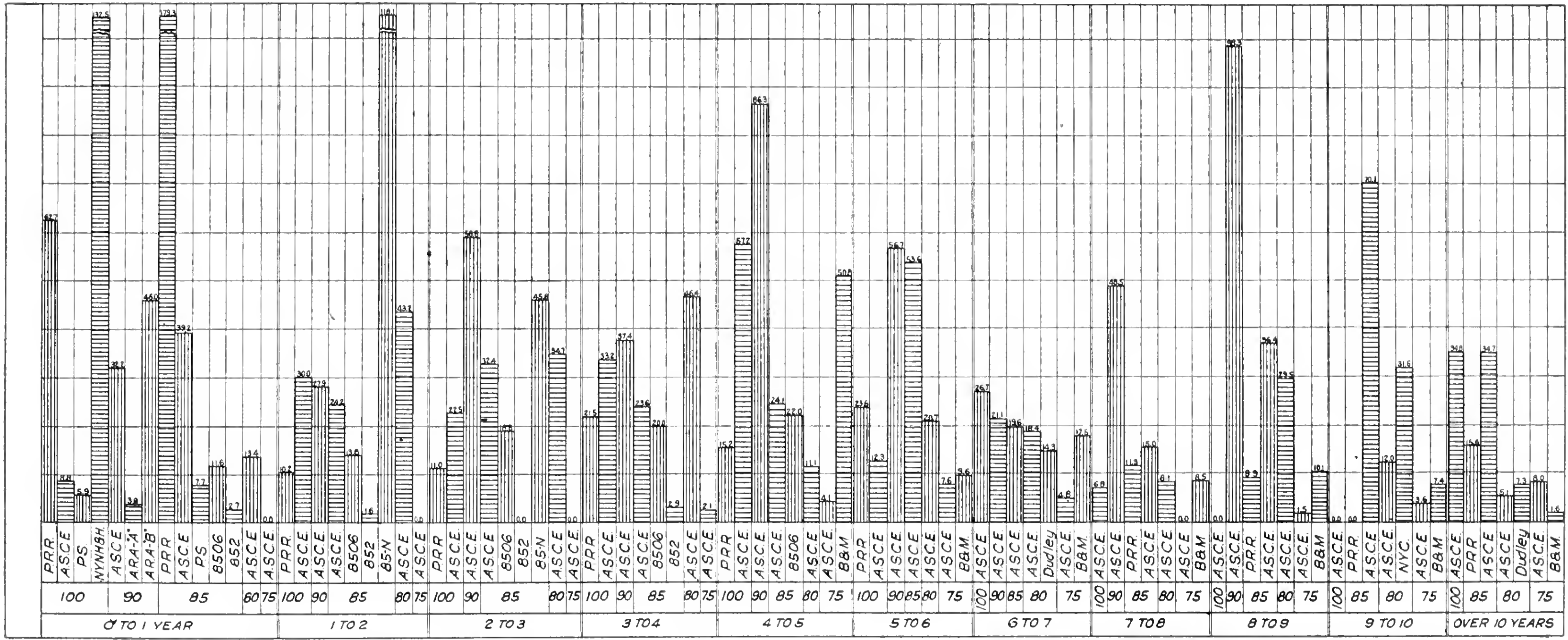
Comparison between different SECTIONS OF RAIL.

OPEN HEARTH STEEL AND VARIOUS ALLOYS

Period of 6 Months from Oct. 31, 1908 to April 30, 1909.

Report from number of Railroads as shown above

* 7 Failures on tangent & 12 on curve are Chrome Nickel and rest Open Hearth.



LEGEND

P.R.R. = Pennsylvania R.R.
A.S.C.E. = Amer. Society of Civil Engr's
P.S. = Pennsylvania System (New, 1908)
A.R.A.-"A" = Amer. Ry. Association "Type A"
85-N = Chgo. Burlington & Quincy R.R.
8506 = Chgo. Burlington & Quincy R.R.
852 = " " " "
Dudley = P.H. Dudley
N.Y.C. = New York Central
B&M. = Boston & Maine

CLASSIFIED RAIL FAILURES

DIAGRAM 5

Comparison of Failures at different LENGTHS OF LIFE

ALL KINDS OF STEEL.

Period of 6 Months from Oct. 31, 1908 to April 30, 1909

Report from Number of Railroads as shown on Diagram 3

As shown below RAILROAD

I

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 1 of 37

Various lb Various Sec Various Steel Rolled by Various Steel Co. Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08 To Apr. 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
~~189~~	120 lb. Special							Wharton	Manganese				No.	Pennsylvania Lines East															
1909													%																
~~189~~								48350	56800			1	No.								1					20	0.4		
													%																
~~189~~													No.																
													%																
	100 lb. Rerolled to 84 lb. Bessemer Steel							Joliet					No.	Pennsylvania Lines East															
													%	75				25											
1907		0.50	0.08	1.00	0.13			65000	61700		4		No.	3				1								115	1.5		
													%																
													No.																
													%																
	100 lb. P.R.R. Sec. Bessemer Steel							Maryland					No.	Cumberland Valley															
1903													%	12	6			12	6	12	35	5	12						
1908	13524							46000	50400		7	10	No.	2	1			2	1	2	6	1	2			594	88		0.06
													%																
													No.																
													%																
	100 lb. P.R.R. Sec. Nickel Steel							Carnegie					No.	Pennsylvania Lines East															
1903							Nickel						%																
1904		0.51	0.08	0.84	0.11	0.05	3.25					5	No.										3			99	1.5		
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
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													No.																
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													No.																
													%																
													No.																
													%																
													No.																
Totals																													

As shown below RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 2 of 3

100 lb A.S.C.E. Sec Bessemer Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct 31,08 To Apr 30,09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								Carnegie					No.	Baltimore & Ohio R.R.															
1901 1906													%																
189	1258	.523	.097	.92	.052	.058					3		No.					3								99	1.50		0.12
													%																
189								Maryland					No.	B & O. R.R															
1901		0.50	.071	0.85	0.10	.056							%	12	6		6	24	8	21	17	1	2		3				
1908	44695	0.55	.10	1.15	0.20	.075		40000	49000		58	42	No	12	6		6	24	8	21	17	1	2		3	3300	50.0		0.11
													%																
								Cambria					No.	B&O.R.R.															
1905		497	.0975			.0562							%	6	4		11	24	30	8	8	5	1		3				
1907	20927	.507	.0984			.0606		23237	25083		48	64	No.	7	5		12	27	34	9	9	5	1		3	3696	56.0		0.26
													%																
								Carnegie					No.	Bessemer & Lake Erie															
1896		45-55	0.10	.80-1.0	From	1896 to	1903						%	13	6	2		9	16	28	21	2½	1½	½	½				
1907	63723	50-60	0.10	80-1.1	"	1904	1907	47100	53700		76	62	No.	18	8	3		13	22	38	29	3	2	1	1	4233	62.9		0.10
													%																
								Illinois					No.	Chicago, Rock Island & Pacific															
		0.50											%					70		30									
1907	825	0.58	.097	0.86	0.104			45575	53550		9		No.					6		3						278	4.2		0.50
													%																
								Lackawanna					No.	Grand Trunk Ry.															
		0.48		0.80									%																
1907	6138	0.58	0.10	1.10	0.20			48720	45976		2		No.											2		60	0.71	0.05	0.01
													%																
								Illinois					No.	Michigan Central															
1905		0.450	0.96	0.90	0.106								%	30	2			18		14	15	5	5	9	2				
1908	39912	0.534	0.106	0.94	0.111			52000	48000		33	11	No.	13	1			8		6	7	2	2	4	1	1445	21.5		0.05
													%																
								Lackawanna.					No.	Michigan Central															
1903		0.49	0.76	0.97	0.87	0.046	0.088						%	27	10			2	2	29	10	4		10	6				
1908	49007	0.62	0.92	1.08	0.139	0.090	0.223	52000	48000		169	63	No.	63	23			4	4	68	23	10		24	13	7567	112.6		0.23
													%																
								Algoma					No.	Michigan Central															
1905		0.548		0.936	0.098								%	41	6			10		21	1	5	3	13					
1907	34959	0.554	0.83	1.030	0.128	0.48		44000	47000		70	8	No.	32	5			8		16	1	4	2	10		2525	37.6		0.11
													%																
													No.																
Totals																													

As shown below RAILROAD III

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet 3 of 37

100 lb A.S.C.E Sec Bessemer Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct 31,08 To Apr. 30,09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189	After 1901							Carnegie					No.	Pennsylvania Lines West-N.W-															
1901		040-055	over 0.07										%	3	10½		1½	20	34	9	19			1½	1½				
1909 ~~189~~	20233	045-060	0.07 under	1.20				51500	61800		22	43	No.	2	7		1	13	22	6	12			1	1	2107½	31.1	0.20	0.15
													%																
189								Cambria					No.	Pennsylvania Lines West-N.W-															
		040-055	over 0.07										%																
1904	1439	045-060	0.07 under	1.20				51500	61800				No.																
													%																
								Carnegie					No.	Pennsylvania Lines West-S.W-															
1902		040-055	over 0.07										%	12	4		3	3	25	21	29		3						
1909	17514	045-060	0.07 under	120				58800	61600		28	50	No.	9	3		2	2	20	17	23		2			2560	38.11	0.16	0.22
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
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													No.																
Totals																													

Pennsylvania Lines West RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 4 of 37

100 lb PS Sec Bessemer Steel. Rolled by Various Steel Co. Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08 To Apr. 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								Carnegie					No.	North-West System															
													%																
1909 ~~189~~	1862	0.50	0.10	1.00	0.12			51500	61600				No.																
													%																
189								Cambria					No.	North-West System															
													%																
1908	493	0.50	0.10	1.00	0.12			51500	61600				No.																
													%																
								Maryland					No.	North-West System															
													%																
1908	490	0.50	0.10	1.00	0.12			51500	61600				No.																
													%																
								Illinois					No.	North-West System															
													%																
1909	245	0.50	0.10	1.00	0.12			51500	61600				No.																
													%																
								Carnegie					No.	South-West System															
													%																
1909	4760	0.50	0.10	1.00	0.12			58800	61600				No.																
													%																
								Cambria					No.	South-West System															
													%																
1908	465	0.50	0.10	1.00	0.12			58800	61600			1	No.								1					33	0.49		0.15
													%																
								Maryland					No.	South-West System															
													%																
1908	444	0.50	0.10	1.00	0.12			58800	61600				No.																
													%																
													No.																
													%																
													No.																
													%																
	100 lb. PS Sec. Bessemer Steel							Cambria					No.	Pennsylvania Lines East															
													%					40	20	40									
1908	1440	0.50	0.08	1.00	0.13			65000	61700		1	4	No.					2	1	2						159	2.4		0.17
													%																
													No.																
Totals																													

As shown below RAILROAD

V

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 5 of 37

100 lb Various Sec Open Hearth Steel Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct 31, 08 To Apr 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189		100 lb A.S.C.E.			O.H.Steel			Dominion					No.	Grand Trunk															
1907		0.56		0.80									%	12		6		35		35		6		6					
~~189~~	11837	0.65	0.065	1.10	0.20	0.069		49532	48720		17		No.	2		1		6		6		1		1		510	6.00	0.007	0.05
													%	Michigan Central															
189		100 lb A.S.C.E. Sec.						Algoma					No.																
													%																
1907	2517	0.61	0.031	0.910	0.595	0.05		44000	47000			1	No.								1					33	0.5		0.02
													%																
	100 lb. N.Y.N.H.& H.Sec.				O.H.Steel			Bethlehem					No.	New York. New Haven & Hartford															
1908		0.70	0.02	0.70	0.10	0.03							%	2			4	2				69	21	2					
1909	2000	0.79	0.03	0.90	0.20	0.05		45000	47700		37	12	No.	1			2	1				34	10	1		1597	24.1		1.20
													%																
	100 lb. N.Y. NH.& H.Sec.				O.H.Steel			Pennsylvania					No.	New York, New Haven & Hartford															
		0.74		0.75		0.02							%		25										75				
1908	2000	0.87	0.01	0.85		0.05		45000	52500			4	No.		1										3	132	1.96		0.10
													%																
		100 lb. P.R.R. Sec.						Carnegie					No.	Pennsylvania Lines East															
													%																
1903		0.85	0.012	0.65	0.041			48350	56800		1		No.									1				33	0.5		
													%																
		100 lb P.R.R. Sec.						Pennsylvania					No.	Pennsylvania Lines East															
													%																
1905		0.85	0.012	0.65	0.041			65000	61700			1	No.								1					33	0.5		
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

Pennsylvania Lines West RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No.6 of 37

100 lb P.S. Sec Open Hearth Class A & B. Steel Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909.

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct 31,08 To Apr 30,09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189		Open Hearth Class-A-						Carnegie					No.	North-West System															
		0.70			0.05								%																
1909 ~~189~~	151	0.83	0.03	0.80	0.20			51500	61800				No.																
													%																
189		Open Hearth Class-B-						Carnegie					No.	North-West System															
		0.62			0.05								%																
1909	152	0.75	0.04	0.80	0.20			51500	61800				No.																
													%																
		Open Hearth Class-A-						Illinois					No.	North-West System															
		0.70			0.05								%																
1909	200	0.83	0.03	0.80	0.20			51500	61800				No.																
													%																
		Open Hearth Class-A-						Carnegie					No.	South-West System															
		0.70			0.05								%																
1909	702	0.83	0.03	0.80	0.20			58800	61600				No.																
													%																
		Open Hearth Class-B-						Carnegie					No.	South-West System															
		062			0.05								%																
1909	343	0.75	0.04	0.80	0.20			58800	61600				No.																
													%																
													No.																
													%																
													No.																
													%																
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													No.																
													%																
													No.																
													%																
													No.																
Totals																													

(Incomplete Records) As to Tons Laid, Section or Steel. As show below RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 7 of 37

100 lb. Various Sec. Unknown & Bessemer Steel Rolled by Various Steel Co Record for Period of 6 Months. ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08 To Apr. 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189	100lb.NYNH&H.Sec.					Steel.		Lackawanna (Scranton)					No.	New York, New Haven & Hartford R.R.															
1893		060		080			1907						%	10	3		12	6	3	14	18	12	3	9	10				
1908 ~~189~~		0.70	0.07	1.05	0.20	Years	1908	45000	52500		40	37	No.	8	2		9	5	2	11	14	9	2	7	8	2302	34.24		
													%																
189	100lb.NY.N.H&H.Sec.					Steel.		Bethlehem					No.	NY. NH. & H. R.R.															
													%					25	50		25								
1893								45000	44000		1	3	No.					1	2		1					120	1.78		
													%																
	100lb.NYNH&H.Sec.					Steel.		Maryland					No.	NY.NH. & H.R.R.															
1907		0.60		0.80									%	25	12	25				25	13								
1908	7882	0.70	0.07	1.05	0.20	0.06		45000	52500		6	2	No	2	1	2				2	1					252	3.74		0.05
													%																
	100lb.NYNH&H.Sec.					Steel.		Lackawanna (Buffalo)					No.	NY.NH&H.R.R.															
		0.50		0.60									%																
1905	3153	0.60	0.10	1.10	0.20			45000	52500		2	2	No.	2							2					120	1.78		0.05
													%																
	100lb.NYNH&H.Sec.					Steel.		Carnegie					No.	NY.NH.&H.R.R.															
		045		080									%																
1904	2000	0.55	0.10	1.10	0.20			45000	52500		2		No.	1						1						58	0.87		0.04
													%																
	100lb.NY.NH&H.Sec.					Steel.		Scranton Steel Co.					No.	NYNH&H.R.R.															
1897		060		0.80									%					75			12½		12½						
1908		0.70	0.07	1.05	0.20	0.06		45000	52500		6	2	No.					6			1		1			240	3.57		
													%																
	100lb.P.R.R.Sec.			Bessemer Steel				Cambria					No	Pennsylvania Lines East															
1889		After 1899											%	18	16	2	3	2	4	10	9	20	12	3	1				
1908		0.50	0.08	1.00	0.13			62900	62900		135	113	No.	44	39	5	8	5	11	23	22	50	30	8	3	7849	116.8		
													%																
	100lb.P.R.R.Sec.			Bessemer Steel				Carnegie					No.	Penn'a. Lines East															
1900													%	14	14	3	3	4	6	18	10	11	11	1	5				
1908		0.50	0.08	1.00	0.13			62900	62900		77	76	No.	21	21	4	5	6	9	28	16	17	17	1	8	4974	74.0		
													%																
	100lb.P.R.R.Sec.Bessemer Steel							Maryland					No.	Penn'a. Lines East.															
1900													%	20	3	1		4	3	5	4	37	15	5	3				
1909		0.50	0.08	1.00	0.13			62900	62900		109	42	No.	30	5	1		6	5	8	6	56	22	8	4	4839	77.5		
													%																
	100lb.P.R.R.Sec. Bessemer Steel							Pennsylvania					No.	Penn'a. Lines East.															
1900 ~~Totals~~													%	30	9			2	7	9	2	33	6	2					
1906		0.50	0.08	1.00	0.13			62900	62900		43	14	No.	17	5			1	4	5	1	19	4	1		2074	30.9		

Incomplete Record, as to Tons Laid *New York, Ontario & Western* RAILROAD VIII

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 8 of 37

95 lb *B&A.* Sec. *Bessemer* Steel. Rolled by *Various* Steel Co. Record for Period of *6 Months* ending *April 30* 19*09*

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From *Oct. 31, 08.* To *Apr. 30, 09.*			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year *1908*	Year *1909*
													%																
189								*Lackawanna*					No.																
													%	*14*	*20*			*20*	*13*	*20*		*13*							
189								*50000*	*45000*		*10*	*5*	No.	*2*	*3*			*3*	*2*	*3*		*2*							
													%																
189								*Maryland*					No.																
													%	*27*	*18*					*9*	*9*	*10*	*27*						
								50000	*45000*		*5*	*6*	No.	*3*	*2*					*1*	*1*	*1*	*3*						
													%																
													No.																
													%																
													No.																
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													No.																
													%																
													No.																
													%																
													No.																
Totals																													

IX

As shown below RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 9 of 37

90 lb Various Sec Bessemer Steel Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909.

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct 31,08 To Apr. 30,09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189		A.S.C.E. Sec.						Maryland					No.	Central R.R. of New Jersey.															
		0.45	0.08	0.90	0.10								%	42	6			13	14	12	4	8		1					
1903 1909 ~~189~~	27105	0.65	1.00	1.15	0.20	0.06		54000	58000		65	20	No.	36	5			11	12	10	3	7		1		2805	37.56		0.14
													%																
189		A.S.C.E. Sec.						Lackawanna					No.	Central R.R. of New Jersey.															
1904		0.54	0.08	0.90	0.10		Copper						%	8	15			30	20	10	6	3	2	2	4				
1907	18835	0.64	0.10	1.15	0.20	0.08	0.06	54000	58000		66	60	No.	10	19			38	26	12	8	4	2	2	5	4158	55.69		0.30
													%																
		A.S.C.E. Sec.						Cambria					No.	Central R.R. of New Jersey.															
		0.54		0.90									%	16	5				5	21	53								
1907	2204	0.58	0.10	1.00	0.20			54000	58000		7	12	No.	3	1				1	4	.10					627	8.40		0.38
													%																
		A.S.C.E. Sec						Carnegie					No.	Central R.R. of New Jersey.															
		0.54		1.05									%																
1906	3210	0.64	0.10	1.30	0.20			54000	58000		1		No.							1						30	0.40		0.01
													%																
		A.R.A. "A" Sec.						Carnegie					No.	Baltimore & Ohio R.R.															
		0.45		0.85	0.10								%																
1908	1500	0.55	0.10	1.15	0.20	0.075		23237	25083		1		No.							1						33	0.5		0.03
													%																
		A.R.A. "A" Sec.						Illinois					No.	Balto. & Ohio R.R.															
		0.45		0.80	0.05								%																
1909	3600	0.55	0.10	1.20	0.20			23237	25083		1		No.									1				33	0.5		0.01
													%																
		90 lb. A.R.A. Sec. (Not stated whether A or B Type)						Carnegie					No.	Balto. & Ohio Southwestern.															
													%																
1908	1000							46475	54750		None		No.																
						For additional Bessemer, See Sheet No. 10							%																
													No.																
													%																
	90 lb	A.S.C.E. Sec.		Chrome Nickel Steel.				Bethlehem					No.	Central R.R. of New Jersey.															
													%	37	58								5						
1909	1934							54000	58000		7	12	No.	7	11								1			627	7.95		0.41
													%																
													No.																
													%																
													No.																
Totals																													

Pittsburgh & Lake Erie (And P.McK.& Y. Division) RAILROAD

X

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 10 of 37

90 lb A.S.C.E. Sec. Bessemer Steel. Rolled by Carnegie Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08. To Apr. 30, 09.			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
1900 1908 ~~189~~	32040	45 .55	Not over .10	.80 1.10	Not over .20			42500	57000		94	62	%	1.3	1.3	0.6	0.6		2.5	41	22	17.3	13.4			4976	66.65		0.28
													No.	3	3	1	1		4	63	34	27	20						
1900 1908 ~~189~~	3719	45 .55	Not over .10	.80 1.10	Not over .20			42500	52000		19	18	%	8	5	3				36	38	5	5			1155	15.45		0.42
													No.	3	2	1				13	14	2	2						
Total 189	35759										113	80	%	3.2	2.6	1	0.5		2.1	39	25	15.1	11.5			6131	82.10		0.23
													No.	6	5	2	1		4	76	48	29	22						
													%																
					Maryland								No.	Philadelphia & Reading															
1902 1909	125510							54833	55150		34	306	%	2½	3	1	48	2	25	2½	6	2	3		5	11201	149.08	—	0.12
													No.	9	10	4	165	7	85	9	20	5	10		16				
													%																
					Cambria								No.																
1905	3450	0.54 0.64	.10	0.90 1.15	.20			54833	55150		2	2	%	25	25					25	25					132	1.76	.051	0.26
													No.	1	1					1	1								
													%																
					Carnegie								No.																
1905	6852	0.54 0.64	.10	0.90 1.15	.20			54833	55150		4	6	%	20		10		10	50		10					327	4.38	.004	096
													No.	2		1		1	5		1								
													%																
					Lackawanna								No.																
1905 1906	5669	0.54 0.64	.10	0.90 1.15	.20			54833	55150		4	5	%	22			22		33					23		297	3.97		0.06
													No.	2			2		3					2					
													%																
					Pennsylvania								No.																
1901 1902	17167	0.53 0.63	.10	0.80 1.20	.20			54833	55150		2	1	%	67	33											90	1.20		0.01
													No.	2	1														
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

As shown below RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 11 of 37

90 lb Various Sec Open Hearth Steel Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct 31, 08. To Apr. 30, 09.			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189		A.R.A. Sec.		" B "				Bethlehem					No.		Baltimore & Ohio R.R.														
1908		045	0.04	0.75	0 05								%		18			4	35	4	39								
1909 ~~189~~	5000	0.80	0.10	1.15	0.20	0.075		23237	25083		2	21	No.		4			1	8	1	9					759	10.4		0.21
													%																
189		A.S.C.E. Sec.						Bethlehem					No.		Central R.R. of New Jersey														
1908		0.57	031	0.75									%	58	17						8			17					
1909	6082	0.75	.060	1.00	0.20	044		54000	58000		9	3	No.	7	2						1			2		396	5.30	None	0.09
													%																
		A.S.C.E. Sec.						Bethlehem					No.		Lehigh Valley R.R.														
1907													%	14	45			2	12	6	17	4							
1908								23.88	25.57		13	38	No.	7	23			1	6	3	9	2				1680	22.5		
													%																
													No.																
													%																
													No.																
													%																
													No.																
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													No.																
													%																
													No.																
Totals																													

(Incomplete Records) As to Tons Laid & Steel As shown below RAILROAD XII

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 12 of 37

90 lb. Various Sec. Bessemer & Unknown Steel Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct 31.08 To Apr. 30,09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189		A.S.C.E. Sec.		Bessemer		Steel.		Cambria					No.	Lehigh Valley R.R.															
1899 1907 ~~188~~													%	12	17		2	7	31	5	5	5	7		9				
								23.88	25.57		12	30	No.	5	7		1	3	13	2	2	2	3		4	1375	18.4		
													%																
189		A.S.C.E. Sec.		Bessemer		Steel.		Maryland					No.	L.V.R.R.															
1902													%	21	11			11	36	11	5	5							
1907								23.88	25.57		9	10	No.	4	2			2	7	2	1	1				558	7.5		
													%																
		A.S.C.E. Sec.		Bessemer		Steel.		Lackawanna					No.	L.V.R.R.															
1900													%	8	10	½	3	24	9	4	3	1½	2	3	32				
1908								23.88	25.57		90	127	No.	18	22	1	5	52	20	9	7	3	4	7	69	6940	92.9		
													%																
		A.S.C.E. Sec.		Bessemer		Steel.		Pennsylvania					No.	L.V.R.R.															
													%					43	29			14	14						
1902								23.88	25.57		4	3	No.					3	2			1	1			210	2.8		
													%																
		A.S.C.E. Sec.		Bessemer		Steel.		Carnegie					No.	L.V.R.R.															
1900													%	15	10	3	2	10	9	17	20	5	5	2	2				
1908								23.88	25.57		76	70	No.	22	14	4	3	15	13	24	29	8	8	3	3	4733	63.4		
													%																
		90 lb. G.N.Ry. Sec.				Steel.		Lackawanna					No.	Northern Pacific															
													%	87	13														
1908	2837							51170	48770		7	1	No.	7	1											258	3.5		0.12
													%																
		A.S.C.E. Sec.		Bessemer		Steel.		Carnegie					No.	Western Allegheny															
													%	80							20								
1902	4124										4	1	No.	4							1					165	2.2		0.05
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

As shown below RAILROAD

XIII

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No.13 of 37

85 lb P.R.R. Sec Bessemer Steel Rolled by Various Steel Co. Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct 31,08 To Apr. 30,09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								Cambria					No.	Baltimore, Chesapeake & Atlantic Ry.															
1906 1909 ~~189~~													%																
	672	0.53	0.97	0.92	0.62	0.77		48 Tons	48 Tons		None		No.																
													%																
189								Maryland					No.	Cumberland Valley															
1900													%																
1901	2016							46000	50400		2		No.	1				1								66	0.80		0.04
													%																
								Carnegie					No.	Penn'a. Lines West. N.W. System.															
1892													%	13	2			25		50	5	3	1	1					
1898	55370							51500	61800		89	8	No.	13	2			24		48	5	3	1	1		3576½	44.9	0.07	0.88
													%																
								Illinois					No.	Penn'a. Lines West. N.W. System.															
1892													%	29	14			43		14									
1898	21060							51500	61800		6	1	No.	2	1			3		1						207½	2.6	0.02	0.01
													%																
								Cambria					No.	Penn'a. Lines West. N.W. System.															
1892													%																
1897	4825							51500	61800		1		No.							1						30	0.4		0.01
													%																
								Carnegie					No.	Penn'a. Lines West. S.W. System.															
1895													%	5	2	6		11	6	62	2	5		1					
1898	20726							58800	61600		58	6	No.	3	1	4		7	4	40	1	3		1		1929½	24.41	0.07	0.12
													%																
								Illinois					No.	Penn'a. Lines West. S.W. System															
1895													%	67						33									
1898	8264							58800	61600		3		No.	2						1						90	1.14		0.01
													%																
								Cambria					No.	Penn'a. Lines West. S.W. System.															
													%																
1897	108							58800	61600				No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

As shown below RAILROAD

XIV

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 14 of 37

85 lb A.S.C.E. Sec. Bessemer Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08 To Apr. 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%		Atlantic Coast Line.														
189								Maryland					No.																
1906 1908		0.48		0.80									%		11					34	22	22			11				
~~189~~	22800	0.58	0.10	1.10	0.20			20000	20000		5	4	No.		1					3	2	2			1	297	3.7		0.02
													%																
189								Pennsylvania					No.		Atlantic Coast Line.														
1906		0.48		0.80									%		33					67									
1907	7300	0.58	0.10	1.10	0.20			20000	20000		2	1	No.		1					2						132	1.64		0.02
													%																
								Lackawanna					No.		Atlantic Coast Line.														
		0.48		0.80									%																
1907	10000	0.58	0.10	1.10	0.20							2	No.		1						1					66	0.82		0.01
													%																
								Carnegie					No.		Baltimore & Ohio R.R.														
1889		0.472	0.822			0.444							%	4	4	2	3	22	28	14	10	7	4	1	1				
1908	192207	0.486	0.942			0.533		29542	27375		512	516	No.	39	36	19	31	231	291	144	102	70	43	9	13	34254	436.6		0.22
													%																
								Maryland					No.		Balt'o. & Ohio. R.R.														
1899		0.501	.068	Years		.54							%	11	9	1	3	15	25	11	15	3	5	½	1½				
1908	84452	0.527	.082	1905 to 1908		.076		23237	25083		90	121	No.	23	20	2	7	32	48	25	33	7	10	1	3	6963	89.7		0.11
													%																
								Cambria					No.		Balt'o. & Ohio R.R.														
1900		.497	.0975	Years		.0562							%	5	4	¼	11	23	29	11	8	3	3	1¼	1½				
1907	71370	.507	.0984	1905 to 1907		.0609					162	214	No.	18	15	1	42	86	110	42	29	10	12	5	6	12408	159.8		0.22
													%																
								Illinois					No.		Balto. & Ohio. R.R.														
													%					17		66	17								
1901	12550							23237	25083		5	1	No.					1		4	1					198	2.6		0.02
													%																
								National					No.		Balt'o. & Ohio. R.R.														
1900													%	44			6	28	6	10				6					
1901	13125							23237	25083		16	2	No.	8			1	5	1	2				1		584	7.6		0.06
													%																
								Illinois					No.		Baltimore & Ohio. Southwestern.														
													%																
1901	575							38780	45750		None		No.																
													%																
													No.																
Totals																													

XV

As shown below RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 15 of 37

85 lb A.S.C.E. Sec Bessemer Steel. Rolled by Various Steel Co. Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08. To Apr. 30, 09.			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								Cambria					No.	Baltimore & Ohio Southwestern.															
1900 1906													%	9	16		3	28	28	9	7								
~~189~~	4457							46475	54750		15	17	No.	3	5		1	9	9	3	2					1056	13.4		0.30
													%																
189								Maryland					No.	Balto. & Ohio Southwestern.															
1902													%	30	10			10	20	30									
1904	1189							38780	54750		7	3	No.	3	1			1	2	3						330	4.2		0.35
													%																
								Carnegie					No.	Balto. & Ohio Southwestern.															
1898													%	2	2	½	2	39	24	18	11	½	1						
1907	97895							46475	54750		622	407	No.	19	23	5	16	407	249	184	108	7	10		1	33957	429.7		0.44
													%																
								Illinois					No.	Chicago, Milwaukee & St. Paul.															
1899													%	21	9			3	51	4	10			1	1				
1908	181700	0.53	0.10	0.95	0.20			50700	46000		243	615	No.	176	79			24	436	35	91			8	9	28020	354.9	0.03	0.20
													%																
								Carnegie					No.	Chicago, Rock Island & Pacific.															
		0.44	.090	0.85	.060								%																
1905	1402	0.52	.095	0.95	.075			45575	53550		1		No.	1												33	0.4		0.03
													%																
								Illinois					No.	C. R.I. & P. Ry.															
1905		0.47	.088	0.82	0.08								%	39	10	2½	2½	2½	17	17	7	2½							
1909	113628	0.58	.100	1.03	0.172			45575	53550		26	15	No.	16	4	1	1	1	7	7	3	1				1317	16.7		0.015
													%																
								Lorain					No.	C. R.I. & P. Ry.															
		0.48		0.80									%	60					20		20								
1906	662	0.58	0.10	1.10	0.20			45575	53550		3	2	No.	3					1		1					16.5	2.1		0.31
													%																
								Maryland					No.	C. R.I. & P. Ry.															
		0.48		0.80									%																
1906	1155	0.58	0.10	1.10	0.20			45575	53550		None		No.																
													%																
								Republic					No.	Cleveland, Akron & Columbus															
													%																
1905	528							46100	48100			5	No.						5							16.5	2.1	0.10	0.40
													%																
													No.																
Totals																													

As shown below RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 16 of 37

85 lb A.S.C.E. Sec Bessemer Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08 To Apr. 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								Carnegie					No.	Cleveland, Akron & Columbus															
1901													%	1½				52	37	1½	5	1½	1½						
1907 ~~189~~								46100	61600		35	27	No.	1				32	23	1	3	1	1			2046	25.9	0.01	0.25
													%																
189								Maryland					No.	Evansville & Terre Haute															
1904		0.48		0.80									%			20		40		20		20							
1907	4705	0.58	0.10	0.10	0.20	0.50		39700	51500		5		No.			1		2		1		1				162	2.0		0.05
													%																
								Cambria					No.	Grand Rapids & Indiana (C.R.& Ft.W.R.R.)															
1903		0.40											%																
1904	2184	0.55	0.10	1.20				49000	44000		2		No.					1				1				63	0.8	0.02	0.04
													%																
								Cambria					No.	Grand Rapids & Indiana															
1903		0.40											%					14	3	6	3		1	38	35				
1907	12945	0.55	0.10	1.20				49000	44000		43	31	No.					10	2	5	2		1	28	26	2442	30.9	0.04	0.24
													%																
								Illinois					No.	Minneapolis, St. Paul & Sault Ste. Marie (Wisconsin Central)															
1900		0.48		0.80									%	26	39			5	7	5	8	5		4	1				
1908	46289	0.58	0.10	1.10	0.20			41000	44050		54	64	No.	31	46			6	8	6	9	6		5	1	3752	47.4		0.10
													%																
								Lackawanna & Maryland					No.	Maine Central															
1905		0.43		0.80									%	57	30							4	1	8					
1908	31689	0.53	0.10	1.00	0.20			47000	48000		59	27	No.	49	26							3	1	7		2832	35.7		0.11
													%																
								Maryland					No.	Norfolk & Western															
1901		0.50	0.09		0.09	0.04							%	4	9		9	4	4	4	44	4	10	4	4				
1908	94500	0.58	0.10	1.10	0.12	0.06		46000	45000		5	18	No.	1	2		2	1	1	1	10	1	2	1	1	759	9.6		0.01
													%																
								Cambria					No.	N.& W. R.R.															
1903		0.50	0.09	1.00	0.10	0.04							%		8	4	4	28	20	8	16	4	4		4				
1908	28000	0.58	0.10	1.10	0.12	0.05		46000	45000		11	14	No.		2	1	1	7	5	2	4	1	1		1	825	10.5		0.04
													%																
								Carnegie					No.	N & W. R.R.															
1901		0.50	0.09		0.10								%	8	15	3	3	13	21	17	10	4	5		1				
1908	86500	0.58	0.10	1.10	0.11	0.04		46000	45000		34	42	No.	6	11	2	2	10	16	13	8	3	4		1	2493	31.4		0.04
													%																
													No.																
Totals																													

As shown below RAILROAD

XVII

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 17 of 37

85 lb A.S.C.E. Sec Bessemer Steel Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08 To Apr. 30, 09.			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								National					No.	Norfolk & Western															
1901													%																
~~189~~	4000	0.52	0.09	0.80	0.15	0.04		44000	45000		0	0	No.																0
													%																
189								Illinois					No.	Northern Pacific															
1903		0.48		0.80									%	25	15	8/10	2	2	5	3	4 4/10	5/10	1 3/10	17	24				
1908	152849	0.58	0.10	1.10	0.20			54730	52300		463	497	No.	237	147	8	20	21	50	33	45	5	13	159	222	30828	389.93		0.26
													%																
								Lackawanna					No.	N. P. Ry.															
1906		0.48		0.80									%	48	10	1		½	5	5	2	1		6½	21				
1908	35603	0.58	0.10	1.10	0.20			54730	52300		137	85	No.	107	23	2		1	10	10	4	2		15	48	7136	90.70		0.25
													%																
								Carnegie					No.	N. P. Ry.															
1906		0.48		0.80									%	58	24	2		2		4	6				4				
1907	5193	0.58	0.10	1.10	0.20			51750	52300		32	17	No.	28	12	1		1		2	3				2	1595	20.17		0.39
													%																
								Lorain					No.	N. P. Ry.															
		0.48		0.80									%	33	11						11			33	12				
1906	4509	0.58	0.10	1.10	0.20			51750	52300		6	3	No.	3	1						1			3	1	292	3.70		0.08
													%																
		After	1901					Carnegie					No.	Penn'a. Lines West. N.W. System.															
1899		0.40-0.55	over 0.7										%	14	8	2½	2/10	25	9	28	8	3	1	1	4/10				
1909	167722	0.45-0.60	0.7 under	1.20				51500	61800		441	162	No.	83	46	15	1	148	59	171	48	16	6	8	2	20545	258.9	0.07	0.15
													%																
		After	1901					Illinois					No.	Penn'a. Lines West. N.W. System.															
1899		0.40-0.55	over 0.07										%	50	30					10	10								
1905	11208	0.45-0.60	0.07 under	1.20				51500	61800		6	4	No.	5	3					1	1					301	3.6	0.01	0.03
													%																
		After	1901					Cambria					No.	Penn'a. Lines West. N.W. System.															
1900		0.40-0.55	over 0.07										%	25	25			12½	25	12½									
1906	12149	0.45-0.60	0.07 under	1.20				51500	61800		4	4	No.	2	2			1	2	1						258	3.2	0.02	0.03
													%																
		After	1901					National					No.	Penn'a. Lines West. N.W. System															
1901		0.40-0.55	over 0.07										%		27	9		18	27		9	9							
1904	12014	0.45-0.60	0.07 under	1.20				51500	61800		4	7	No.		3	1		2	3		1	1				327½	41	0.01	0.03
													%																
													No.																
Totals																													

As shown below RAILROAD

XVIII

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 18 of 37

85 lb A.S.C.E. Sec Bessemer Steel. Rolled by Various Steel Co. Record for Period of 6 Months ending April 30 1909.

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08 To Apr. 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								Republic					No.	Penn'a. Lines West. N.W. System.															
1905 1906		0.40-0.55	over 0.07										%		22			33	22	22									
~~189~~	1758	0.45-0.60	0.07 under	1.20				51500	61800		5	4	No.		2			3	2	2						297	3.7	0.11	0.21
													%																
189								Lorain					No.	Penn'a. Lines West. N.W. System.															
1900		0.40-0.55	over 0.07										%	41	18			14	14	4	9								
1903	8323	0.45-0.60	0.07 under	1.20				51500	61800		13	9	No.	9	4			3	3	1	2					660	8.3		0.09
													%																
								Lackawanna					No.	Penn'a. Lines West. N.W. System.															
													%																
1900	100							51500	61800				No.																
													%																
			After 1901					Carnegie					No.	Penn'a Lines West. South-West System.															
1899		0.40-0.65	over 0.07										%	7	3	1 3/10		24	7	45	8	4	7/10						
1909	200557	0.45-0.60	0.07 under	1.20				58800	61600		357	82	No.	32	15	5		103	30	200	34	17	3			14851	187.84	0.08	0.09
													%																
			After 1901					Cambria					No.	Penn'a. Lines West. S.W. System.															
1900		0.40-0.55	over 0.07										%					45		45	10								
1906	4922	0.45-0.60	0.07 under	1.20				58800	61600		10	1	No.					5		5	1					363	4.60	0.02	0.09
													%																
								National					No.	Penn'a. Lines West. S.W. System.															
													%																
1900	1305							58800	61600				No.																
													%																
			After 1901					Illinois					No.	Penn'a. Lines West S.W. System.															
1899		0.40-0.55	over 0.07										%	17		17	6	11		44				5					
1906	15322	0.45-0.60	0.07 under	1.20				58800	61600		17	1	No.	3		3	1	2		8				1		567½	7.22	0.06	0.05
													%																
								Carnegie E.T.					No.	St. Lous & San Francisco															
		0.48		0.80									%		8			38	38	8	8								
1907	6340	0.58	0.10	1.10	0.20	0.05		50000	50000		6	7	No.		1			5	5	1	1					429	5.4		0.09
													%																
								Carnegie Ohio Works					No.	St. L & S.F.R.R.															
		0.48		0.80									%		8			15	31	23	23								
1907	3700	0.58	0.10	1.10	0.20	0.05		50000	50000		5	8	No.		1			2	4	3	3					429	5.4		0.15
													%																
													No.																
Totals																													

As shown below RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 19 of 37

85 lb A.S.C.E. Sec Bessemer Steel Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct 31, 08 To Apr. 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								Illinois					No.	St Louis & San Francisco															
1898 1907		0.48		080									%	14				14	29	43									
~~189~~	3930	0.58	0.10	1.10	0.20	005		50000	50000		5	2	No.	1				1	2	3						229	2.9		0.07
													%																
189								Carnegie					No.	Vandalia. St Louis Div.															
1899		040	0.07	1.00									%	10	1		10	30	9	31	4	4	1						
1907	10152	0.60	0.10	1.20				57500	55500		55	19	No.	7	1		7	22	7	23	3	3	1			2406	30.4		0.29
													%																
								Cambria					No.	Vandalia St Louis Div.															
1901		040	0.07	1.00									%						27	67	6								
1907	7129	0.60	0.10	1.20				57500	55500		10	5	No.						4	10	1					495	6.2		0.09
													%																
								Illinois					No.	Vandalia. St Louis Div.															
1900		040	0.07	1.00									%	22									11		67				
1905	3398	0.60	0.10	1.20				57500	55500		2	7	No.	2									1		6	297	3.8		0.11
													%																
								Illinois					No.	Illinois Central R.R.															
1898		043	Not over	80 to	Not over								%	59	8			7	4	11	8	1	1		1				
1908	209004	0.53	0.10	1.10	0.20			48500	46000		100	27	No.	76	10			9	5	14	10	1	1		1	3913	49.47	0.023	0.026
													%																
								Carnegie					No.	Illinois Central															
1901		043	Not over	80	Not over								%					62½	37½										
1905	6970	0.53	0.10	1.10	0.20						5	3	No.					5	3							272	3.43	0.049	
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

Pennsylvania Lines West RAILROAD

XX

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 20 of 37

85 lb P.S. Sec. Bessemer Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08 To Apr. 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								Carnegie					No.	North-West System															
													%																
1909 189	1295	0.50	0.10	1.00	0.12			51500	61800				No.																
													%																
189								Illinois					No.	N.W. System															
													%																
1909	139	0.50	0.10	1.00	0.12			51500	61800				No.																
													%																
								Cambria					No.	N.W. System															
													%																
1908	488	0.50	0.10	1.00	0.12			51500	61800				No.																
													%																
								Maryland					No.	N.W. System															
													%																
1909	455	0.50	0.10	1.00	0.12			51500	61800				No.																
													%																
								Carnegie					No.	S.W. System															
													%																
1909	577	0.50	0.10	1.00	0.12			58800	61600				No.																
													%																
								Cambria					No.	S.W. System															
1908													%																
1909	469	0.50	0.10	1.00	0.12			58800	61600				No.																
													%																
								Illinois					No.	S.W. System															
													%																
1909	2004	0.50	0.10	1.00	0.12			58800	61600				No.																
													%																
								Maryland					No.	S.W. System															
1908													%																
1909	463	0.50	0.10	1.00	0.12			58800	61600				No.																
													%																
													No.																
													%																
	85 lb. P.S. Sec. Bessemer Steel							Cambria					No.	Pennsylvania Lines East															
1908													%	17	17					17	16	33							
1909	263	0.50	0.08	1.00	0.13			58300	61500		4	2	No.	1	1					1	1	2				198	25		0.95
Totals																													

Pennsylvania Lines West RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 21 of 37

85 lb. A.S.C.E. Sec. Nickel Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08 To Apr. 30, 09		Kind of Failure													Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S	Nickel	Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								Carnegie					No.	North-West System															
													%	2				4	33	17	44								
1903 1907 ~~189~~	1639	044	0.09	0.80	0.10	0.03	342	51500	61800		11	36	No.	1				2	16	8	20					1458	18.4	0.96	1.12
													%																
189								Carnegie					No.	South-West System															
1902			Actual Analysis										%																
1903	3008	044	0.09	0.80	0.10	0.03	342	58800	61600				No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
		85 lb. A.S.C.E. Sec. Illinois Steel Co. McKenna Rerolled to 81± lbs.											No.	Penna. Lines West S.W. System															
1904													%																
1905	460							58800	61600				No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

XXII

As shown below RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 22 of 37

85 lb Various Sec. Open Hearth Steel. Rolled by Various Steel Co. Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08. To Apr. 30, 09.			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189		A.S.C.E. Sec. Open Hearth Steel.						Tennessee Coal & Iron					No.	Norfolk & Western															
													%																
1904 ~~189~~	500	0.58	0.05	0.94	0.09	0.04		44000	45000		0	0	No.																
													%																
189		P.S. Sec. Open Hearth Steel. Class "A"						Carnegie.					No.	Penna. Lines West. N.W. System.															
													%																
1909	405	0.70 0.83	0.03	0.80	0.05 0.20			51500	61800				No.																
													%																
		P.S. Sec. Open Hearth Steel. Class "B"						Carnegie					No.	Penna. Lines West. N.W. System.															
													%																
1909	602	0.62 0.75	0.04	0.80	0.05 0.20			51500	61800				No.																
													%																
		P.S. Sec. Open Hearth Steel Class "A."						Illinois					No.	Penn'a Lines West. S.W. System.															
													%																
	292	0.70 0.83	0.03	0.80	0.05 0.20			58800	61600				No.																
													%																
		P.S. Sec. Open Hearth Steel. Class "B"						Illinois					No.	Penn'a. Lines West S.W. System.															
													%																
1909	300	0.62 0.75	0.04	0.80	0.05 0.20			58800	61600				No.																
													%																
		A.S.C.E. Sec. Open Hearth Steel.						Tennessee Coal & Iron					No.	Penna Lines West S.W. System.															
													%																
1904	480							58800	61600				No.																
													%																
		A.S.C.E. Sec. Open Hearth Steel						Tennessee Coal & Iron.					No.	St. Louis & San Francisco															
													%																
1906	10000							50000	50000		1		No.									1				33	0.4		
													%																
		A.S.C.E. Sec. Open Hearth Steel						Tennessee Coal & Iron					No.	Illinois Central R.R.															
1907		.55	Not over	.80	Not over								%		11				11	33½	33½			11					
1908	14980	.65	.06	1.10	.20			48500	46000		4	5	No.		1				1	3	3			1		284	3.59	0024	028
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

(Incomplete Records) As to Tonnage, Section or Steel As shown below. RAILROAD

XXIII

Unknown & Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 23 of 37

85 lb. Various Sec. Bessemer Steel. Rolled by Various Steel Co. Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08 To Apr. 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189		85lb.		Sec. Bessemer Steel.				Illinois					No.	Chicago & Eastern Illinois															
1899													%	22				30	8	11		22		7					
1906 ~~189~~	13517	0.52	.095	0.90	0.115			47300	51500		25	2	No.	6				8	2	3		6		2		888	11.3		0.08
													%																
189		85lb.		Sec. Bessemer Steel.				Carnegie					No.	Chicago & Eastern Illinois															
1905													%	14				21	2	47	2	13		2					
1908	11519	0.51	.095	0.95	084	0.39		47300	51750		41	2	No.	6				9	1	20	1	5		1		1419	17.9	0.41	0.16
													%																
		85lb. (85 N. Sec.) Bessemer Steel.						Carnegie					No.	Chicago, Burlington & Quincy															
1906		0.48		0.80									%	12	3	1½	1½	22	26	21	6	4		1½	1½				
1907	8300	0.58	0.10	1.10	0.20			52300	52000		42	26	No.	8	2	1	1	15	18	14	4	3		1	1	2244	31.4		0.38
													%																
		85lb.	8506	Sec. Bessemer Steel.				Illinois.					No.	C. B & Q.															
1904		.48-.58	0.10	.80-1.10	0.20	From 1906-1908							%	15	7	2	2	9	17	17	14	1½	½	6	9				
1908	175900	43-53	0.10	"	"	Year 1904		52300	52000		132	129	No.	40	20	5	6	24	44	44	35	4	1	15	23	8613	108.9		0.06
													%																
		85lb.	852	Sec. Bessemer Steel.				Colorado Fuel & Iron					No.	C. B & Q.															
1905				.80									%	32	23	4			9	9	23								
1908	90000	0.58	0.10	1.10	0.20			52300	52000		10	12	No.	7	5	1			2	2	5					726	9.18		0.01
													%																
		85lb.		Sec. Bessemer Steel.				National					No.	Cincinnati, New Orleans & Texas Pacific Ry.															
1902													%	16	33			17		17	17								
1904								44200	46150		3	3	No.	1	2			1		1	1					198	2.5		
													%																
		85lb.		Sec.		Steel		Tennessee Coal & Iron					No.	C. N. O. & T. P. Ry.															
1906													%	22						11¼	33	11¼		11¼	11¼				
1908								44200	46150		5	4	No.	2						1	3	1		1	1	289	3.7		
													%																
		85lb.		Sec.		Steel.		Cambria					No.	C. N. O. & T. P. Ry.															
1902													%	9	18		9	9		9	37	9							
1906								44200	46150		4	7	No.	1	2		1	1		1	4	1				360	4.6		
													%																
		85lb.		Sec.		Steel.		Carnegie					No.	C. N. O. & T. P. Ry.															
1903													%	20					20		20	20			20				
1905								44200	46150		2	3	No.	1					1		1	1			1	165	2.1		
													%																
													No.																
Totals																													

(*Incomplete Records*) *As to Tonnage, Section or Rail* *As shown below* RAILROAD

XXIV

Unknown & **Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year**

Sheet No. 24 of 37

85 lb *Various* Sec. *Bessemer* Steel. Rolled by *Various* Steel Co. Record for Period of *6 Months* ending *April 30* 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From *Oct 31, 08.* To *Apr. 30, 09.*			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year *1908*	Year *1909*
													%																
189		85lb.		Sec.		Steel		Illinois					No.	Elgin, Joliet & Eastern															
1905 1908 ~~189~~													%																
											2		No.			2										66	0.8		
													%																
189		85lb.	P.R.R.	Sec. Bessemer Steel.				Cambria					No.	Pennsylvania Lines East.															
													%	17	22			7		10	15	13	7	4	5				
		0.50	0.08	1.00	0.13			58300	61500		30	29	No.	10	13			4		6	9	8	4	2	3	1920	24.3		
													%																
		85lb.	P.R.R.	Sec. Bessemer Steel.				Carnegie					No.	Penna. Lines East															
1891													%	15	14	1	4	8	5	26	11	2	5	3	6				
1909		0.50	0.08	1.00	0.13	From 1900		58350	61500		110	90	No.	30	28	2	8	15	9	51	22	5	11	7	12	5977	75.6		
													%																
		85lb.	P.R.R.	Sec. Bessemer Steel.				Lackawanna.					No.	Penn'a. Lines East															
1901													%	19	15			6	8	8	16	1	3	2	22				
1909		0.50	0.08	1.00	0.13			58300	61500		34	59	No.	18	14			6	7	7	15	1	3	2	20	3003	38.0		
													%																
		85lb.	P.R.R.	Sec. Bessemer Steel.				Maryland					No.	Penn'a. Lines East.															
1900													%	11	26		3		6	6	14	5	11	3	15				
1908		0.50	0.08	1.00	0.13			47800	48100		16	49	No.	7	17		2		4	4	9	3	7	2	10	2096	26.5		
													%																
		85lb.	P.R.R.	Sec. Bessemer Steel.				Pennsylvania					No.	Penn'a. Lines East.															
1889		After 1899											%	16	20		4		16	12	8	12	4	4	4				
1901		0.50	0.08	1.00	0.13			65000	61700		11	14	No.	4	5		1		4	3	2	3	1	1	1	736	9.3		
													%																
		85lb.	ASCE.	Sec. Bessemer Steel.				Pennsylvania					No.	Penn'a. Lines East.															
													%	30								60		10					
1906		0.50	0.08	1.00	0.13			60000.	60000		10		No.	3								6		1		330	4.2		
													%																
													No.																
													%																
		85lb.		Sec.	Open Hearth Steel.			Bethlehem					No.	Chicago, Burlington & Quincy															
		0.55		0.70									%	20						40		20		20					
1908	10000	0.67	0.04	1.00				52300	52000		5		No.	1						2		1		1		165	2.10		0.02
													%																
													No.																
													%																
													No.																
Totals																													

As Shown Below RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 25 of 37

80 lb. A.S.C.E. Sec Bessemer Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08. To Apr. 30, 09.			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
~~188~~								Illinois					No.	Chicago & Alton															
1905													%	27	8			13	4	18	4	15	9	1	1				
1908 ~~188~~	10514										118	40	No.	44	12			20	6	28	6	24	14	2	2	4860	57.9		0.55
													%																
189								Carnegie					No.	Chicago, Rock Island & Pacific Ry.															
1893		0.43		0.80									%																
1907	250	0.58	0.10	1.10	0.20			45575	53550		None		No.																
													%																
								Illinois					No.	C.R.I.& P.Ry.															
1894		0.43		0.80									%	56	17			1	8	2	5	7	2		2				
1908	260977	0.58	0.10	1.10	0.20			45575	53550		55	28	No.	46	14			1	6	2	4	6	2		2	2504	29.8		0.01
													%																
								Lorain					No.	C.R.I.& P.Ry.															
1902		0.43		0.80									%																
1904	20451	0.53	0.10	1.10	0.20			45575	53550		2		No.	2												66	0.8		0.004
													%																
								Maryland					No.	C.R.I.& P.Ry.															
1902		0.43		0.80									%	50									50						
1906	14808	0.58	0.10	1.10	0.20			45575	53550		2	2	No.	2									2			120	1.4		0.01
													%																
								National					No.	C.R.I.& P.Ry.															
1901		0.43		0.80									%																
1902	4141	0.53	0.10	1.10	0.20			45575	53550			2	No.		2											66	0.8		0.02
													%																
								Pennsylvania					No.	C.R.I.& P.Ry.															
1903		0.43		0.80									%	8	8			8	25	9	25		17			328			
1906	4575	0.53	0.10	1.10	0.20			45575	53550		3	9	No.	1	1			1	3	1	3		2				3.9		0.09
													%	Evansville & Terre Haute															
								Carnegie					No.																
1899		0.48		0.80									%	40				40			20								
1904	5473	0.58	0.10	1.00	0.20	0.50		39700	51500		4	1	No.	2				2			1					148	1.8		0.03
													%																
								Boghum					No.	Grand Trunk Ry.															
													%	8				8		76				8					
1903	10350							48720	45976		13		No.	1				1		10				1		210	2.50	0.01	0.02
													%																
													No.																
Totals																													

As shown below RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 26 of 37

80 lb A.S.C.E. Sec Bessemer Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909.

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct 31,08 To Apr. 30,09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
188								Barrow					No.		Grand Trunk Ry.														
1903													%																
~~188~~	2587							48720	45976		1		No.	1												30	0.35	0.0	0.01
													%																
~~188~~								Illinois					No.		G.T. Ry.														
													%																
1905	19650							47264	45876		8		No.							8						240	2.67	0.03	0.01
													%																
								National					No.		G.T. Ry.														
													%	4½				18		73		4½							
1902	3000							47264	45876		22		No.	1				4		16		1				660	7.84	0.43	0.26
													%																
								Cammell					No.		G.T. Ry.														
1891													%	67				25		8									
1895	19796							48720	47264		12		No.	8				3		1						360	4.24	0.04	0.02
													%																
								Carnegie					No.		G.T. Ry.														
1899													%	2½		7/10		29		65		2½		3/10					
1905	94575							48720	45976		370		No.	9		3		106		242		9		1		11100	132.10	0.06	0.14
													%																
								Lackawanna					No.		G.T. Ry.														
1904		0.48		0.80									%	28				43		20		3		6					
1907	4725	0.58	0.10	1.10	0.20			48720	45976		35		No.	10				15		7		1		2		1050	12.50	0.19	0.26
													%																
								Carnegie					No.		Michigan Central														
													%	7	2			10	4	69	4	2		2					
1903	8400	0468	0.096	0.920	0.043	0.044		5200	48000		40	5	No.	3	1			4	2	31	2	1		1		1465	17.4		0.21
													%																
								Lackawanna					No.		Michigan Central														
													%	44				21		25	10								
1901	15755	0.538	0.065	1.17	0.140	0.066		44000	47000		17	2	No.	8				4		5	2					595	7.1		0.04
													%																
								Algoma.					No.		Michigan Central														
													%	17				33		50									
1902	5149	0.446	0.097	0.901	0.107	0.052		44000	47000		6		No.	1				2		3						196	2.3		0.05
													%																
													No.																
Totals																													

As shown below RAILROAD XXVII

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 27 of 37

80 lb. A.S.C.E. Sec. Bessemer Steel. Rolled by Various Steel Co. Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08 To Apr. 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								Illinois					No.	Minneapolis, St. Paul & Sault Ste Marie (Wisconsin Central)															
1898 1900		0.48		0.80									%	50						25		13	6		6				
~~188~~	9118	0.58	0.10	1.10	0.20			41000	44050		14	2	No.	8						4		2	1		1	478	5.7		0.06
													%																
~~188~~								Illinois					No.	Munising Ry.															
													%																
1906	629	0.48	0.39	0.92	0.094			48250	32600		None		No.																
													%																
								Lackawanna					No.	Marquette & South Eastern Ry.															
1907		0.49		0.75									%																
1908	1941	0.58	0.10	1.10	0.20			48250	32600		None		No.																
													%																
								Illinois					No.	Munising Ry. Lake Superior & Ishpeming Ry.															
1906													%																
1904	2500	0.48	0.09	0.92	0.094			48250	32600		None		No.																
													%																
								Lackawanna					No.	Munising Ry.															
		0.48		0.80									%																
1906	1454	0.58	0.10	1.10	0.20			48250	32600		None		No.																
													%																
								Colorado Fuel & Iron					No.	St Louis, Rocky Mountain & Pacific															
													%																
1907	12000										None		No.																
													%																
								Carnegie					No.	Pittsburgh & Lake Erie															
1898		.45	Not over	.80	Not over								%	6	10		6	8	8	26	22	1 3/10	9		3 7/10				
1908	16142	.55	.10	1.10	.20			42000	52000		33	45	No.	5	8		5	6	6	20	17	2	6		3	2486	29.59		0.18
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

Buffalo, Rochester & Pittsburgh RAILROAD

XXVIII

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 28 of 37

80 lb Dudley Sec. Bessemer Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08 To Apr. 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								Bethlehem					No.																
1891 1895		0.48		0.80									%	33	67														
~~189~~	4100	0.58	0.10	1.10	0.20			41000	53000		1	2	No.	1	2											120	1.44		0.035
													%																
~~189~~								Cambria					No.																
		0.48		0.80									%																
1902	700	0.58	0.10	1.10	0.20			41000	53000			1	No.		1											33	0.39		0.06
													%																
													No.																
													%																
	80 lb. NYC Sec. Bessemer Steel							Carnegie					No.	Pittsburgh & Lake Erie															
		.45	Not over	.80	Not over								%	9	13				9	37	27								
1899	3500	.55	.10	1.10	.20			42000	52000		5	6	No.	1	2				1	4	3					326	4.95		0.14
													%																
													No.																
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Totals																													

XXIX

As shown below RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 29 of 37

80 lb A.S.C.E. Sec Open Hearth Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08. To Apr. 30, 09.			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
~~180~~								Tennessee Coal & Iron					No.	Chicago Rock Island & Pacific															
1903													%		20				60				20						
~~180~~	123	0.56	0.04	0.82	.006			45575	53550			5	No.		1				3				1			148	1.8		143
													%																
~~180~~								Dominion					No.	Grand Trunk															
1905		0.50	0.05	0.80	0.15	0.05							%	37		2		15		24		6		16					
1908	62073	0.65	0.065	1.30	0.20	0.069		49532	48720		167		No.	63		3		25		40		10		26		5010	59.71		0.10
											Not		%																
								Tennessee Coal & Iron			Separated		No.	Louisville & Nashville															
1905		0.55		0.80		From							%	32		16		4		24		18		6					
1909	132210	0.68	0.06	1.10	0.20	1905 to 1908		43000	42400		147		No.	47		23		6		35		27		9		4783	56.94		0.04
													%																
													No.																
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Totals																													

XXX

Incomplete Records As to Tonnage, Section or Steel As shown below RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 30 of 37

80 lb Unknown & Various Sec. Unknown & Bessemer Steel. Rolled by Various Steel Co. Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08. To Apr. 30, 09.			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189		Sec.			Steel			Lackawanna					No.	Central Vermont Ry.															
1905		0.40		0.70									%	8	8					25		25	34						
1907 ~~189~~		0.50	0.10	0.90		0.05		101 $\frac{500}{2000}$	77 $\frac{500}{2000}$		7	5	No.	1	1					3		3	4			360	4.6		
													%																
189								Carnegie					No.	Central Vermont Ry.															
1900													%	14	14					34	38								
1904								101 $\frac{500}{2000}$	77 $\frac{500}{2000}$		10	11	No.	3	3					7	8					630	8.0		
													%																
		Sec.	Bessemer		Steel			Illinois					No.	Chicago & Eastern Illinois															
1891													%	27	4	7		27	4	4		19	4	4					
1904	43603							47300	51500		23	3	No.	7	1	2		7	1	1		5	1	1		759	9.1	0.02	0.02
													%																
		Sec			Steel			Tennessee Coal & Iron					No.	Cincinnati, New Orleans & Texas Pacific Ry.															
													%																
1907								44200	47900		2		No.					1		1						66	0.8		
													%																
	8004	Sec.			Steel			Illinois					No.	Elgin, Joliet & Eastern															
1886													%	19	15	62	4												
1906											21	5	No.	5	4	16	1									828	9.9		
													%																
	8004	Sec.			Steel			Illinois					No.	Elgin, Joliet & Eastern															
1899													%	33		50	17												
1905											5	1	No.	2		3	1									198	2.4		
													%																
		Sec.	Bessemer		Steel			Pennsylvania & Maryland					No.	Lehigh & Hudson River															
1904		0.65		0.70									%			5		5	29	28	19	5	9						
1908	8474	0.80	0.06	1.00	0.20			45750	33500		9	12	No.			1		1	6	6	4	1	2			678	8.1		0.10
													%																
	A.S.C.E.	Sec.	Bessemer		Steel			Carnegie & National					No.	Michigan Central															
													%	10	1½			30	1½	48	6			1½	1½				
1902	13472	0.466	0.094	0.930	0.053	0.047		52000	48000		62	7	No.	7	1			21	1	33	4			1	1	2223	26.5		0.20
													%																
	A.S.C.E.	Sec.	Bessemer		Steel			Cambria					No.	Pennsylvania Lines East															
													%	40	20					20			20						
1900		0.50	0.08	1.00	0.13			47800	48100		3	2	No.	2	1					1			1			147	1.8		
													%																
													No.																
Totals																													

Incomplete Records) As to Tonnage, Section or Steel. As shown below RAILROAD XXXI

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 31 of 37

80 lb Unknown & Various Sec Unknown & Bessemer Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08. To Apr. 30, 09.			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
~~189~~	A.S.C.E. Sec. Bessemer Steel							Carnegie					No.	Pennsylvania Lines East															
1900													%							66		34							
~~189~~		0.50	0.08	1.00	0.13			47800	48100		3		No.							2		1				90	1.1		
													%																
~~189~~	N.Y.N.H.&H. Sec.				Steel			Maryland					No.	New York. New Haven & Hartford															
1907		0.57		0.80									%	35	30		12				11	6	6						
1908	17565	0.65	0.07	1.05	0.20	0.06		45000	44000		7	10	No.	6	5		2				2	1	1			546	6.5		0.04
													%																
													No.																
													%																
													No.																
													%																
	80 & 90 lb. Dudley & A.S.C.E. Sec. Bessemer Steel							Carnegie					No.	Buffalo, Rochester & Pittsburgh.															
1900		0.40		0.80									%	9	2		19	2	4	9	34		4	4	13				
1907	28300	0.50	0.10	1.10	0.20			41000	53000		11	36	No.	4	1		9	1	2	4	16		2	2	6	1571	20.80		0.07
													%																
	80 & 90 lb. Dudley & A.S.C.E. Sec. Bessemer Steel							Lackawanna					No.	Buffalo, Rochester & Pittsburgh.															
1897		0.48		0.80									%	5	45		10	2	11	5	11			2	9				
1907	14600	0.58	0.10	1.10	0.20			41000	53000		6	38	No.	2	20		4	1	5	2	5			1	4	1449	19.36		0.13
													%																
													No.																
													%																
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Totals																													

Incomplete Records
As to Tons Laid, Section or Rail

New York, New Haven & Hartford RAILROAD

XXXII

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 32 of 37

78 lb. N.Y.N.H.&H. Sec ______ Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30, 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct 31,08. To Apr. 30,09.			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								Lackawanna (Scranton)					No.																
1902 1907													%		20				20	20	40								
189								45000	44000		1	4	No.		1				1	1	2					180	2.10		
													%																
189								Lackawanna (Buffalo)					No.																
1908		0.45		0.75									%	67	33														
1905	12535	0.55	0.10	1.05	0.20			45000	44000		2	1	No.	2	1											90	1.05		0.01
													%																
								Lackawanna (Scranton)					No.																
													%																
1899								33000	35100		1		No.	1												30	0.35		
													%																
								Troy Steel & Iron Co.					No.																
1896													%		67					33									
1898								45000	44000		1	2	No.		2					1						90	1.05		
													%																
								Carnegie					No.																
		0.40		0.75									%	33			33				34								
1904	4000	0.50	0.10	1.05	0.20			45000	44000		1	2	No.	1			1				1					90	1.05		0.03
													%																
								Maryland					No.																
1908													%		86									14					
1906	12072							45000	44000		1	6	No.		6									1		219	2.55		0.02
													%																
													No.																
													%																
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Totals																													

Incomplete Records
As to Tons Laid, Section or Rail — New York, Ontario & Western RAILROAD — **XXXIII**

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 33 of 37

76 lb Lack. Sec. Bessemer Steel. Rolled by Various Steel Co. Record for Period of 6 Months ending April 30, 1909.

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31,08. To Apr. 30,09.			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length In Feet	Total Weight In Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908.	Year 1909
													%																
189								Pennsylvania					No.																
													%		57					14		14	15						
189								50000	45000		2	5	No.		4					1		1	1						
													%																
189								Lackawanna (Scranton)					No.																
													%																
								50000	45000			1	No.										1						
													%																
								Lackawanna Iron & Steel Co.					No.																
													%	9	48			5		5	19	5	9						
								50000	45000		5	16	No.	2	10			1		1	4	1	2						
													%																
								Maryland					No.																
													%						11	22	11	22			34				
								50000	45000		4	5	No.						1	2	1	2			3				
													%																
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Totals																													

As shown below RAILROAD

XXXIV

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 34 of 37

75 lb Various Sec Bessemer Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30, 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct 31,08 To Apr 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189	75 lb.	B & M Section						Lackawanna					No.	Maine Central (Sommerset Ry.)															
1907		0.50		0.75									%																
189	4200	0.60	0.085	1.00	0.20	.0075					None		No.																
													%																
189	75 lb	B & M Section						Lackawanna					No.	Maine Central															
1896		0.40	0.085	1.05									%	43	21				2	2			4	14	14				
1904	37063	0.60	0.10	1.30	0.20	0.69=	year 1902	47000	48000		29	20	No.	21	10				1	1			2	7	7	1614	18.00		0.05
													%																
	75 lb.	A.S.C.E. Section						Maryland					No.	Norfolk & Western															
1902													%				8	8	50		17	17							
1904	6000	0.55	0.09	1.10	0.10	0.04		44000	45000		3	9	No.				1	1	6		2	2				396	44		0.07
													%																
	75 lb.	A.S.C.E. Section						Carnegie					No.	St. Louis & San Francisco															
1897		0.48		0.80									%	16	20			10	18	16	18	2							
1898	8890	0.58	0.10	1.10	0.20			50000	50000		22	28	No.	8	10			5	9	8	9	1				1496	16.7		0.19
													%																
	75 lb.	A.S.C.E. Section						Illinois					No.	St. Louis & San Francisco															
1900		0.48											%	27	25			10	3	10	3		10	3	9				
1899	28200	0.58	0.10	1.10	0.20			50000	50000		16	16	No.	9	8			3	1	3	1		3	1	3	970	10.8		0.03
													%																
	75 lb.	A.S.C.E. Section						National					No.	St. Louis & San Francisco															
1902													%						33		33		34						
	940											3	No.						1		1		1			96	1.1		0.11
													%																
	75 lb.	A.S.C.E. Section						Carnegie					No.	Illinois Central.															
1893		.40	Not over	.75	Not over								%	18	18			9		18	37								
1901	10510	.50	.10	1.05	.20						5	6	No.	2	2			1		2	4					315	3.50	0.033	0.047
													%																
	75 lb.	A.S.C.E. Section						Illinois					No.	Illinois Central															
1899		.40	Not over	.75	Not over								%	77	17					2	2		2						
1907	174350	.50	.10	.85	.20			48500	46000		38	10	No.	37	8					1	1		1			1419	15.80	0.009	0.003
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

Incomplete Records
As to Tons Laid, Section or Rail
As shown below RAILROAD

XXXV

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No 35 of 37

75 lb — Sec — Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08 To Apr. 30, 09			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189			Sec.		Steel			Pennsylvania Steel Co					No.	Central Vermont Ry.															
1895		0.40		0.70									%																
~~189~~		0.50	0.10	0.90		0.05		$68\frac{500}{2000}$	$57\frac{600}{2000}$			2	No.		2											60	0.8		
													%																
189			Sec.		Steel			Lackawanna					No.	Central Vermont Ry.															
1892		0.40		0.70									%	44	44							12							
1890		0.50	0.10	0.90		0.05		$68\frac{500}{2000}$	$57\frac{600}{2000}$		9	7	No.	7	7							2				480	6.1		
													%																
			Sec.		Steel			Carnegie					No.	Central Vermont Ry															
		0.40		0.70									%																
1897		0.50	0.10	0.90		0.05		$68\frac{500}{2000}$	$57\frac{600}{2000}$		1	1	No.	1	1											60	0.8		
													%																
			Sec.		Steel			Carnegie					No.	Cincinnati, New Orleans & Texas Pacific Ry.															
1892													%	12	3	3		20	10	28	15	8	1						
1906								44200	47900		80	32	No.	14	3	3		23	11	31	17	9	1			3457	38.6		
													%																
			Sec.		Steel			Cambria					No.	Cinti. N.Orleans & T. Pacific Ry.															
1897													%	22½				11		33½	11	22							
1901								44200	47900		8	1	No.	2				1		3	1	2				273	3.1		
													%																
			Sec.		Steel			Tennessee Coal & Iron					No.	Cinti. N.Orleans & T. Pacific Ry.															
													%	20				20		20		20	20						
1903								44200	47900		4	1	No.	1				1		1		1	1			165	1.8		
													%																
			Sec.		Steel			National Steel Co.					No.	Cinti. N.Orleans & T. Pacific Ry.															
													%																
1902								44200	47900		1	1	No.	1					1							66	0.7		
													%																
			Sec.		Steel			Maryland					No.	Cinti. N.Orleans & T. Pacific Ry.															
													%	33					33	34									
1901								44200	47900		2	1	No.	1					1	1						99	1.1		
													%																
			Sec.		Steel			Illinois					No.	Cinti. N.Orleans & T. Pacific Ry.															
													%																
1902								44200	47900		1		No.							1						33	0.3		
													%																
			Sec.		Steel			Pennsylvania					No.	Cinti. N.Orleans & T. Pacific Ry.															
1898													%	33	33							34							
Totals								44200	47900		2	1	No.	1	1							1				90	1.0		

Sheet No. 36 of 37

Incomplete Records
As to Tons Laid, Section or Rail
As shown below RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

75 lb Sec Steel Rolled by Various Steel Co Record for Period of 6 Months ending April 30, 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct. 31, 08. To Apr. 30, 09.			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189	75 lb.	7502 Sec.			Steel			Illinois					No.	Elgin, Joliet & Eastern															
													%																
1894 ~~189~~											1		No.	1												30	0.3		
													%																
189	75 lb.	A.S.C.E. Sec.			Steel			Carnegie					No.	Louisiana & Arkansas															
													%																
1906	3700							32900	26000		1		No.	1												33	0.4		
													%																
	75 lb.	A.S.C.E. Sec.		Bessemer				Lackawanna I & S Co					No.	New York, Ontario & Western															
													%	9	27				18	27	9			10					
								50000	45000		5	6	No.	1	3				2	3	1			1					
													%																
	75 lb.	A.S.C.E. Sec.			Steel		Carnegie, Lorain & Illinois						No.	Toledo St. Louis & Western															
1905													%	11				32	26	16		5	5		5				
1907	29795										12	7	No.	2				6	5	3		1	1		1	627	7.1		0.02
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
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													%																
													Nn.																
													%																
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													No.																
													%																
													No.																
													%																
													No.																
Totals																													

Incomplete Record
As to Tons Laid; Section of Rail

Northern Pacific. RAILROAD

XXXVII

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 37 of 37

72 lb A.S.C.E. Sec Bessemer Steel. Rolled by Various Steel Co Record for Period of 6 Months ending April 30, 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From Oct 31, 08. To Apr. 30, 09.			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year 1908	Year 1909
													%																
189								Illinois					No.	Northern Pacific															
1897		0.40		075									%	23½	15	½		2½	4	4½	2	½	½	32	15				
1903 189		0.50	0.10	1.05	0.20			54730	52300		127	71	No.	47	30	1		5	8	9	2	1	1	64	30	5877	62.80		
													%																
189								Lackawanna					No.	Northern Pacific															
1899		0.40		075									%	4	12		4	7	12	15	4	4	4	34					
1902		0.50	0.10	1.05	0.20			54730	52300		17	9	No.	1	3		1	2	3	4	1	1	1	9		762	8.13		
													%																
								Lorain					No.	Northern Pacific															
1900													%		83			17											
1901								54730	52300		1	5	No.		5			1								180	1.93		
													%																
													No.																
													%																
													No.																
													%																
													No.																
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													No.																
													%																
													No.																
													%																
													No.																
Totals																													

XXXVIII

Summary by Sections, Weights and kind of Steel (of 37 Sheets) RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 1 of 5

lb Sec. Steel. Rolled by Steel Co ^ Record for Period of 6 Months ending April 30 1909

~~Year Laid~~ Section	~~Tons of New Rail Laid~~ Weight	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From——— To———			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C Kind of Steel	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year....	Year....
P.R.R. ~~100~~	100	Bessemer		2 Companies							371	255	%	18	11	1½	2	3	5	10	8	22	14	3	2½	20330	308.0		
													No.	114	71	10	13	20	30	66	51	143	75	18	15				
A.S.C.E ~~100~~	"	"		6	"						518	343	%	18	7	4/10	2 4/10	13	13	21	14	3	1 9/10	5	2	27870	416.2		
													No.	156	58	3	21	108	110	184	121	25	11	42	22				
P.S ~~100~~	"	"		2	"						1	5	%						33	17	50					192	2.9		
													No.						2	1	3								
Total	100	Bessemer		8 Companies							890	603	%	18	9	1	2	8	9	17	12	11	6	4	3	48392	727.1		
													No.	270	129	13	34	128	142	251	175	168	86	60	37				
													%																
													No.																
P.R.R	100	Nickel		1 Company								3	%													99	1.5		
													No.										3						
													%																
													No.																
P.R.R	100	Open Hearth		1 Company							1	1	%													66	1.0		
													No.								1	1							
ASCE	"	"	"	2 Companies							17	1	%	10		6		33		33	6	6		6		543	6.0		
													No.	2		1		6		6	1	1		1					
NY.NH. & H.	"	"	"	1 Company							37	16	%	2	2		4	2				63	19	2	6	1729	26.1		
													No.	1	1		2	1				34	10	1	3				
P.S	"	"	"	1	"								%																
													No.																
Total	100	Open Hearth		5 Companies							55	18	%	4	1	1	3	10		8	3	49	14	3	4	2338	33.1		
													No.	3	1	1	2	7		6	2	36	10	2	3				
													%																
													No.																
NY.NH & H.	100			1 Company Incomplete as to Steel							57	46	%	13	3	2	9	11½	4	13½	18	8½	3	7	7½	3092	460		
													No.	13	3	2	9	12	4	14	19	9	3	7	8				
													%																
													No.																
All	100	All		13, All Companies							1002	670	%	17	8	1	3	9	9	16	12	12	6	4	3	53921	807.7		
													No.	286	133	16	45	147	146	271	196	213	102	69	48				
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

Summary by Sections, Weights and kind of Steel. (Of 37 Sheets) RAILROAD

XXXIX

Sheet No. 2 of 5

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

lb ______ Sec ______ Steel ______ Rolled by ______ Steel Co ______ Record for Period of 6 Months ending April 30 1909

~~Year Laid~~ Section	~~Tons of New Rail Laid~~ Weight	Specified Chemical Analysis C Kind of Steel	P	Mn	Si	S		Maximum Axle Load of Locomotives Freight	Passenger	Approx. Gross Tons over Rail	No. of Rails which failed From ____ To ____ Tan.	Curve		Kind of Failure Broken Tan.	Broken Curve	Flow of Metal Tan.	Flow of Metal Curve	Crushed Head Tan.	Crushed Head Curve	Split Head Tan.	Split Head Curve	Split Web Tan.	Split Web Curve	Broken Base Tan.	Broken Base Curve	Aggregate Length and Weight of Rails which failed Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid Year ____	Year ____
A.S.C.E. ~~189~~	95	Bessemer		New York, Ontario & Western. Incomplete							15	11	%	19	19			12	7	15	4	12	12						
													No.	5	5			3	2	4	1	3	3						
													%																
189													No.																
A.S.C.E. ~~189~~	90	Bessemer		4 Companies							447	413	%	13	9	1	1	14	11	16	13	6	5	2	9	27732	371.4		
													No.	108	75	7	10	124	98	140	109	55	40	13	81				
A.R.A.	"	"		2	"						2		%													66	1.0		
													No.							1		1							
Total	90	Bessemer		6 Companies							449	413	%	13	9	1	1	14	11	16	13	6	5	2	9	27798	372.4		
													No.	108	75	7	10	124	98	141	109	56	40	13	81				
													%																
													No.																
A.S.C.E.	90	Chrome Nickel		1 Company							7	12	%	37	58								5			627	8.0		
													No.	7	11								1						
													%																
													No.																
A.S.C.E.	90	Open Hearth		2 Companies							22	41	%	22	40			1	10	5	16	3		3		2076	27.8		
													No	14	25			1	6	3	10	2		2					
A.R.A.	"	"	"	1 Company							2	21	%		18			4	35	4	39					759	10.4		
													No.		4			1	8	1	9								
Total	90	Open Hearth		3 Companies							24	62	%	17	33			2	17	5	22	2		2		2835	38.2		
													No.	14	29			2	14	4	19	2		2					
													%																
													No.																
G.N.	90			1 Company			Incomplete as to Steel				7	1	%	88	12											258	3.5		
													No.	7	1														
													%																
													No.																
All	90	All		7 Companies							487	488	%	14	12	½	1	13	12	15	13	6	4	1½	8	31518	422.1		
													No.	136	116	7	10	126	112	145	128	58	41	15	81				
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

Summary by Sections, Weights and Kind of Steel. (Of 37 Sheets) ______ RAILROAD

XL

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 3 of 5

______ lb ______ Sec ______ Steel Rolled by ______ Steel Co Record for Period of *6 Months* ending *April 30* 19*09*

~~Year Laid~~ SECTION	~~Tons of New Rail Laid~~ WEIGHT	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From To			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C KIND OF STEEL	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year	Year
P.R.R. ~~189~~													%	15	13	1	2	10	5	26	10	4	4	3	7				
	85	Bessemer		4 Companies							360	256	No.	90	81	6	11	60	28	162	63	26	27	16	46	19631	248.0		
A.S.C.E. ~~189~~													%	15	8	1	2	18	21	14	8	2	2	4	5				
	"	"		18	"						3650	3102	No.	995	544	67	133	1200	1409	961	567	165	110	252	345	222140	2809.9		
P.S. ~~189~~													%	17	17					17	16	33							
	"	"		1	"						4	2	No.	1	1					1	1	2				198	2.5		
													%	16	7	1¾	1¾	13	16	20	11	4	¼	4	5¼				
	"	"		3	"		Incomplete as to Section				253	174	No.	68	29	7	7	57	67	84	46	18	1	19	24	14088	180.0		
Total													%	15	8	1	2	17	19	16	9	3	2	3	5				
	85	Bessemer		21 Companies							4267	3534	No.	1154	655	80	151	1317	1498	1218	677	211	138	287	415	256057	3240.4		
													%																
													No.																
													%	2				4	34	17	43								
A.S.C.E.	85	Nickel		1 Company							11	36	No.	1				2	16	8	20					1458	184		
													%																
													No.																
													%		10				10	40	30			10					
A.S.C.E.	85	Open Hearth		2 Companies							5	5	No.		1				1	4	3			1		317	4.0		
													%	20						40		20		20					
	"	"		1	"		Incomplete as to Section				5		No.	1						2		1		1		165	2.1		
													%	7	7				7	40	20	6		13					
Total	85	Open Hearth		3 Companies							10	5	No.	1	1				1	6	3	1		2		482	6.1		
													%																
													No.																
													%	15	7	7	4	4	4	7	30	11		4	7				
	85			2 Companies. Incomplete as to Sec. or Steel							13	14	No.	4	2	2	1	1	1	2	8	3		1	2	814	10.3		
													%																
													No.																
													%	15	8	1	2	17	19	16	9	2½	1½	4	5				
All	85	All		22 Companies							4301	3589	No.	1160	658	82	152	1320	1516	1234	708	215	138	290	417	258811	3275.2		
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

Summary by Sections, Weights and kind of Steel. (Of 37 Sheets) RAILROAD

XLI

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 4 of 5

lb Sec. Steel. Rolled by Steel Co Record for Period of 6 Months ending April 30 1908.

~~Year Laid~~ SECTION	~~Tons of New Rail Laid~~ WEIGHTS	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From—— To——			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C KIND OF STEEL	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year....	Year....
													%																
A.S.C.E. ~~100~~	80	Bessemer		8 Companies							823	145	No.	161	40	3	5	190	24	414	39	47	28	8	9	29422	350.1		
													%																
Dudley ~~100~~	"	"		1 Company							1	3	No.	1	3											153	1.8		
													%																
N.Y.C. ~~100~~	"	"		1	"						5	6	No.	1	2				1	4	3					326	4.9		
													%																
—	"	"		2 Companies.			Incomplete as to Section				32	15	No.	7	1	3		8	7	7	4	6	3	1		1437	17.2		
													%																
Total	80	Bessemer		12 Companies.							861	169	No.	170	46	6	5	198	32	425	46	53	31	9	9	31338	374.0		
													%																
													No.																
													%																
A.S.C.E.	80	Open Hearth		2 Companies							167	5	No.	63	1	3		25	3	40		10	1	26		5158	61.5		
													%																
	80			3	"	Incomplete as to Sec. & Steel.					45	22	No.	11	8	19	2	1		11	8	3	4			2082	25.7		
													%																
NY.NH. & H.	80			1 Company.			"	" "	Steel.		7	10	No.	6	5		2				2	1	1			546	6.5		
													%																
Total	80			4 Companies.			Incomplete				52	32	No.	17	13	19	4	1		11	10	4	5			2628	32.2		
													%																
													No.																
													%																
All	80	All		16 Companies							1080	206	No.	250	60	28	9	224	35	476	56	67	37	35	9	39124	467.7		
													%																
													No.																
													%																
													No.	Tangent & Curve Not Separated															
													%																
A.S.C.E.	80	Open Hearth		1 Company							147		No.	47		23		6		35		27		9		4783	56.9		
													%																
													No.																
													%																
													No.	Sections & Weights Not Separated.															
													%																
A.S.C.E. & Dudley	80 & 90	Bessemer		1 Company.			Incomplete				17	74	No.	6	21		13	2	7	6	21		2	3	10	3020	40.2		
													%																
													No.																
Totals																													

Summary by Section, Weight and Kind of Steel. (Of 37 Sheets) ____ RAILROAD

XLII

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 5 of 5

____ lb ____ Sec. ____ Steel. Rolled by ____ Steel Co. Record for Period of 6 Months ending April 30 1909.

~~Year Laid~~ SECTION	Tons of New Rail Laid WEIGHT	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From____ To____			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C KIND OF STEEL	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve	Tan.	Curve			Year....	Year....
N.Y.N.H. & H. ~~189~~	78			1 Company. Incomplete as to Steel							7	15	%	18	46		4½		4½	9	13½			4½		699	8.1		
													No.	4	10		1		1	2	3			1					
189													%																
													No.																
Lackawanna ~~189~~	76	Bessemer		1 Company							11	27	%	5	37			2	2	11	13	11	11		8				
													No.	2	14			1	1	4	5	4	4		3				
													%																
													No.																
ASCE	75	Bessemer		4 Companies							89	78	%	34	19		¾	6	11	10	11	2	3	1¼	2	5022	56.0		
													No.	57	31		1	10	19	17	19	3	5	2	3				
BBM	"	"		1 Company							29	20	%	43	20				2	2			4	14½	14½	1614	18.0		
													No.	21	10				1	1			2	7	7				
Total	75	Bessemer		5 Companies							118	98	%	36	19		½	4½	9	8	9	1½	3½	4½	4½	6636	74.0		
													No.	78	41		1	10	20	18	19	3	7	9	10				
													%																
													No.																
	75			3 Companies Incomplete as to Sec. & Steel							109	47	%	19	8	2		16	8	24	12	10	1			4813	53.7		
													No.	29	14	3		25	13	37	18	15	2						
ASCE	"			2 " " " " Steel							13	7	%	15				30	25	15		5	5		5	660	7.4		
													No.	3				6	5	3		1	1		1				
Total	75			5 Companies. Incomplete.							122	54	%	18	8	2		18	10	23	10	9	1½		½	5473	61.1		
													No.	32	14	3		31	18	40	18	16	3		1				
													%																
													No.																
All	75	All		10 Companies							240	152	%	28	14	¾	¼	10	9	15	10	5	3	2	3	12109	135.1		
													No.	110	55	3	1	41	38	58	37	19	10	9	11				
													%																
													No.																
ASCE	72	Bessemer		1 Company							145	85	%	20	17	½	½	3	5	6	1	1	1	32	13	6819	72.9		
													No.	48	38	1	1	8	11	13	3	2	2	73	30				
													%																
													No.																
Grand Total of Failures											59	41	%	16	9	1¼	1¾	15	15	17	9	4¾	2¾	4	4½				
											7435	5243	No.	2048	1089	160	219	1876	1862	2242	1137	608	337	501	599				
													%																
													No.																
													%																
													No.																
Totals																													

DATA FOR DIAGRAM I. Comparison between different Weights of Rail. ______ RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

XLIII

______ lb ______ Sec. ______ Steel. Rolled by ______ Steel Co Record for Period of 6 Months ending April 30 1909.

Year Laid	~~Tons of New Rail Laid~~ WEIGHT	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From____ To____			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		~~Flow of Metal~~		~~Crushed Head~~ HEAD		~~Split Head~~		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	~~Tan.~~	~~Curve~~	~~Tan.~~ Tan.	~~Curve~~ Curve	~~Tan.~~	~~Curve~~	Tan.	Curve	Tan.	Curve			Year____	Year____
													%	5.0	2.0			9.13	8.7			1.0	0.5	1.3	0.8	No. of Failures per 10,000 Tons Laid			
189	100	Bessemer.		8 Companies.							530	386	No.	162	65			294	280			31	17	43	24	Tons 322058			
													%																
189	Balto. & Ohio — Bessemer & Lake Erie — Chgo. Rock Island & Pacific — Grand Trunk — Michigan Central — Penna. Lines East — Penna. Lines West — Cumberland Valley																												
													%																
189													No.																
													%	6.0	3.1			14.8	11.8			3.6	2.4	0.3	0.5	No. of Failures per 10,000 Tons Laid			
	90	Bessemer.		4 Companies.							239	172	No.	58	30			143	114			35	23	3	5	Tons 96337			
													%																
	Central R.R. of New Jersey — Balto. & Ohio — Pittsburgh & Lake Erie — Western Allegheny.																												
													%																
													No.																
													%	4.2	2.5			9.6	8.9			0.54	0.33	1.2	1.7	No. of Failures per 10,000 Tons Laid.			
	85	Bessemer		20 Companies							3557	2966	No.	1034	553			2139	1975			119	73	265	365	Tons 2222456			
													%																
	Atlantic Coast Line. Balto. & Ohio. Balto. & Ohio Southwestern. Chgo. Burlington & Quincy. Chgo. & Eastern Illinois. Chgo. Milwaukee & St. Paul. Chgo. Rock Island & Pacific.																												
													%																
	Cincinnati, Richmond & Ft. Wayne. Cleveland, Akron & Columbus. Cumberland Valley. Evansville & Terre Haute. Illinois Central. Maine Central.																												
													%																
	Minneapolis, St. Paul & Sault St. Marie. Norfolk & Western. Northern Pacific. Penna. Lines East. Penna. Lines West. St. Louis & San Francisco. Vandalia.																												
													%																
													No.																
													%	2.8	0.7			10.3	1.4			0.9	0.5	0.15	0.15	No. of Failures per 10,000 Tons Laid			
	80	Bessemer		10 Companies							856	167	No.	168	45			626	83			53	30	9	9	Tons 604035			
													%																
	Chicago & Alton. Chgo. Rock Island & Pacific. Evansville & Terre Haute. Grand Trunk. Michigan Central.												No.																
													%																
	Minneapolis, St. Paul & Sault St. Marie. Pittsburgh & Lake Erie. Buffalo, Rochester & Pittsburgh. Chgo. & Eastern Illinois. Lehigh & Hudson.												N																
													%																
													No.																
													%	2.9	1.5			0.95	1.4			0.12	0.27	0.3	0.4	No. of Failures per 10,000 Tons Laid			
	75	Bessemer		4 Companies							113	92	No.	77	38			25	37			3	7	8	10	Tons 265943			
													%																
	Maine Central. Norfolk & Western. St. Louis & San Francisco. Illinois Central.																												
													%																
													No.																
													%																
													No.																
Totals																													

DATA FOR DIAGRAM 2. Comparison between different Weights of Rail. ______RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

XLIV

______lb ______Sac ______Steel. Rolled by ______Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	~~Tons of New Rail Laid~~ WEIGHT	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From____ To____			Kind of Failure												Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		~~Flow of Metal~~		~~Crushed Head~~ HEAD		~~Split Head~~		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	~~Tan.~~	~~Curve~~	~~Tan.~~ Tan.	~~Curve~~ Curve	~~Tan~~	~~Curve~~	Tan.	Curve	Tan.	Curve			Year____	Year____
													%	1.6	0.5			7.6	1.6			19.1	5.4	1.1	1.6	No. of Failures per 10000 Tons Laid			
189	100	Open Hearth 3 Companies									54	17	No.	3	1			14	3			35	10	2	3	Tons 18354			
													%																
189	Grand Trunk. Michigan Central. New York, New Haven & Hartford												No.																
													%																
189													No.																
													%	10.7	13.0			1.5	13.9				0.8	1.5		No. of Failures per 10000 Tons Laid			
	90	Open Hearth 2 Companies									18	36	No.	14	17			2	18				1	2		Tons 13016			
													%																
	Central R.R. of New Jersey. Baltimore & Ohio.												No.																
													%																
													No.																
													%	0.4	0.4			4.9	15.0			0.4		0.4		No. of Failures per 10000 Tons Laid			
	85	Open Hearth 3 Companies									16	41	No.	1	1			13	40			1		1		Tons 26619			
													%																
	Penn'a Lines West. St. Louis & San Francisco. Illinois Central												No.																
													%																
													No.																
													%	10.1	0.2			10.9	0.5			1.6	0.2	4.2		No. of Failures per 10000 Tons Laid			
	80	Open Hearth 2 Companies									167	5	No.	63	1			68	3			10	1	26		Tons 62196			
													%																
	Chicago, Rock Island & Pacific. Grand Trunk.												No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

DATA FOR DIAGRAM 3. Comparison between different Sections of Rail. ____ RAILROAD

XLV

Sheet No. 1 of 3.

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

____ lb. ____ Sec. ____ Steel. Rolled by ____ Steel Co. Record for Period of 6 Months ending April 30 1909

~~Year Laid~~ SECTION	~~Tons of New Rail Laid~~ WEIGHT	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From ____ To ____		Kind of Failure													Aggregate Length and Weight of Rails which failed			
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		~~Flow of Metal~~		~~Crushed Head~~ HEAD		~~Split Head~~		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	~~Tan.~~	~~Curve~~	~~Tan.~~ Tan.	~~Curve~~ Curve	~~Tan.~~	~~Curve~~	Tan.	Curve	Tan.	Curve			Year.....	Year.....
P.R.R. ~~100~~	100	Bessemer		2 Companies							17	38	%	3.3	3.9			2.2	12.8			3.4	3.4	0.6	1.1	No. of Failures per 10000 Tons Laid			
													No.	6	7			4	23			6	6	1	2	Tons 17902			
189	Cumberland Valley. Penna. Lines East.												%																
													No.																
189													%																
													No.																
A.S.C.E.	100	Bessemer		6 Companies							518	343	%	5.2	1.9			9.7	8.3			0.8	0.4	1.4	0.7	No. of Failures per 10000 Tons Laid			
													No.	156	58			295	252			25	11	42	22	Tons 300982			
	Balto. & Ohio. Bessemer & Lake Erie. Chgo. Rock Island & Pacific. Grand Trunk. Michigan Central. Penna. Lines West.												%																
													No.																
													%																
													No.																
P.S.	100	Bessemer		2 Companies							1	5	%					1.0	4.9							No. of Failures per 10000 Tons Laid			
													No.					1.	5							Tons 19218			
	Penna. Lines East. Penna. Lines West.												%																
													No.																
													%																
													No.																
A.S.C.E.	90	Bessemer		3 Companies							237	172	%	6.3	3.3			15.5	12.5			3.7	2.5	0.3	0.5	No. of Failures per 10000 Tons Laid			
													No.	58	30			142	114			34	23	3	5	Tons 91237			
	Central R.R. of N.J. ~~New York Central~~ Pittsburgh & Lake Erie. Western Allegheny.												%																
													No.																
													%																
													No.																
A.R.A.^{A}	90	Bessemer.		1 Company.							2		%					20				20				No. of Failures per 10000 Tons Laid			
													No.					1				1				Tons 5100			
	Baltimore & Ohio.												%																
													No.																
													%																
													No.																
P.R.R.	85	Bessemer		3 Companies.							162	35	%	1.9	1.0			11.5	1.3			0.6	0.3	0.2	0.5	No. of Failures per 10000 Tons Laid.			
													No.	22	12			131	15			7	3	2	5	Tons 113701			
	Cumberland Valley. Penna. Lines East. Penna. Lines West.												%																
													No.																
													%																
													No.																
Totals																													

DATA FOR DIAGRAM 3. Comparison between different Sections of Rail ____________ RAILROAD

XLVI

Sheet No. 2 of 3

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

______ lb. ______ Sec. ______ Steel. Rolled by ______ Steel Co. Record for Period of 6 Months ending April 30 1908

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From------- To-------		Kind of Failure													Aggregate Length and Weight of Rails which failed			
SECTION	WEIGHT	C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		~~Flow of Metal~~		~~Crushed~~ Head HEAD		~~Split Head~~		Split Web		Broken Base		Total Length In Feet	Total Weight In Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	~~Tan.~~	~~Curve~~	~~Tan.~~ Tan.	~~Curve~~ Curve.	~~Tan.~~	~~Curve~~	Tan.	Curve	Tan.	Curve			Year----	Year----
ASC.E	85	Bessemer		16 Companies							3141	2758	%	5.2	2.8			10.3	10.2			0.5	04	1.35	1.3	No. of Failures per 10000 Tons Laid			
													No.	944	513			1861	1840			92	69	244	336	Tons	1809256		
													%																
189	Atlantic Coast Line. Balto. & Ohio. Balto. & Ohio Southwestern. Chgo. Milwaukee & St. Paul. Chgo. Rock Island & Pacific. Cint'i. Richmond & Ft. Wayne. Cleveland, Akron & Col's.																												
													%																
189	Evansville & Terre Haute. Illinois Central. Maine Central. Minneapolis, St. Paul & Sault St. Marie. Norfolk & Western. Northern Pacific. St. Louis & San Francisco. Vandalia. Penna. Lines West.																												
													%																
													No.																
P.S.	85	Bessemer.		2 Cos.' Penna. Lines East. Penna. Lines West.							4	2	%	1.6	1.6			1.6	1.6			3.3				No. of Failures per 10000 Tons Laid			
													No.	1	1			1	1			2				Tons	6153		
													%																
													No.																
85N.	85	Bessemer		1 Co. Chgo. Burlington & Quincy.							42	26	%	9.6	2.4			36.1	27.7			0.4		1.2	1.2	No. of Failures per 10000 Tons Laid			
													No.	8	2			30	23			3		1	1	Tons	8300		
													%																
													No.																
8506	85	Bessemer		1 Co. Chgo. Burlington & Quincy							132	129	%	2.3	1.1			4.1	4.8			0.2	0.05	0.9	1.3	No. of Failures per 10000 Tons Laid			
													No.	40	20			73	85			4	1	15	23	Tons	175900		
													%																
													No.																
852	85	Bessemer		1 Co. Chgo. Burlington & Quincy							10	12	%	7.2	5.6			3.3	7.8							No. of Failures per 10000 Tons Laid			
													No.	7	5			3	7							Tons	90000		
													%																
													No.																
ASC.E	80	Bessemer		7 Companies							818	143	%	2.9	0.7			11.7	1.3			0.9	0.5	0.1	0.2	No. of Failures per 10000 Tons Laid			
													No.	159	39			604	68			47	27	8	9	Tons	543658		
													%																
	Chgo. & Alton. Chgo. Rock Island & Pacific. Evansville & Terre Haute. Grand Trunk.												No.	Michigan Central. Minneapolis, St. Paul & Sault St. Marie. Penna. Lines East.															
													%																
													No.																
Dudley	80	Bessemer		1 Co. Buffalo, Rochester & Pittsburgh.							1	3	%	2.1	6.3											No. of Failures per 10000 Tons Laid			
													No.	1	3											Tons	4800		
													%																
													No.																
N.Y.C.	80	Bessemer		1 Co. Pittsburgh & Lake Erie							5	6	%	2.9	5.7			11.4	11.4							No. of Failures per 10000 Tons Laid			
													No.	1	2			4	4							Tons	3500		
													%																
													No.																
Totals																													

DATA FOR DIAGRAM 3. Comparison between different Sections of Rail. ________ RAILROAD

XLVII

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

Sheet No. 3 of 3.

______ lb ______ Sec ______ Steel. Rolled by ______ Steel Co. Record for Period of 6 Months ending April 30 1909

Year Laid SECTION	Tons of New Rail Laid WEIGHT	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From ------ To ------			Kind of Failure												Aggregate Length and Weight of Rails which failed			
														Broken		~~Flow of Metal~~		~~Crushed Head~~ HEAD		~~Split Head~~		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
		C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Tan.	Curve	~~Tan.~~	~~Curve~~	~~Tan.~~ Tan.	~~Curve~~ Curve	~~Tan.~~	~~Curve~~	Tan.	Curve	Tan.	Curve			Year.....	Year.....
A.S.C.E. 189	75	Bessemer 3 Companies									84	72	%	2.5	1.22			1.05	1.6			0.13	0.22	0.05	0.13	No. of Failures per 10000 Tons Laid			
													No.	56	28			24	36			3	5	1	3	Tons	228890		
189	Norfolk & Western. St.Louis & San Francisco. Illinois Central.												%																
													No.																
189													%																
													No.																
B&M.	75	Bessemer 1 Company. Maine Central									29	20	%	5.7	2.7			0.3	0.3				0.6	1.9	1.9	No. of Failures per 10000 Tons Laid			
													No.	21	10			1	1				2	7	7	Tons	37063		
													%																
													No.																
													%																
													No.																
													%																
													No.																
													%																
													No.																
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													No.																
													%																
													No.																
													%																
													No.																
Totals																													

DATA FOR DIAGRAM 4. Comparison between different Sections of Rail ____RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

XLVIII

____lb. ____Sec. ____Steel. Rolled by____ ____Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid	Tons of New Rail Laid	Specified Chemical Analysis						Maximum Axle Load of Locomotives		Approx. Gross Tons over Rail	No. of Rails which failed From____ To____			Kind of Failure												Aggregate Length and Weight of Rails which failed			
SECTION	WEIGHT	C	P	Mn	Si	S		Freight	Passenger		Tan.	Curve		Broken		~~Flow of Metal~~		~~Crushed~~ Head HEAD		~~Split Head~~		Split Web		Broken Base		Total Length in Feet	Total Weight in Tons	Failures in Percentage of Tons of Rail Laid	
														Tan.	Curve	~~Tan.~~	~~Curve~~	~~Tan.~~ Tan.	~~Curve~~ Curve	~~Tan.~~	~~Curve~~	Tan.	Curve	Tan.	Curve			Year.____	Year.____
ASCE													%	1.4				9.0	0.7			0.7		0.7		No. of Failures per 10000 Tons Laid			
~~189~~	100	Open Hearth		2 Companies							17	1	No.	2				13	1			1		1		Tons	14354		
													%																
189	Grand Trunk.			Michigan Central									No.																
													%																
189													No.																
													%	2.5	2.5			2.5	5.0			85	2.50	2.5	7.5	No. of Failures per 10000 Tons Laid			
NYNH&H	100	Open Hearth		1 Co.	New York, New Haven & Hartford						37	16	No.	1	1			1	2			34	10	1	3	Tons	4000		
													%																
													No.																
													%	17.5	16.2				1.2				1.2	2.5		No. of Failures per 10000 Tons Laid			
ASCE	90	Open Hearth		Nickel	1 Co.	Central R.R. of New Jersey					16	15	No.	14	13				1				1	2		Tons	8016		
													%																
													No.																
													%		8.0			4.0	34.0							No. of Failures per 10000 Tons Laid			
A.R.A-B	90	Open Hearth		1 Co.	Baltimore & Ohio						2	21	No.		4			2	17							Tons	5000		
													%																
													No.																
													%	0.4	0.4			4.9	15.0			0.4		0.4		No. of Failures per 10000 Tons Laid			
ASCE	85	Open Hearth		3 Companies							16	41	No.	1	1			13	40			1		1		Tons	26619		
													%																
	Illinois Central.			Penn'a Lines West.			St. Louis & San Francisco						No.																
													%																
													No.																
													%	10.1	0.2			10.9	0.5			1.6	0.2	42		No. of Failures per 10000 Tons Laid			
ASCE	80	Open Hearth		2 Companies							167	5	No.	63	1			68	3			10	1	26		Tons	62196		
													%																
	Chicago, Rock Island & Pacific.					Grand Trunk.							No.																
													%																
													No.																
													%																
P.S	85	Open Hearth		1 Company		Penn'a Lines West							No.													Tons	1599.		
													%																
													No.																
													%																
													No.																
													%																
													No.																
Totals																													

DATA FOR DIAGRAM No. 5. Comparison of Failures at different lengths of life. All kinds of Steel RAILROAD

Summary of Steel Rail Failures for 6 Months Compared with same Period of Previous Year

XLIX.

———lb ———Sec ———Steel. Rolled by ——— Steel Co Record for Period of 6 Months ending April 30 1909

Year Laid | Tons of New Rail Laid | Specified Chemical Analysis: C, P, Mn, Si, S | Maximum Axle Load of Locomotives: Freight, Passenger | Approx. Gross Tons over Rail | No. of Rails which failed From—— To——: Tan., Curve | Kind of Failure: Broken (Tan., Curve), Flow of Metal (Tan., Curve), Crushed Head (Tan., Curve), Split Head (Tan., Curve), Split Web (Tan., Curve), Broken Base (Tan., Curve) | Aggregate Length and Weight of Rails which failed: Total Length in Feet, Total Weight in Tons, Failures in Percentage of Tons of Rail Laid (Year——, Year——)

100 LB. RAIL

SECTION	LIFE IN YEARS	TONS LAID	No. OF FAILURES	No. OF FAILURES PER 10000 TONS LAID
A.S.C.E.	0-1	15913	14	8.8
"	1-2	84715	254	30.0
"	2-3	64755	146	22.5
"	3-4	48181	160	33.2
"	4-5	23604	135	57.2
"	5-6	8939	11	12.3
"	6-7	20952	56	26.7
"	7-8	19219	13	6.8
"	8-9	2290		
"	9-10	879		
"	10+	25889	90	34.8
Total		315336	879	
P.R.R.	0-1	5743	36	62.7
"	1-2	2936	3	10.2
"	2-3	2735	3	11.0
"	3-4	3248	7	21.5
"	4-5	1973	3	15.2
"	5-6	1269	3	23.6
Total		17902	55	
P.S.	0-1	10218	6	5.9
N.Y.N.H.&H.	0-1	4000	53	132.5
Grand Total		347456	993	

90 LB. RAIL

SECTION	LIFE IN YEARS	TONS LAID	No. OF FAILURES	No. OF FAILURES PER 10000 TONS LD.
A.S.C.E.	0-1	13968	45	32.2
"	1-2	16870	47	27.9
"	2-3	14290	84	58.8
"	3-4	14143	53	37.4
"	4-5	5912	51	86.3
"	5-6	13751	78	56.7
"	6-7	13262	28	21.1
"	7-8	3091	15	48.5
"	8-9	3966	39	98.3
"	9-10			
"	10 & over			
Total		99253	440	
A.R.A.	0-1	10160	25	24.8 see *

75 LB. RAIL

SECTION	LIFE IN YEARS	TONS LAID	No. OF FAILURES	No. OF FAILURES PER 10000 TONS LAID
A.S.C.E.	0-1			
	1-2	12		
	2-3			
	3-4	4755	1	2.1
	4-5	7320	3	4.1
	5-6	10459	8	7.6
	6-7	31422	15	4.8
	7-8	2956		
	8-9	6504	1	1.5
	9-10	11017	4	3.6
	10+	154445	124	8.0
Total		228890	156	
B.&M.	4-5	4725	24	50.8
	5-6	3150	3	9.6
	6-7	6300	11	17.5
	7-8	3528	3	8.5
	8-9	2952	3	10.1
	9-10	4044	3	7.4
	10+	12364	2	1.6
Total		37063	49	
Grand Total		265953	205	

85 LB. RAIL

SECTION	LIFE IN YEARS	TONS LAID	No. OF FAILURES	No. OF FAILURES PER 10000 TONS LAID
P.R.R.	0-1	1282	23	179.3
"	7-8	888	1	11.3
"	8-9	1128	1	8.9
"	9-10			
"	10+	110403	172	15.6
Total		113701	197	
85 N.	1-2	4150	49	118.1
"	2-3	4150	19	45.8
Total		8300	68	
8506	0-1	36200	42	11.6
"	1-2	29700	41	13.8
"	2-3	50000	94	18.8
"	3-4	20000	40	20.0
"	4-5	40000	44	22.0
Total		175900	261	
852	0-1	30000	8	2.7
"	1-2	25000	4	1.6
"	2-3			
"	3-4	35000	10	2.9
Total		90000	22	
P.S.	0-1	7752	6	7.7
A.S.C.E.	0-1	161739	634	39.2
"	1-2	288200	699	24.2
"	2-3	305042	988	32.4
"	3-4	234062	552	23.6
"	4-5	137133	330	24.1
"	5-6	204114	1094	53.6
"	6-7	131450	258	19.6
"	7-8	140129	210	15.0
"	8-9	126437	460	36.4
"	9-10	100941	708	70.1
"	10+	6628	23	34.7
Total		1835875	5956	
Grand Total		2231528	6510	

80 LB. RAIL

SECTION	LIFE IN YEARS	TONS LAID	No. OF FAILURES	No. OF FAILURES PER 10000 TONS LAID
Dudley	6-7	700	1	14.3
"	10+	4100	3	7.3
Total		4800	4	
N.Y.C.	9-10	3500	11	31.5
A.S.C.E.	0-1	20976	28	13.4
"	1-2	10415	45	43.2
"	2-3	37758	131	34.7
"	3-4	43958	204	46.4
"	4-5	28641	32	11.1
"	5-6	113718	235	20.7
"	6-7	64583	119	18.4
"	7-8	92855	75	8.1
"	8-9	60524	179	29.5
"	9-10	25002	30	12.0
"	10+	107424	55	5.1
Total		605854	1133	
Grand Total		614154	1148	

90 LB. RAIL

*				
A.R.A. "A"	0-1	5100	2	3.9
A.R.A. "B"	0-1	5000	23	46.0

Totals

THE BALTIMORE AND OHIO RAILROAD COMPANY

~~THE BALTIMORE AND OHIO SOUTHWESTERN RAILROAD COMPANY~~

MAINTENANCE OF WAY DEPARTMENT

A L L Divisions

Position in Ingot of Steel Rails which failed for Period of Six months **ending** April 30th **1909**

A S C E **Type of Rail Section**

Sheet No. 1 **of** 2 **Sheets**

Kind of Failure		Carnegie Steel Co.								Edgar Thomson Mill							
		85 lb.								100 lb.							
		A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken	%	1.4	1.4	2.7				94.5	100								
	No	1	1	2				69	73								
Flow of Metal	%	16.0	4.0	14.0		2.0		64.0	100								
	No	8	2	7		1		32	50								
Crushed Head	%	15.7	1.6	11.8	5.3	.4	.4	64.9	100							100	100
	No	80	8	60	27	2	2	336	515							3	3
Split Head	%	2.8	1.2	1.6	.4	.4	.4	93.1	100								
	No	7	3	4	1	1	1	237	254								
Split Web	%	.9	2.0	3.9				93.1	100								
	No	1	2	4				106	113								
Broken Base	%							100	100								
	No							23	23								
Totals	%	9.7	1.6	7.7	2.8	.4	.3	77.7	100							100	100
	No	97	16	77	28	4	3	780	1028							3	3
		Maryland Steel Co. Co								Sparrows Point Mill							
Broken	%	16.5	4.7	2.3		2.3	2.3	72.1	100						16.7	83.3	100
	No	7	2	1		1	1	31	43						3	15	18
Flow of Metal	%			22.2		44.4		33.3	100	33.3		16.7	16.7	16.7		16.7	100
	No			2		4		3	9	2		1	1	1		1	7
Crushed Head	%	25.3	3.8	5.1	3.8	17.7		44.3	100	21.8		6.3	15.6	3.1	3.1	50.0	100
	No	20	3	4	3	14		36	80	7		2	5	1	1	16	32
Split Head	%	22.8	8.8	3.7	1.8	7.0	1.8	54.4	100	13.2	2.6		5.3			78.8	100
	No	13	5	2	1	4	1	31	57	5	1		2			30	38
Split Web	%	27.8			11.1	5.6		55.6	100	33.3						66.7	100
	No	5			2	1		10	18	1						2	3
Broken Base	%	25.0	25.0					50.0	100		33.3		33.3			33.3	100
	No	1	1					2	4		1		1			1	3
Totals	%	21.9	5.2	4.3	28.0	11.4	1.0	53.3	100	15.0	2.0	3.0	9.0	2.0	4.0	65.0	100
	No	46	11	9	6	24	2	113	211	15	2	3	9	2	4	65	100
		Cambria Steel Co								Johnstown Mill							
Broken	%							100	100							100	100
	No							33	33							12	12
Flow of Metal	%							100	100							100	100
	No							43	43							12	12
Crushe Head	%							100	100							100	100
	No							182	182							60	60
Split Head	%							100	100							100	100
	No							87	87							19	19
Split Web	%							100	100							100	100
	No							20	20							6	6
Broken Base	%							100	100							100	100
	No							11	11							3	3
Totals	%							100	100							100	100
	No							376	376							112	112

Kind of Failure		Illinois Steel Co.								South Chicago Mill							
		85 lb.								100 lb.							
		A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken	%																
	No																
Flow of Metal	%																
	No																
Crushed Head	%							100	100								
	No							1	1								
Split Head	%							100	100								
	No							5	5								
Split Web	%																
	No																
Broken Base	%																
	No																
Totals	%							100	100								
	No							6	6								
		National Steel Co								South Chicago Mill							
Broken	%							100	100								
	No							8	8								
Flow of Metal	%							100	100								
	No							1	1								
Crushed Head	%							100	100								
	No							5	5								
Split Head	%							100	100								
	No							2	2								
Split Web	%																
	No																
Broken Base	%							100	100								
	No							2	2								
Totals	%							100	100								
	No							18	18								
		Unknown Co								Mill							
Broken	%	33.3						66.7	100								
	No	1						2	3								
Flow of Metal	%																
	No																
Crushe Head	%																
	No																
Split Head	%							100	100								
	No							1	1								
Split Web	%																
	No																
Broken Base	%																
	No																
Totals	%	25.0						75.0	100								
	No	1						3	4								

Note - The letters A, B, C, etc denote the position of the Rail in the ingot, "A" being the top Rail, "B" the second, etc.

200 1-27-09

THE BALTIMORE AND OHIO RAILROAD COMPANY

~~THE BALTIMORE AND OHIO SOUTHWESTERN RAILROAD COMPANY~~

MAINTENANCE OF WAY DEPARTMENT

LI

A L L Divisions

Position in Ingot of Steel Rails which failed for Period of Six Months ending April 30th 1909

A. R. A. Type of Rail Section

Sheet No. 2 of 2 Sheets

Kind of Failure		Illinois Steel Co.								South Chicago Mill							
		90 lb. "A"								lb.							
		A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken	%																
	No																
Flow of Metal	%																
	No																
Crushed Head	%																
	No																
Split Head	%																
	No																
Split Web	%	100.							100.								
	No	1							1								
Broken Base	%																
	No																
Totals	%	100							100								
	No	1							1								

Kind of Failure		Bethlehem Steel Co. Co								South Bethlehem Mill							
		90 lb. "B"								lb.							
		A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken	%	25.0	50.0				25.0		100.								
	No	1	2				1		4								
Flow of Metal	%																
	No																
Crushed Head	%	44.4	22.2			11.1	11.1	11.1	100.								
	No	4	2			1	1	1	9								
Split Head	%	30.0	30.0	10.0	10.0	10.0		10.0	100.								
	No	3	3	1	1	1		1	10								
Split Web	%																
	No																
Broken Base	%																
	No																
Totals	%	34.8	20.4	4.3	4.3	8.7	8.7	8.7	100								
	No	8	7	1	1	2	2	2	23								

		Carnegie Steel Co.								Edgar Thomson Mill							
Broken	%																
	No																
Flow of Metal	%																
	No																
Crushed Head	%		100.						100.								
	No		1						1								
Split Head	%																
	No																
Split Web	%																
	No																
Broken Base	%																
	No																
Totals	%		100						100								
	No		1						1								

		Co								Mill							
Broken	%																
	No																
Flow of Metal	%																
	No																
Crushed Head	%																
	No																
Split Head	%																
	No																
Split Web	%																
	No																
Broken Base	%																
	No																
Totals	%																
	No																

		Co								Mill							
Broken	%																
	No																
Flow of Metal	%																
	No																
Crushe Head	%																
	No																
Split Head	%																
	No																
Split Web	%																
	No																
Broken Base	%																
	No																
Totals	%																
	No																

		Co								Mill.							
Broken	%																
	No																
Flow of Metal	%																
	No																
Crushe Head	%																
	No																
Split Head	%																
	No																
Split Web	%																
	No																
Broken Base	%																
	No																
Totals	%																
	No																

Note:- The letters A, B, C, etc. denote the position of the Rail in the ingot, "A" being the top Rail, "B" the second, etc.

CENTRAL RAILROAD COMPANY OF NEW JERSEY RAILROAD

Position in Ingot of Steel Rails which Failed, for Period of Six Months ending April 30th, 19 09

Sheet No
of Sheets

TYPE OF RAIL SECTION

Kind of Failure	Maryland Steel Co.								Sparrows Point Mill								Cambria Steel Co								Mill							
	90 lb. A.S.C.E.								85 lb.								90 lb. A.S.C.E.								85 lb.							
	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken	5	4	2	1		2	27	41															4	4								
Flow of Metal																																
Crushed Head		4		3	1	1	14	23															1	1								
Split Head	2						11	13															14	14								
Split Web	1	1			1	1	3	7																								
Broken Base	1							1																								
Totals	9	9	2	4	2	4	55	85															19	19								
	Lackawanna Steel Co.								Mill								Bethlehem Steel Co.								Open-Hearth Carbon Mill							
Broken	6	5	2	2	1	1	12	29										4	3	1			1	9								
Flow of Metal																																
Crushed Head	4		2	1			57	64																								
Split Head	1		1				18	20											1					1								
Split Web							6	6																								
Broken Base							7	7									1		1					2								
Totals	11	5	3	4	2	1	100	126									1	4	5	1			1	12								
	Carnegie Steel Co.								Mill								Bethlehem Steel Co.								Chrome Nickel Mill							
Broken																	3	6	2	1	2		4	18								
Flow of Metal																																
Crushed Head																																
Split Head																																
Split Web							1	1												1				1								
Broken Base																																
Totals							1	1									3	6	2	2			4	19								

CHICAGO, BURLINGTON & QUINCY RAILROAD

LIII

Position in Ingot of Steel Rails which Failed, for Period of six months ending April 30, 1909.

Sheet No

of Sheets

TYPE OF RAIL SECTION

Kind of Failure	Illinois Steel Co.								South Chicago Mill								Bethlehem Steel Co.								Bethlehem Mill							
	100 lb.								85 lb.								100 lb.								85 lb.							
	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken									2	5	3	2	1		47	60															1	1
Flow of Metal									1	1					9	11																
Crushed Head									11	1	2	1	4		49	68																
Split Head									15	9	4	1	3		47	79									1		1					2
Split Web									1						4	5															1	1
Broken Base										1	3	1	1		32	38										1						1
Totals									30	17	12	5	9		188	261									1	1	1				2	5
	Carnegie Steel Co.								Edgar Thomson Mill								Co.								Mill							
Broken												3	1		6	10																
Flow of Metal															2	2																
Crushed Head									1		2				30	33																
Split Head									1						17	18																
Split Web															3	3																
Broken Base															2	2																
Totals									2		2	3	1		60	68																
	Colorado Fuel & Iron Co.								Pueblo Mill								Co.								Mill							
Broken											1		2		9	12																
Flow of Metal															1	1																
Crushed Head															2	2																
Split Head															7	7																
Split Web																																
Broken Base																																
Totals											1		2		19	22																

LIV

LEHIGH VALLEY RAILROAD

Position in Ingot of Steel Rails which Failed, for Period of six months ending April 30, 1909.

Sheet No 1. of 1. Sheets

90 A.S.C.E. TYPE OF RAIL SECTION

Kind of Failure	90 lb.								85 lb.							
	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Bethlehem Steel Co. Mill																
Broken		2	1	1	2		24	30								
Flow of Metal																
Crushed Head	2			1	1		3	7								
Split Head	2			2	3		5	12								
Split Web				1	1			2								
Broken Base																
Totals	4	2	1	5	7		32	51								
Cambria Steel Co. Mill																
Broken							12	12								
Flow of Metal							1	1								
Crushed Head							16	16								
Split Head							4	4								
Split Web							5	5								
Broken Base							4	4								
Totals							42	42								
Maryland Steel Co. Mill																
Broken							6	6								
Flow of Metal																
Crushed Head	2		2				5	9								
Split Head							3	3								
Split Web							1	1								
Broken Base																
Totals	2		2				15	19								

Kind of Failure	90 lb.								85 lb.							
	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Lackawanna Steel Co. Mill																
Broken		1	1	3	1		34	40								
Flow of Metal							6	6								
Crushed Head	5	20		2	2		43	72								
Split Head	1	1		2			12	16								
Split Web							7	7								
Broken Base							76	76								
Totals	6	22	1	7	3		178	217								
Carnegie Steel Co. Mill																
Broken	1					1	34	36								
Flow of Metal							7	7								
Crushed Head							28	28								
Split Head					1		52	53								
Split Web					1		15	16								
Broken Base							6	6								
Totals	1				2	1	142	146								
Pennsylvania Steel Co. Mill																
Broken																
Flow of Metal																
Crushed Head							5	5								
Split Head																
Split Web							2	2								
Broken Base																
Totals							7	7								

NORFOLK and WESTERN RAILWAY RAILROAD LV

Position in ingot of Steel Rails which Failed, for Period of six months ending April 30, 1909.

TYPE OF RAIL SECTION

Sheet No

of Sheets

Kind of Failure	Cambria Steel Co.								Johnstown, Pa. Mill								Co.								Mill							
	100 lb.								85 lb.								100 lb.								85 lb.							
	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken															2	2																
Flow of Metal															2	2																
Crushed Head													1		11	12																
Split Head															6	6																
Split Web															2	2																
Broken Base															1	1																
Totals													1		24	25																
	Maryland Steel Co.								Sparrows Point, Md. Mill								Co.								75 lb. Mill							
Broken															3	3																
Flow of Metal															3	3															1	1
Crushed Head									1						8	9															7	7
Split Head															13	13															2	2
Split Web															5	5															2	2
Broken Base															2	2																
Totals									1						34	35															12	12
	Carnegie Steel Co.								Mill								Co.								Mill							
Broken										1					16	17																
Flow of Metal															4	4																
Crushed Head									1		2				23	26																
Split Head									1		1				19	21																
Split Web															7	7																
Broken Base															1	1																
Totals									2	1	3				70	76																

NORTHERN PACIFIC RAILROAD

LVI

Position in Ingot of Steel Rails which Failed, for Period of six months ending April 30, 1909.

A.S.C.E. TYPE OF RAIL SECTION

Sheet No 1 of 2 Sheets

Kind of Failure	Illinois Steel Co.								South Works, Chicago, Ill. Mill								Co.								Mill							
	72 lb.								85 lb.								100 lb.								85 lb.							
	A	B	C	O	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken							77	77	10	11	12	38	3	4	306	384																
Flow of Metal							1	1						1	27	28																
Crushed Head							13	13	1	2	3	2	1		62	71																
Split Head							11	11		2	2	2	2		70	78																
Split Web							2	2	1						17	18																
Broken Base							94	94	13	7	31	13	6	6	305	381																
Totals							198	198	25	22	48	55	12	11	787	960																
	72 lb. Lackawanna Steel Co.								85 lb. Mill								90 lb. Co.								Mill							
Broken							4	4	22	12	11	18	3	2	62	130	1	2	3				2	8								
Flow of Metal							1	1	1						1	2																
Crushed Head							5	5							11	11																
Split Head							5	5			1	2			11	14																
Split Web							2	2							2	2																
Broken Base							9	9	1	11	3	1			47	63																
Totals							26	26	24	23	15	21	3	2	134	222	1	2	3				2	8								
	72 lb. Lorain Steel Co.								85 lb. Mill								Co.								Mill							
Broken							5	5							4	4																
Flow of Metal																																
Crushed Head							1	1																								
Split Head															1	1																
Split Web																																
Broken Base															4	4																
Totals							6	6							9	9																

NORTHERN PACIFIC RAILROAD

LVII

Position in Ingot of Steel Rails which Failed, for Period of six months ending April 30, 1909.

TYPE OF RAIL SECTION

Sheet No. 2

of 2 Sheets

Kind of Failure	Carnegie Steel Co. Mill																Co. Mill															
	100 lb.								85 lb.								100 lb.								85 lb.							
	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken									9	2					29	40																
Flow of Metal															1	1																
Crushed Head															1	1																
Split Head															5	5																
Split Web																																
Broken Base															2	2																
Totals									9	2					38	49																
	Co. Mill																Co. Mill															
Broken																																
Flow of Metal																																
Crushed Head																																
Split Head																																
Split Web																																
Broken Base																																
Totals																																
	Co. Mill																Co. Mill															
Broken																																
Flow of Metal																																
Crushed Head																																
Split Head																																
Split Web																																
Broken Base																																
Totals																																

PENNSYLVANIA RAILROAD -- LINES EAST RAILROAD

LVIII

Position in Ingot of Steel Rails which Failed, for Period of six months ending April 30, 1909.

Sheet No. 3 of 4 Sheets

P. S. TYPE OF RAIL SECTION

Kind of Failure	Cambria Co. Johnstown Mill																Co. Mill															
	100 lb.								85 lb.								100 lb.								85 lb.							
	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken													2			2																
Flow of Metal																																
Crushed Head	1				1			2																								
Split Head	1	1		1				3		1			1			2																
Split Web											2					2																
Broken Base																																
Totals	2	1		1	1			5		1	2		3			6																

	Co. Mill																Co. Mill															
Broken																																
Flow of Metal																																
Crushed Head																																
Split Head																																
Split Web																																
Broken Base																																
Totals																																

	Co. Mill																Co. Mill															
Broken																																
Flow of Metal																																
Crushed Head																																
Split Head																																
Split Web																																
Broken Base																																
Totals																																

PHILADELPHIA AND READING RAILROAD

LIX

Position in Ingot of Steel Rails which Failed, for Period of six months ending April 30, 1909.

Sheet No.______

of______ Sheets

A.S.C.E. TYPE OF RAIL SECTION

Kind of Failure	Maryland Steel Co. Mill															
	90 lb.								85 lb.							
	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken	4	2	1	3	1		7	18								
Flow of Metal	52	46	34	23	14		1	170								
Crushed Head	26	16	21	14	11		1	89								
Split Head	20	2	0	2	3		4	31								
Split Web	2	2	1	3	3		3	14								
Broken Base	2	4	5	9	11		0	31								
Totals	106	72	62	54	43		16	353								

Kind of Failure	Co. Mill															
	100 lb.								85 lb.							
	A	B	C	D	E	F	Unknown	Total	A	B	C	D	E	F	Unknown	Total
Broken																
Flow of Metal																
Crushed Head																
Split Head																
Split Web																
Broken Base																
Totals																

	Co. Mill															
Broken																
Flow of Metal																
Crushed Head																
Split Head																
Split Web																
Broken Base																
Totals																

	Co. Mill															
Broken																
Flow of Metal																
Crushed Head																
Split Head																
Split Web																
Broken Base																
Totals																

	Co. Mill															
Broken																
Flow of Metal																
Crushed Head																
Split Head																
Split Web																
Broken Base																
Totals																

	Co. Mill															
Broken																
Flow of Metal																
Crushed Head																
Split Head																
Split Web																
Broken Base																
Totals																

THE BALTIMORE & OHIO RAILROAD CO.

~~THE BALTIMORE & OHIO SOUTHWESTERN RAILROAD CO~~

MAINTENANCE OF WAY DEPARTMENT.

A L L Divisions

Record of Comparative Wear of Special Rail.

LX

Date of Report April 30th 19 09.

Special Rail													Chemical Composition of Md. Stl. Co. Bessemer Rail of A.S.C.E. Section with which Special Rail was compared							Special and Comparitive Rail						
Kind of Steel.	Location	Number of Tons Laid in test	Weight per Yard	Type of Section	Manufacturer	Chemical Composition.														Date Laid	Date Removed	Length of Service at Date of Report	Average Area Abraded of all the Sections taken			
																							Special		Comparitive	
						C	P	Mn	Si	S	N		C.	P	Mn.	Si	S.						Sq in. Abraded	% of area of Head	Sq in Abraded	% of area of Head.
Titanium Alloy	Kesslers Curve	7.9	100#	A S CE	Md. Steel Co	.701	.086	.92	.079	.048	.004	1½%	.54	.069	1.01	.074	.073			10-10-08	In Trk	6 mo.	H R .115 L R .0435	H R 2.81 L R 1.07	H R .240 L R .132	H R 6.006 L R 3.303
													Cambria Steel Co Bessemer ASCE Rail													
Bessemer Special Roll	East of Hollifield, Md.	7.95	85#	A S CE	Penna Stl Co	.472	.024	.79		.062	Cr .21		.505	.0975	.945	.066	.0625			9-17-08	Do.	15½ Mo	H R .41 L R .19	H R 11.84 L R 5.44	H R .30 L R .16	H R 9.06 L R 4.47
													Carnegie Steel Co Bessemer ASCE Rail													
Bessemer	East of Union Dam Tunnel	12.83	85#	A S CE	Penna Stl Co	.472	.024	.79		.062	.21		.485	.093	.95	.20	.047			9-17-08	Do.	15½ Mo	H R .27 L R .10	H R 7.87 L R 2.92	H R .17 L R .06	H R 5.13 L R 1.81
													Cambria Steel Co Bessemer ASCE Rail													
Bessemer	East of Union Dam Tunnel	12.83	85#	A S CE	Penna Stl Co	.472	.024	.79		.062	.21		.505	.0975	.945	.066	.0625			9-17-08	Do	15½ Mo	H R .27 L R .10	H R 7.87 L R 2.98	H R .18 L R .06	H R 5.41 L R 1.79

LXI

Pennsylvania R.R- Lines East RAILROAD

Sheet #2 of 2sheets

Record of Comparative Wear of Special Rail

Date of Report April 30 1909

Special Rail													Chemical Composition of .... Rail of .... Section with which Special Rail was Compared							Special and Comparative Rails						
Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Chemical Composition														Date Laid	Date Removed	Length of Service at date of Report	Average Area Abraded of all the Sections taken			
																							Special		Comparative	
						C	P	Mn	Si	S	Ni.	Cr.	C	P	Mn	Si	S						Sq. In. abraded	% of area of Head	Sq. In. abraded	% of area of Head
	Tyrone Div												Carnegie Bessemer													
Mayari	Gardner	3.97	80	A.S.C.E.	Maryland	.51	.026	.87				.17	.50	.08	1.00	.13				10-07	10-08	1y-1m	0.63	19.7	0.57	14.8
"	"	12.30	85	P.R.R.	"	"	"	"					"	"	"	"				10-07	10-08	1y-1m	0.53	13.7	0.57	14.8
	Pittsburgh Dir.												Cambria Bessemer													
Nickel	Kittanning Pt.	2.92	100	P.R.R.	Carnegie	.51	.092	.84	.11	.046	3.25		.50	.08	1.00	.13				9-03	7-04	0y-10m	0.79	17.5	0.76	18.7
"	Pittsburgh	20.83	"	"	"	"	"	"	"	"	"									6-03	6-05	2y-0m	0.55	12.2		
"	Donohoe	50.09	"	"	"	"	"	"	"	"	"									8-04	1-06	1y-5m	0.63	13.9		
"	Kittanning Pt.		"	A.S.C.E.	"	.50	.094	1.00	"	"	3.22									1-00	3-06	6y-2m	1.21	29.8		
"	Sang Hollow	68.13	"	P.R.R.	"	.51	.092	.84	.11	.046	3.25									8-03	6-07	3y-10m	0.72	15.9		
"	Altoona	30.00	"	A.S.C.E.	"	.50	.094	1.00	"	"	3.22									1-00	4-07	7y-3m	1.12	27.6		
Mayari	Kittanning Pt.		"	P.R.R.	Maryland	.65	.019	.94				.23	.50	.096	.84	.104	.045			9-07	3-08	0y-6m	0.74	16.4	0.81	17.9
"	" "	46.55	"	"	"	"	"	"				"	"	"	"	"	"			4-06	11-08	2y-7m	1.88	42.3	2.27	50.2

Appendix D.

CHARACTERISTIC RAIL FAILURES.

(Bulletin 116.)

The Secretary on April 3, 1909, issued Circular No. 114, calling for photographs of typical characteristic rail failures, illustrating and corresponding to the adopted classification which is printed on the back of form M. W. 2002-A. Comparatively few responses were received in reply to the circular. There is submitted herewith abstracts of a number of the reports received, and also reproductions of the photographs accompanying them. Some of the photographs furnished did not contain sufficient information to justify using them, and some were too indistinct to be of service.

An examination of the reports and photographs has brought out the following points, to which your attention is invited:

(1) When the classification was originally proposed, it was the intention that all rails which broke in service, or which had a straight crack working from top to bottom, or from bottom to top, which would very quickly result in a broken rail, should be classified as "broken rails," regardless of internal defects. All of the other defective rails which were removed, not being "broken" or damaged on account of wrecks, were to be classified under one of the other heads, from 3 to 7, both inclusive. It has developed, however, from the reports received by the Committee, that sometimes a rail broken in service which has shown a cavity in the head has been called a "split head" instead of a "broken rail," and that sometimes a rail with a crescent piece out of the base has been called a "broken rail." Doubtless these classifications are strictly true from one point of view, but they are not true from the point of view of the adopted classification, and that classification should be in force until changed by the Association.

(2) The rail manufacturers have claimed that the heavy wheel loads might crush down the head by reason of overloading or overstressing the metal without the presence of any internal defect causing the failure, and classification No. 4, "crushed head," was made with the intention of ascertaining whether such was the fact or not. In these reports every case of crushed head, when the rail was cut open, shows that it was accompanied by an internal defect and it should have been classed as "split head" rather than "crushed head." It was supposed that a crushed head might be considered the fault of the railroad company, while the "split head," full of seams and cavities, which we call "pipes," would be clearly the fault of the manufacturer. It seems advisable to the Committee at present to continue the classification of "crushed head" in order to ascertain if any examples can be found where good metal has been caused to fail by overloading and overstressing.

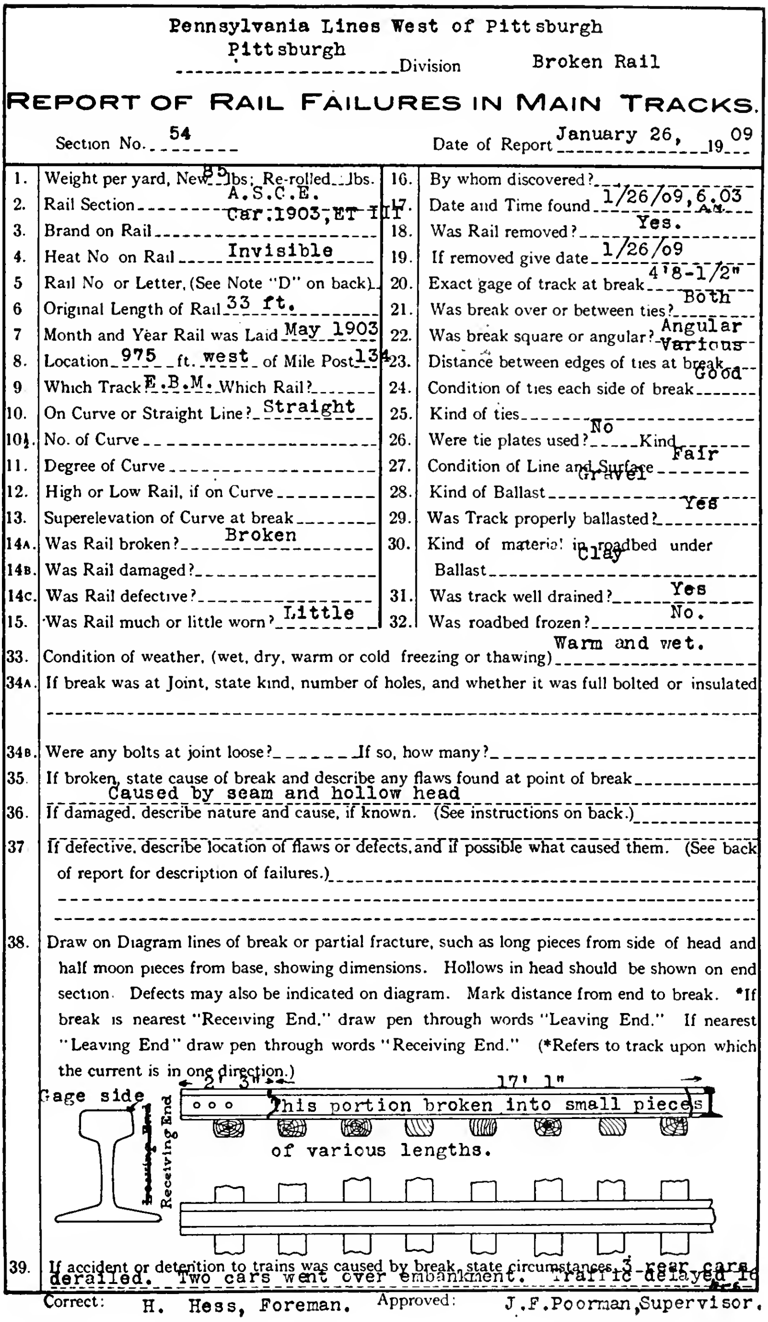
The Committee deems it desirable to call especial attention to examples of reports and photographs of the Rock Island Lines and the Pennsylvania Railroad Company, as the information furnished by those companies is more complete than that furnished by most of the other companies. Some of the photographs, however, furnished by the Pennsylvania Railroad Company are not quite as good as some of those furnished by some other companies.

The report on the next page is in the form adopted by the Association and is exhibited as an example of properly filled out report. In order to save printing the information from other reports was condensed into the form shown herewith.

We recommend that each member securing a copy of this report make it a matter of special consideration to secure good examples of rail failures to be photographed and reported to the Committee for further study.

Respectfully submitted,

CHAS. S. CHURCHILL, *Chairman.*



Pennsylvania Lines West of Pittsburgh

Pittsburgh Division Broken Rail

REPORT OF RAIL FAILURES IN MAIN TRACKS.

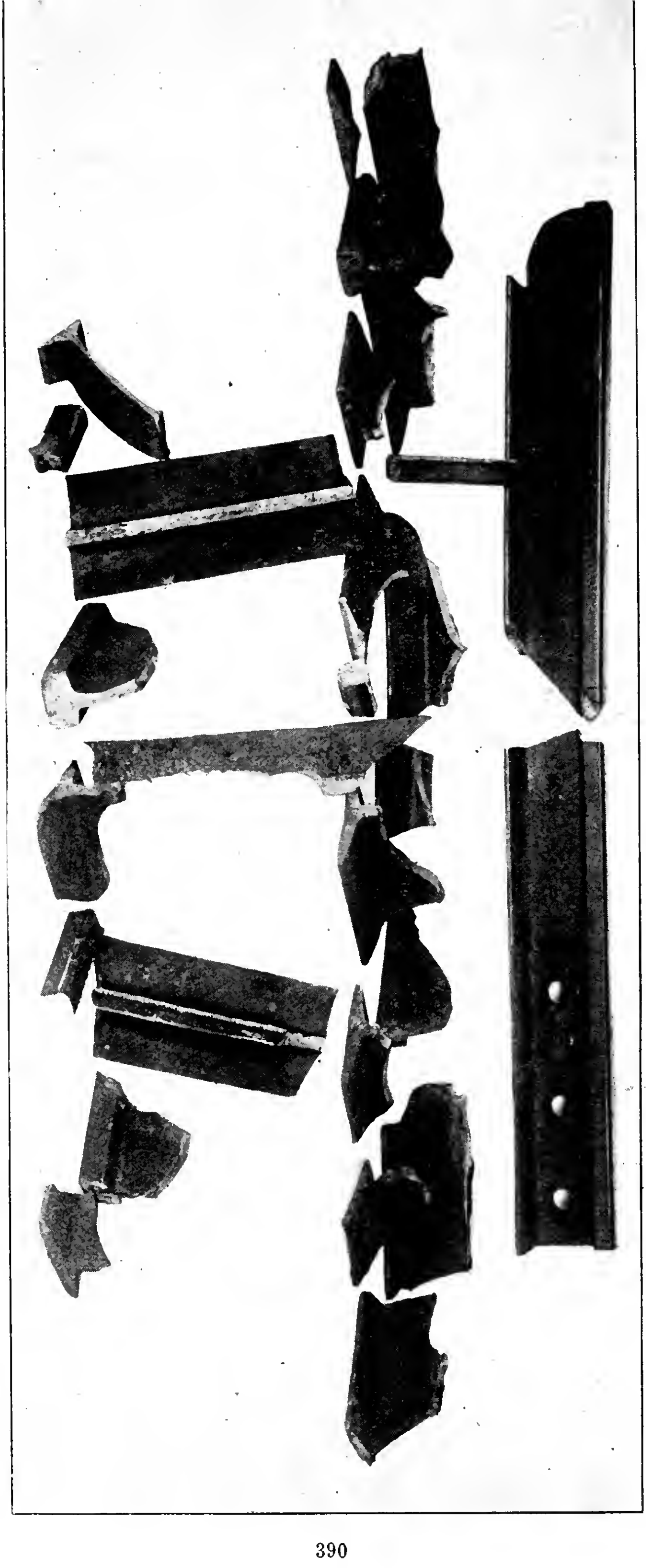
Section No. 54 Date of Report January 26, 1909

1. Weight per yard, New 85 lbs; Re-rolled lbs.
2. Rail Section A.S.C.E.
3. Brand on Rail Car.1903,ET III
4. Heat No on Rail Invisible
5 Rail No or Letter, (See Note "D" on back)
6 Original Length of Rail 33 ft.
7 Month and Year Rail was Laid May 1903
8. Location 975 ft. west of Mile Post 134
9 Which Track E.B.M. Which Rail?
10. On Curve or Straight Line? Straight
10½. No. of Curve
11. Degree of Curve
12. High or Low Rail, if on Curve
13. Superelevation of Curve at break
14A. Was Rail broken? Broken
14B. Was Rail damaged?
14C. Was Rail defective?
15. Was Rail much or little worn? Little
16. By whom discovered?
17. Date and Time found 1/26/09, 6.03 A.M.
18. Was Rail removed? Yes.
19. If removed give date 1/26/09
20. Exact gage of track at break 4'8-1/2"
21. Was break over or between ties? Both
22. Was break square or angular? Angular
23. Distance between edges of ties at break Various
24. Condition of ties each side of break Good
25. Kind of ties
26. Were tie plates used? No Kind
27. Condition of Line and Surface Fair
28. Kind of Ballast Gravel
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? No.
33. Condition of weather, (wet, dry, warm or cold freezing or thawing) Warm and wet.
34A. If break was at Joint, state kind, number of holes, and whether it was full bolted or insulated
34B. Were any bolts at joint loose? If so, how many?
35. If broken, state cause of break and describe any flaws found at point of break Caused by seam and hollow head
36. If damaged, describe nature and cause, if known. (See instructions on back.)
37. If defective, describe location of flaws or defects, and if possible what caused them. (See back of report for description of failures.)
38. 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 is in one direction.)

This portion broken into small pieces of various lengths.

39. If accident or detention to trains was caused by break, state circumstances. 3 rear cars derailed. Two cars went over embankment. Traffic delayed 16

Correct: H. Hess, Foreman. Approved: J.F.Poorman, Supervisor.



ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

Classification: BROKEN RAIL.

1. Weight per yard: 85 lbs.
3. Brand: Carnegie, 2-1907.
10. On curve or straight line: Curve.
35. Cause of break and description of flaws: Unknown.

LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

Location of borings, head.

	Head.	Web.
Carbon	0.569	0.553
Manganese	0.97	0.97
Phosphorus	0.095	0.086
Silicon	0.084	0.084
Sulphur	0.036	0.035

Metal is comparatively sound and analyses throw very little light on the cause of the fracture.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

Classification: BROKEN RAIL.

1. Weight per yard: 100 lbs.
2. Section: P. R. R. Standard.
3. Brand: Cambria, 1905 VIII.
7. Month and year laid: Fall of 1905.
10. On curve or straight line: On curve.
14a. Rail was broken.
15. Rail was little worn.
21. Break occurred at west edge of tie.
22. Break was square.
32. Roadbed was not frozen.
35. Rail snapped under train. Rail was of good section, being worn down evenly on top 1/8 in. less than original height. Top of rail showed slight marks, indicating that an engine had slipped wheels, and this may have contributed to fracture.

LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

	Head.	Web.
Carbon	0.525	0.485
Manganese	0.98	0.96
Phosphorus	0.09	0.078
Silicon	0.10	0.09
Sulphur	0.077	0.067

The sample shows a break through apparently sound metal. The analyses do not show segregation, and there is nothing in them to explain the failure of this rail.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ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

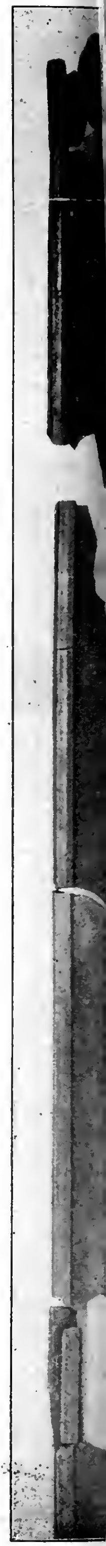
Classification: BROKEN RAIL.

1. Weight per yard: 85 lbs.
3. Brand: Carnegie, 1903.
10. On curve or straight line: Straight line.
14a. Rail broken: Yes.
14c. Rail defective: Pipe defect.
35. Cause of break and description of flaws: Rail broke into more than 18 pieces and had evidently been broken during the night.
37. Location of flaws and cause: Pipe defect; no defect noticed on top of rail, where defect usually appears.

LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

	Head.	Web.	Base.	Cross-section.
Carbon	0.56	0.74	0.58	0.61
Manganese	1.07	1.07	1.19	1.12
Phosphorus	0.088	0.147	0.092	0.099
Silicon	0.10	0.08	0.09	0.08
Sulphur	0.038	0.071	0.036	0.042

Pipe in head extending to within 1-16 in. of running surface. Tensile strength of metal in head and base ranges from 100,600 to 113,800 lbs. per sq. in., and elongation from 3 to 5 per cent. in 2 in., while in the web the portion nearest the head shows 74,800 lbs. per sq. in. and 1 per cent. elongation, and that nearest the base 78,700 lbs. per sq. in. and 1 per cent. elongation. The low tensile strength and elongation in the web is what might be expected from the composition, which shows high segregation in the web. This seems to be clearly a case of a piped rail rolled from the insufficiently cropped end of the ingot, and this appears to be practically the only cause of the failure.



ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

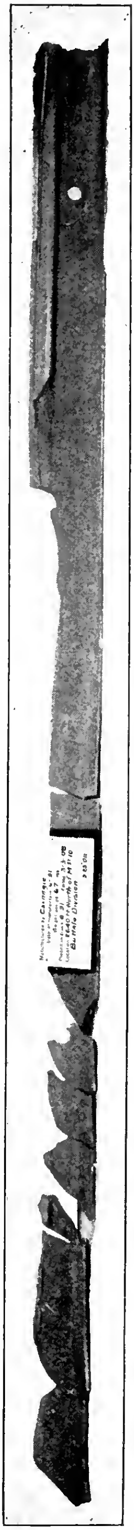
Classification: BROKEN RAIL.

1. Weight per yard: 67 lbs.
2. Section: A. S. C. E.
3. Brand: Carnegie, 6-1891.
5. Rail No. or Letter: E. T.
7. Month and year laid: 6-1891.
10. On curve or straight line: Curve.
14a. Rail broken: Broken.
15. Rail much or little worn: Little.
21. Break over or between ties: Over and between ties.
22. Break square or angular: Square.
32. Roadbed frozen: Yes.
35. Cause of break and description of flaws: Pipe in head.

LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

	Head.	Web.
Carbon	0.334	0.404
Manganese	0.33	0.36
Phosphorus	0.105	0.172
Silicon	0.03	0.026
Sulphur	0.017	0.042

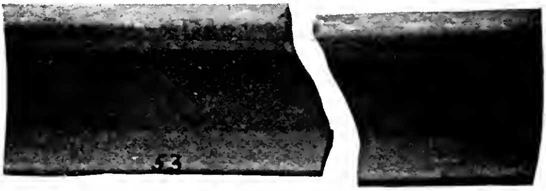
Rail broke into 37 pieces. Piece from gage side of head apparently broke off first. A vertical fissure in the head is clearly defined. It will be noted from the analysis that the carbon, phosphorus and sulphur are considerably higher in the metal taken from the web, indicating marked segregation. Apparently this rail was made from steel too near the pipe end of the ingot. We are inclined to think that the vertical fissure in the head resulted from the segregated condition of the metal.



ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

Classification: BROKEN RAIL.

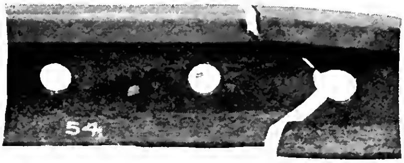
1\. Weight per yard: 85 lbs.
2\. Section: A. S. C. E.
3\. Brand: Carnegie, E. T., 3-04.
7\. Month and year laid: 3-1904.
10\. On curve or straight line: Straight.
14a. Rail broken: Broken.
15\. Rail much or little worn: Little.
21\. Break over or between ties: Over tie.
22\. Break square or angular: Angular.
32\. Roadbed frozen: Yes.
35\. Cause of break and description of flaws: No flaw at point of break.



ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

Classification: BROKEN RAIL.

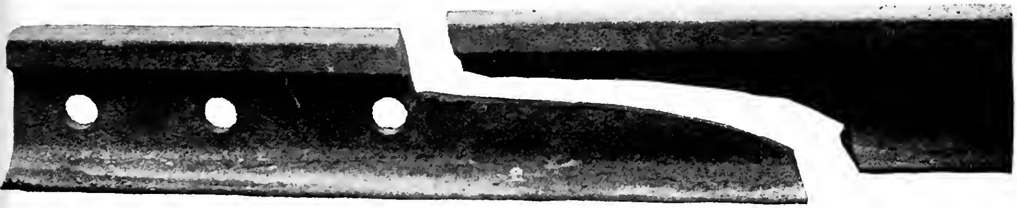
1\. Weight per yard: 85 lbs.
2\. Section: A. S. C. E.
3\. Brand: Carnegie, E. T., 5-04.
7\. Month and year laid: 7-04.
10\. On curve or straight line: Straight.
14a. Rail broken: Yes.
15\. Rail much or little worn: Little.
21\. Break square or angular: Angular.
32\. Roadbed frozen: No.
35\. Cause of break and description of flaws: Rail broken in joint 5½ in. from end. The only cause that can be given for the breaking of this rail is a weak place in rail joint; no flaws found in rail at point of break.



ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

Classification: BROKEN RAIL.

1. Weight per yard: 85 lbs.
2. Section: A. S. C. E.
3. Brand: Carnegie, E. T., 9-04.
7. Month and year laid: 9-04.
10. On curve or straight line: Straight.
14a. Rail broken: Broken.
15. Rail much or little worn: Much worn.
21. Break square or angular: Angular.
35. Cause of break and description of flaws: Split in web, and broke 24 in. from end under ball and through web. Cause not known.



Classification: BROKEN RAIL.

Kansas City Belt Railway.
Broken in 10 pieces.
1. Weight per yard: 75 lbs.
2. Section: A. S. C. E.
10. On curve or straight line: On 17 degree curve.
21. Square break.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—........ RAILROAD.

Classification: BROKEN RAIL.

1. Weight per yard: 80 lbs.
3. Brand: 80 A. S., 12-06.
7. Month and year laid: 1-07.
10. On curve or straight line: Curve.
14a. Rail broken: Broken.
15. Rail much or little worn: Little.
21. Break square or angular: Angular.
32. Roadbed frozen: No.
37. Location of flaws or defects and cause: The only defect noticed was a small flaw on top of rail head. Old crack found after rail broke. Cracks were 7 ft. apart.

LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

Location of borings, center of head.

	Laboratory Analysis.	Specifications.	Inspector's Report.
Carbon	0.77	0.55-0.65	0.64
Manganese	1.03	0.80-1.10	0.82
Phosphorus	0.131	0.06	0.041
Silicon	0.030	0.20	0.009
Sulphur	0.037		0.29

Drop-test deflection, 2.2 in.
Height of drop, 18 ft.
Weight of tup, 2,000 lbs.
Supports, 3 ft.

An etching of a polished section of this rail showed no dangerous unsoundness, though it did give evidence that the rail was of steel from toward the upper part of ingot.

The percentages of phosphorus, carbon and manganese indicate a hardness and necessarily corresponding brittleness which would render the rail unsafe for use, and when taken in conjunction with the presence of the piping or unwelded seam, which is indicated in the photographs of the broken rail, the cause of the compound fracture is apparent.

[illegible]

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—SOUTHERN PACIFIC COMPANY.

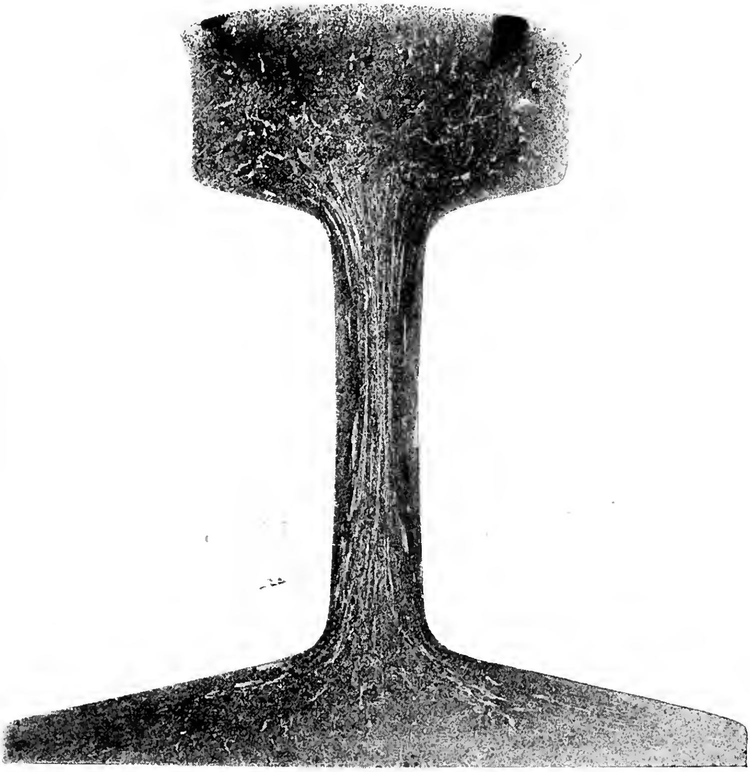
Classification: BROKEN RAIL.

1. Weight per yard: 75 lbs.
2. Section: Southern Pacific Standard.
3. Brand: Carnegie, E. T., 12-05.
7. Month and year laid: October, 1906.
10. On curve or straight line: Curve.
14a. Rail broken: Broken.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
21. Break square or angular: Angular.
32. Roadbed frozen: No.
35. Cause of break and description of flaws: Flaw in web of rail.
37. Location of flaws or defects and cause: Flaw in web of rail right at break.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—OREGON SHORT LINE.

Classification: BROKEN RAIL.

1. Weight per yard; 80 lbs.
2. Section: A. S. C. E.
3. Brand: C. F. & I. Co.
7. Month and year laid: March, 1905.
10. On curve or straight line: Straight.
14a. Rail broken: Broken.
21. Break square or angular: Square.
35. Cause of break and description of flaws: Poor material.



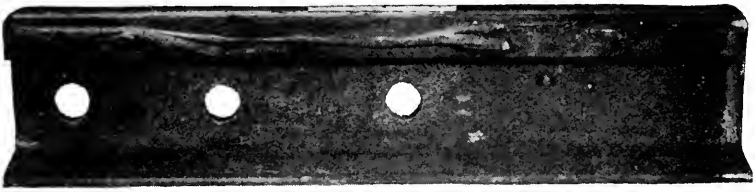
REPORT OF RAIL FAILURES IN MAIN TRACKS—ILLINOIS CENTRAL RAILROAD.

Classification: BROKEN RAIL.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

Classification: FLOW OF METAL.

1. Weight per yard: 100 lbs.
2. Section: Pennsylvania Railroad.
3. Brand: Maryland, 11-06.
7. Month and year laid: 1907.
10. On curve or straight line: Curve.
14c. Rail defective: Yes.



LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

	Head.	Web.	Base.
Carbon	0.49	0.51	0.52
Manganese	0.98	1.07	0.98
Phosphorus	0.056	0.062	0.061
Silicon	0.08	0.092	0.078
Sulphur	0.103	0.116	0.096

It will be noted that the carbon, phosphorus, manganese and sulphur are a little higher in the metal taken from the web, indicating a certain amount of segregation. The difference in the chemical composition of the different parts of the section is not very great, and the amount of segregation is rather small. There is no evidence of the presence of a pipe in this rail. The chemical composition of the steel in general is about what would be expected, and does not appear to account for the peculiar way that this rail has worn.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

Classification: FLOW OF METAL.

1. Weight per yard: 100 lbs.
2. Section: A. S. C. E.
3. Brand: Carnegie, E. T., 6-06.
7. Month and year laid: July, 1906.
10. On curve or straight line: Curve.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
32. Roadbed frozen: No.
37. Location of flaws or defects and cause: 4 ft. from end head crushed for 5-ft. flaw. (Should be "Flow of Metal.")

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

Classification: FLOW OF METAL.

1. Weight per yard: 100 lbs.
2. Section: A. S. C. E.
3. Brand: Carnegie, E. T., 6-06.
7. Month and year laid: July, 1906.
10. On curve or straight line: Curve.
14c. Rail defective: Yes.
15. Rail much or little worn: None.
32. Roadbed frozen: No.
37. Location of flaws or defects and cause: 9 ft. of ball of rail was flattened 5 ft. from end; 7 ft. of a seam in ball slightly split; split 10 in. long on inside of ball.

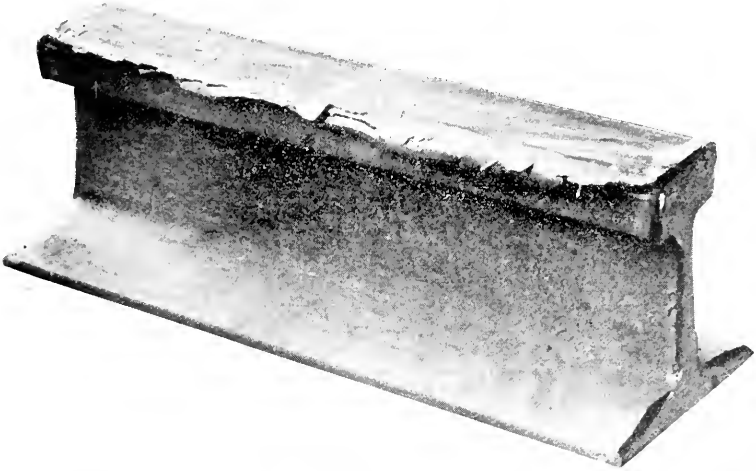
ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—UNION PACIFIC RAILROAD.

Classification: FLOW OF METAL.

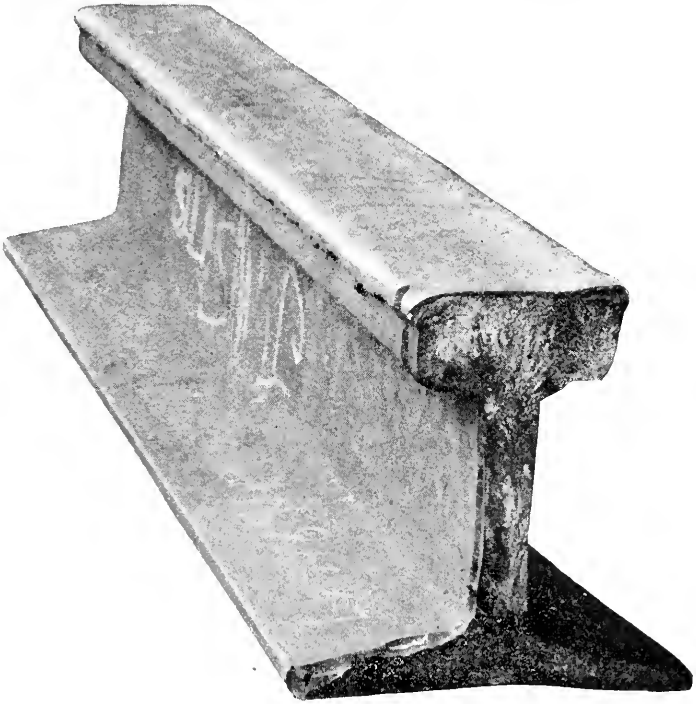
1. Weight per yard: 90 lbs.
2. Section: C. S.
3. Brand: Carnegie Steel Company.
7. Month and year laid: 1907.
10. On curve or straight line: Straight line.

REPORT OF RAIL FAILURES IN MAIN TRACKS—ILLINOIS CENTRAL RAILROAD.

Classification: FLOW OF METAL.



85-lb. Rail from Dubuque Division, Mile 191. Bessemer, rolled at South Chicago by Illinois Steel Company, May, 1907, and laid November, 1907, taken out January, 1908. Rail was on a six-degree curve, one-half inch wide gage. The chemical analysis is as follows, which shows 11 per cent. high in Carbon and .14 per cent. high in Manganese: Carbon, .600; Phosphorus, .111; Silicon, .087; Manganese, .660.



85-lb. Rail from Dubuque Division, Mile 169. Bessemer rail. Rolled at South Chicago, Illinois Steel Company, August, 1906; laid in track October same year; removed January, 1908. Rail was on a six-degree curve, one-half inch wide gage; rail badly flowed. The chemical analysis is as follows, which is all right except Carbon, which is .02 per cent. high; Carbon, .600; Phosphorus, .084; Silicon, .132; Manganese, 1.02.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

Classification: CRUSHED HEAD.

1. Weight per yard: 85 lbs.
3. Brand: Carnegie, E. T., 1900.
10. On curve or straight line: Straight line.
14c. Rail defective: Mashed and split head.
37. Location of flaws or defects and cause: Piped rail, head split through and mashed down, crack open over ½ in.

LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

	Head.	Web.
Carbon	0.458	0.551
Manganese	0.83	0.88
Phosphorus	0.071	0.126
Silicon	0.108	0.070
Sulphur	0.024	0.046

The analyses show quite serious segregation, especially in the phosphorus. Pipe in head, which was split through and mashed down; crack open ½ in.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

Classification: CRUSHED HEAD.

1. Weight per yard: 85 lbs.
3. Brand: Maryland, 1904.
10. On curse or straight line: Curve.
14c. Rail defective: Flaw in rail.
35. Cause of break and description of flaws: Rail split for about 5 ft. in center of ball.
37. Location of flaws or defects and cause: Pipe in center of head, head broken down on gage side.

LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

	Head.	Web.
Carbon	0.448	0.509
Manganese	0.81	0.87
Phosphorus	0.041	0.070.
Silicon	0.042	0.052
Sulphur	0.034	0.065

The analyses show quite considerable segregation. Pipe in center of head, which was broken down on gage side.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

Classification: CRUSHED HEAD.

1. Weight per yard: 85 lbs.
2. Section: P. S.
3. Brand: Carnegie, E. T., 2-09.
7. Month and year laid: May, 1909.
10. On curve or straight line: Curve.
14c. Rail defective: Yes.
15. Rail much or little worn: None.
32. Roadbed frozen: No.
35. Cause of break and description of flaws: Split was not apparent until rail was cut.
37. Location of flaws or defects and cause: Crushed head. Black streak in center of head commencing at end of rail and running back 8 ft. Long crack underneath head, caused by bad material in rail.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

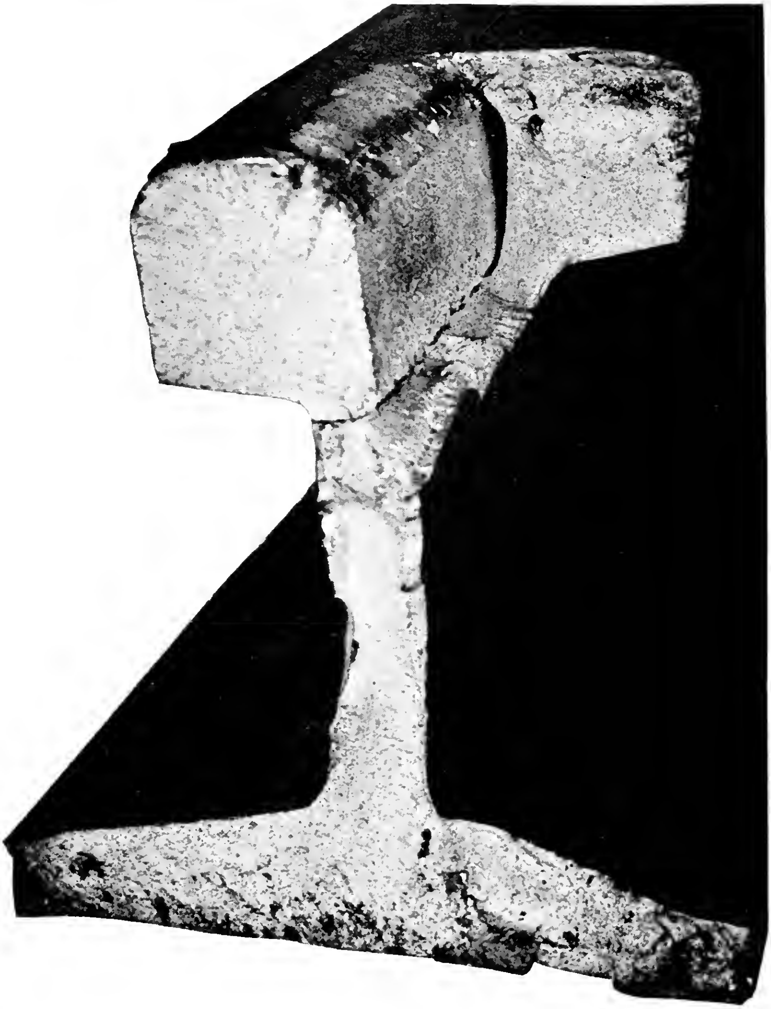
Classification: CRUSHED HEAD.

1. Weight per yard: 85 lbs.
2. Section: P. S.
3. Brand: Carnegie, E. T., 2-09.
7. Month and year laid: May, 1909.
10. On curve or straight line: Curve.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
32. Roadbed frozen: No.
35. Cause of break and description of flaws: This rail seems to have been crushed on account of flaw in head; also soft material.
37. Location of flaws or defects and cause: Started to flatten 8 ft. from end and run flat for 5 ft. Starts again 15 ft. from end and runs flat 4 ft. 6 in.; starts again 24 ft. from end and runs flat 4 ft. 6 in.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

Classification: CRUSHED HEAD.

1. Weight per yard: 85 lbs.
2. Section: P. S.
3. Brand: Carnegie, E. T., 2-09.
5. Rail No. or Letter: C. C.
7. Month and year laid: May, 1909.
10. On curve or straight line: Curve.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
32. Roadbed frozen: No.
37. Location of flaws or defects and cause: This rail started to crush 4 ft. from end and run flat 5 ft. 6 in.; started again 13 ft. 6 in. from end and run flat for 3 ft. 6 in.; cause, flaw in manufacture and soft material.



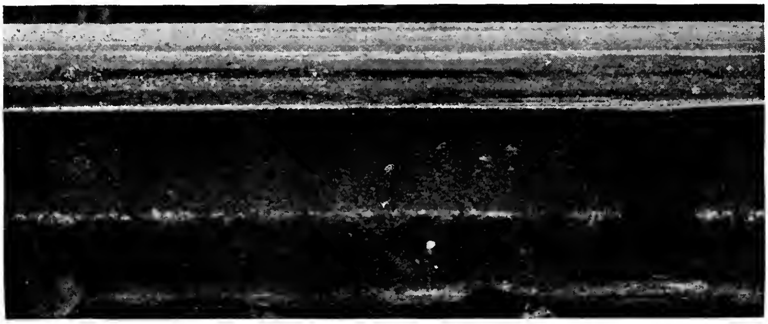
ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

Classification: CRUSHED HEAD.

1. Weight per yard: 85 lbs.
2. Section: P. S.
3. Brand: Carnegie, E. T., 2-09.
5. Rail No. or Letter: C. C.
7. Month and year laid: May, 1909.
10. On curve or straight line: Curve.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
32. Roadbed frozen: . No.
35. Cause of break and description of flaws: This rail seems to have crushed on account of flaw in head and soft material.
37. Location of flaws or defects and cause: Rail started to flatten one foot from end and run flat for 16 ft.

REPORT OF RAIL FAILURES IN MAIN TRACKS—ILLINOIS CENTRAL RAILROAD.

Classification: CRUSHED HEAD.



85-lb. Rail from Tennessee Division, Mile 257. Laid September, 1907, rolled by Tennessee Coal & Iron Company at Birmingham, Ala. Open-hearth, removed same month, cause of failure pipe which extended the full length of the rail. The following is the chemical analysis, which shows Carbon .04 per cent. high, Phosphorus .057 per cent. high, and Manganese .05 per cent. low. Carbon, .690; Phosphorus, .117; Silicon, .009; Manganese, .750.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

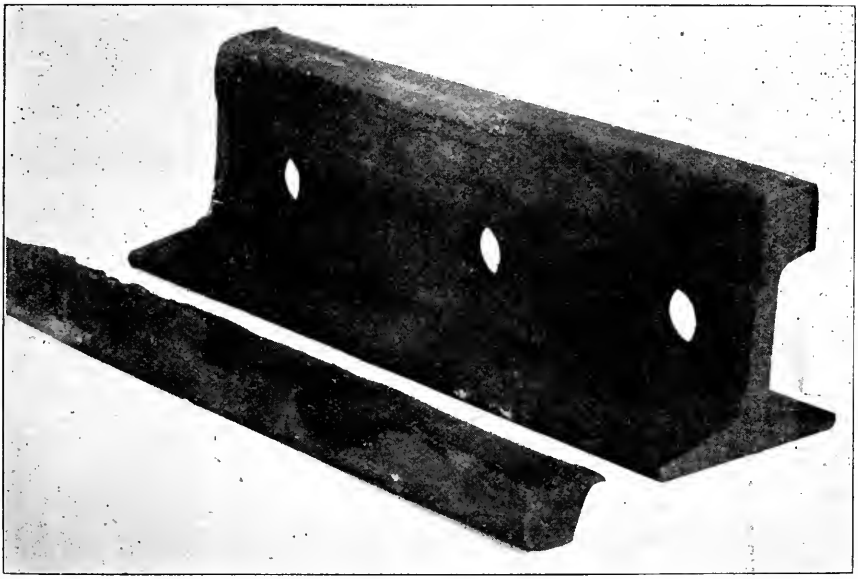
Classification: SPLIT HEAD.

1. Weight per yard: 85 lbs.
3. Brand: Carnegie, 1900.
10. On curve or straight line: Curve.
14c. Rail defective: Split head.
37. Location of flaws or defects and cause: Clear case of piping; head split through.

LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

	Head.	Web.
Carbon	0.471	0.591
Manganese	0.79	0.83
Phosphorus	0.085	0.140
Silicon	0.084	0.080
Sulphur	0.021	0.037

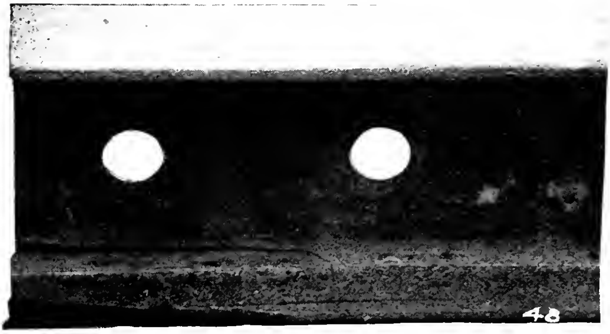
The analyses clearly show serious segregation, and apparently internal physical defects in the head where the head is split off.

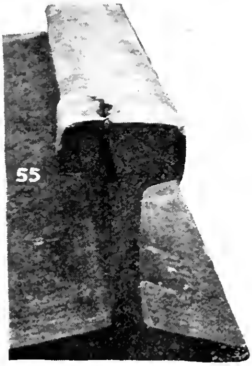


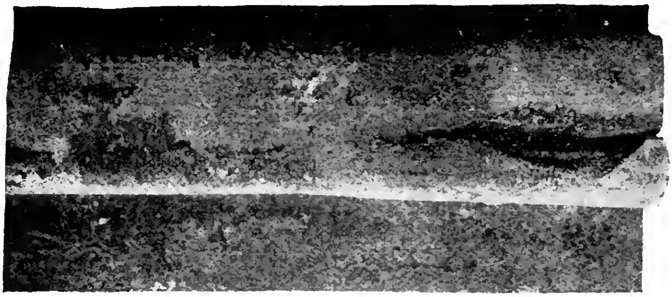
ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

Classification: SPLIT HEAD.

1. Weight per yard: 100 lbs.
2. Section: A. S. C. E.
3. Brand: Carnegie, E. T., 1907.
7. Month and year laid: October, 1907.
10. On curve or straight line: Straight line.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
32. Roadbed frozen: No.
37. Location of flaws or defects and cause: Split head starting at end and extending back 8 in.; caused by piped rail.



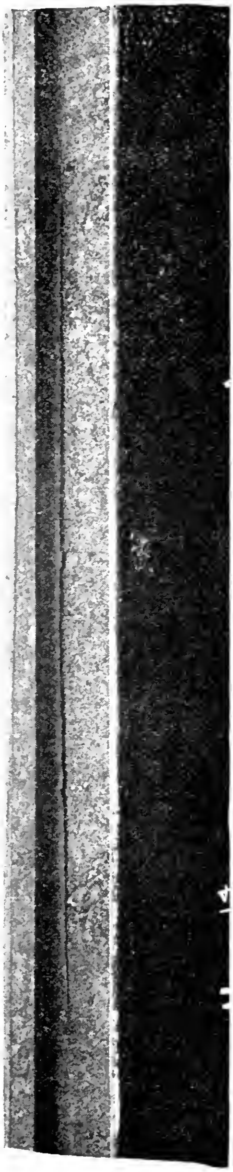




ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

Classification: SPLIT HEAD.

1. Weight per yard: 100 lbs.
2. Section: A. S. C. E.
3. Brand: Carnegie, E. T., 1907.
7. Month and year laid: October, 1907.
10. On curve or straight line: Straight line.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
32. Roadbed frozen: No.
37. Location of flaws or defects and cause: Split head starting 6 ft. from end and extending 4 ft.; caused by piping.



REPORT OF RAIL FAILURES IN MAIN TRACKS—BALTIMORE & OHIO RAILROAD.

Classification: SPLIT HEAD.

REPORT OF RAIL FAILURES IN MAIN TRACKS—BALTIMORE & OHIO RAILROAD.

Classification: SPLIT HEAD.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

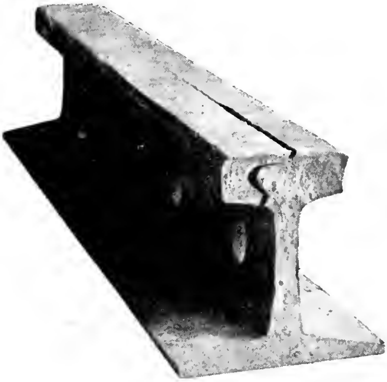
Classification: SPLIT HEAD.

1. Weight per yard: 100 lbs.
2. Section: A. S. C. E.
3. Brand: Carnegie, 10-07.
7. Month and year laid: October, 1907.
10. On curve or straight line: Curve.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
32. Roadbed frozen: No.
37. Location of flaws or defects and cause: Crushed head and split head, 12 ft. from end, extending 5 ft. along head of rail, accompanied by seam.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—SOUTHERN PACIFIC COMPANY.

Classification: SPLIT HEAD.

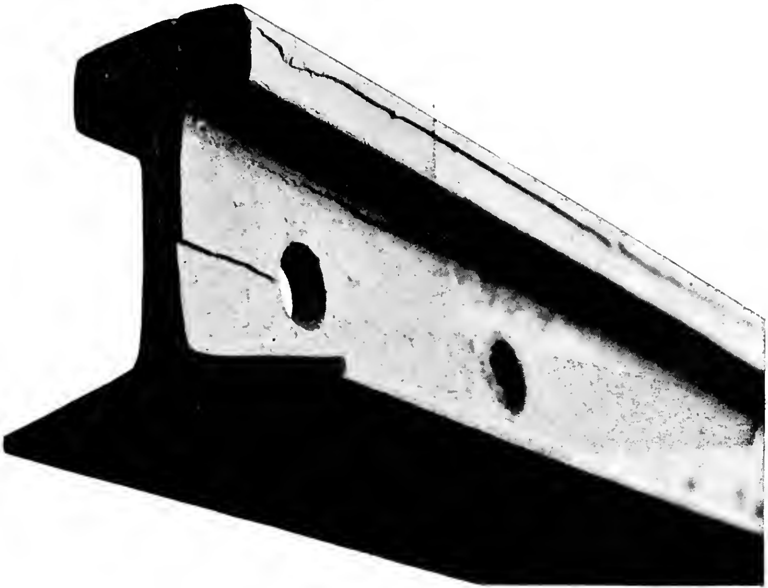
1. Weight per yard: 75 lbs.
2. Section: S. P. Standard.
3. Brand: T. C. & I. Co.
5. Rail No. or Letter: 752.
7. Month and year laid: March, 1908.
10. On curve or straight line: Straight line.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
32. Roadbed frozen: No.
37. Location of flaws or defects and cause: Ball split near end of rail, caused by improper rolling.



REPORT OF RAIL FAILURES IN MAIN TRACKS—OREGON RAILROAD & NAVIGATION COMPANY.

Classification: SPLIT HEAD.

1. Weight per yard: 75 lbs. (1906).



ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—OREGON SHORT LINE.

Classification: SPLIT HEAD.

1. Weight per yard: 80 lbs.
2. Section: A. S. C. E.
3. Brand: C. F. & I. Co.
7. Month and year laid: November, 1903.
10. On curve or straight line: Curve.
14c. Rail defective: Yes.
37. Location of flaws or defects and cause: Split through web and head and head flattened.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—UNION PACIFIC RAILROAD.

Classification: SPLIT HEAD.

1. Weight per yard: 80 lbs.
2. Section: A. S. C. E.
3. Brand: Ill. Steel Co., 1905.
5. Rail No. or Letter: 28.
7. Month and year laid: 1905.
10. On curve or straight line: Straight line.

ANALYSES.

Carbon	0.534
Silicon	0.117
Sulphur	0.037
Phosphorus	0.112
Manganese	0.75

REPORT OF RAIL FAILURES IN MAIN TRACKS—UNION PACIFIC RAILROAD.

Classification: SPLIT HEAD.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—ROCK ISLAND LINES.

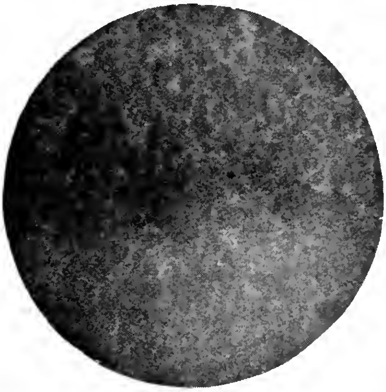
Classification: SPLIT HEAD.

1. Weight per yard: 85 lbs.
2. Section: A. S. C. E.
3. Brand: Ill. Steel Co., South Works.
5. Rail No. or Letter: 68604.
7. Month and year laid: October, 1907.
10. On curve or straight line: Curve.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
37. Location of flaws or defects and cause: Rail battered and flattened on head, commencing about two months ago and gradually getting worse.

LABORATORY REPORT OF CHEMICAL AND PHYSICAL ANALYSIS.

	Head.	Web.	Base.
Carbon	0.597	0.640	0.505
Manganese	0.601	0.675	0.655
Phosphorus	0.057	0.086	0.055
Sulphur	0.034	0.053	0.031

Tensile strength, 97,532 lbs.
Elastic limit, 57,728 lbs.
Reduction of area, 32.7 per cent.
Elongation per cent. in 2 in., 26.9.
Fracture, slightly crystalline.



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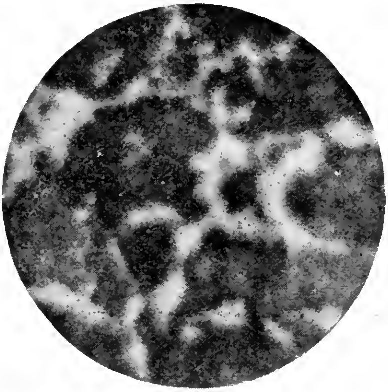

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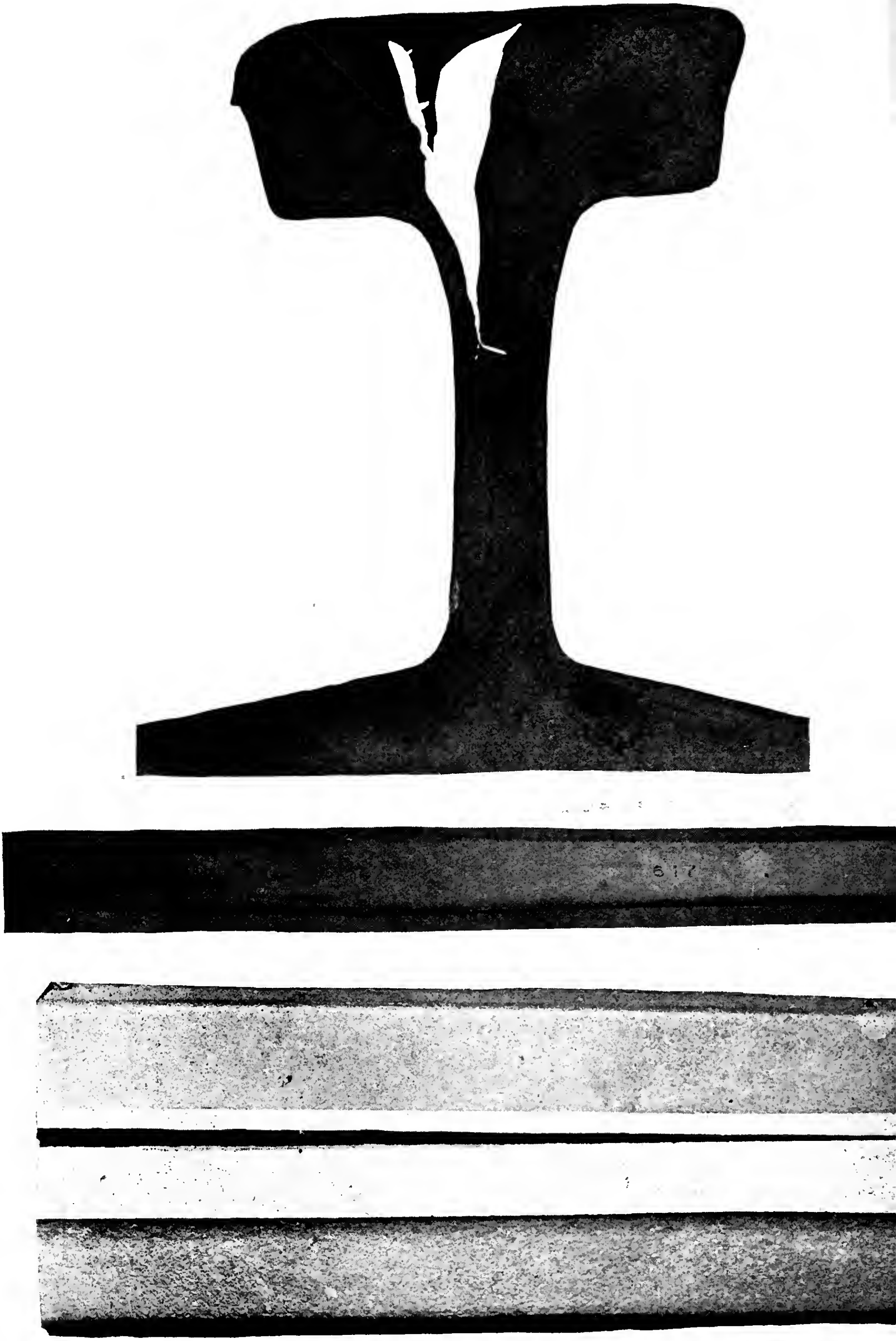
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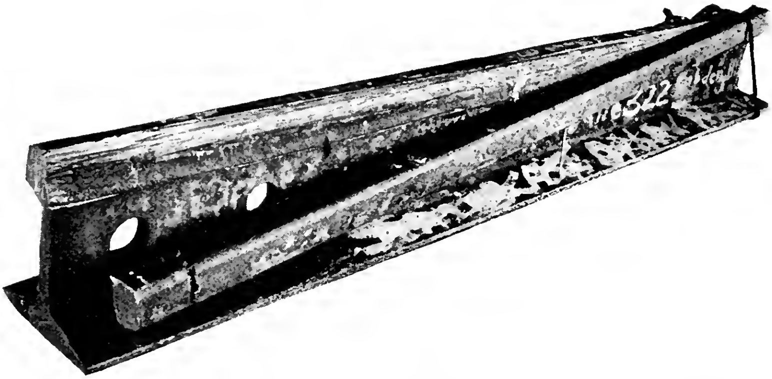
REPORT OF RAIL FAILURES IN MAIN TRACKS—ILLINOIS CENTRAL RAILROAD.

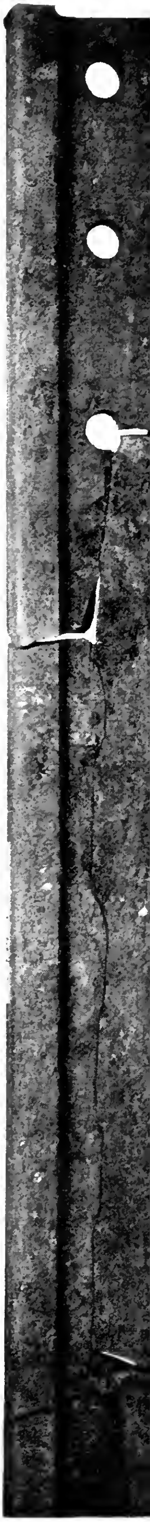
Classification: SPLIT HEAD.

85-lb. Rail from Tennessee Division, Mile 267. Laid September, 1907. Open-hearth rail rolled by Tennessee Coal & Iron Company at Birmingham, removed from track February, 1908, cause of failure pipe. The following is the chemical analysis which shows Phosphorus .048 high; Carbon, .610; Phosphorus, .108; Silicon, .093; Manganese, .900.



85-lb. Rail from St. Louis Division, Mile 322. Open-hearth rail rolled by Tennessee Coal & Iron Company and laid September, 1907, on the low side of a six-degree curve, where alternate rails were laid of Bessemer and open-hearth. Cause of failure pipe. The following is the analysis and shows Carbon .04 per cent. high, Phosphorus .04 per cent. high, and Manganese .04 per cent. low. Carbon, .690; Phosphorus, .120; Silicon, .012; Manganese, .760.

85-lb. Rail from Tennessee Division, Mile 263. Bessemer rail rolled by Illinois Steel Company at South Chicago, laid September, 1907, and removed from track February, 1908. Cause of failure pipe. The following is the chemical analysis, which shows Carbon .10 per cent. high and Phosphorus .017 high. Carbon, .680; Phosphorus, .117; Silicon, 104; Manganese, .910.



ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

Classification: SPLIT WEB.

1. Weight per yard: 100 lbs.
3. Brand: Maryland, 1906.
10. On curve or straight line: Straight line.

LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

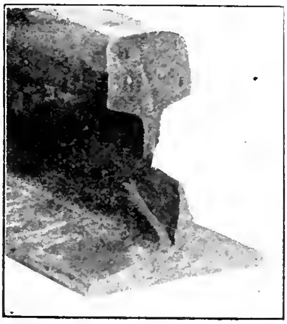
	Head.	Web.
Carbon	0.543	0.497
Manganese	0.77	0.78
Phosphorus	0.063	0.055
Silicon	0.038	0.061
Sulphur	0.051	0.047

The failure apparently started with horizontal crack in web. Rather surprisingly the analyses do not show serious segregation and the segregation shown is toward the head. This would indicate that this rail came from toward the bottom of ingot. It seems probable that this steel may have been cast from an ingot with a wet bottom, and that the seam worked up into the molten metal, leaving a cavity, which was rolled out but did not weld up. A seam in the bottom of an ingot is rather of a rare occurrence.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

Classification: SPLIT WEB.

1. Weight per yard: 85 lbs.
3. Brand: Maryland, 1905.
10. On curve or straight line: Curve.
14c. Rail defective: Flaw in rail.
37. Location of flaws or defects and cause: Badly piped in web; web split from under side of head to upper side of base for a distance of 10 in. from transverse fracture.



LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

	Head.	Web.
Carbon	0.623	0.620
Manganese	1.10	1.10
Phosphorus	0.064	0.065
Silicon	0.056	0.052
Sulphur	0.074	0.078

The web shows a large seam embracing pretty nearly the whole depth of web. The analyses show almost no segregation, and apparently this sample was from nearly the top of the ingot. The manganese is rather high, and carbon a little above the limits of our present specifications.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

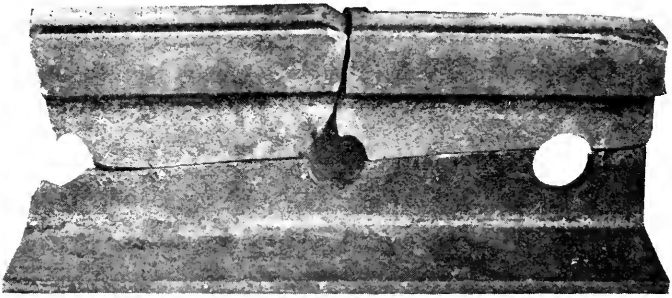
Classification: SPLIT WEB.

1. Weight per yard: 100 lbs.
3. Brand: Maryland, 2-04.
10. On curve or straight line: Straight line.
14c. Rail defective: Flaw in rail.
37. Location of flaws or defects and cause: Horizontal seam in web.

LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

	Head.	Web.
Carbon	0.542	0.540
Manganese	0.94	0.95
Phosphorus	0.079	0.075
Silicon	0.038	0.023
Sulphur	0.054	0.065

There is nothing in the chemistry which explains this break. The chemistry is normal and shows good metal. Failure evidently started from horizontal crack in web.



ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—SOUTHERN PACIFIC COMPANY.

Classification: SPLIT WEB.

1. Weight per yard: 75 lbs.
2. Section: S. P. Standard.
3. Brand: Bethlehem.
5. Rail No. or Letter: 75 B.
7. Month and year laid: May, 1908.
10. On curve or straight line: Curve.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
32. Roadbed frozen: No.
37. Location of flaws and cause: Horizontal flaw in web of rail.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

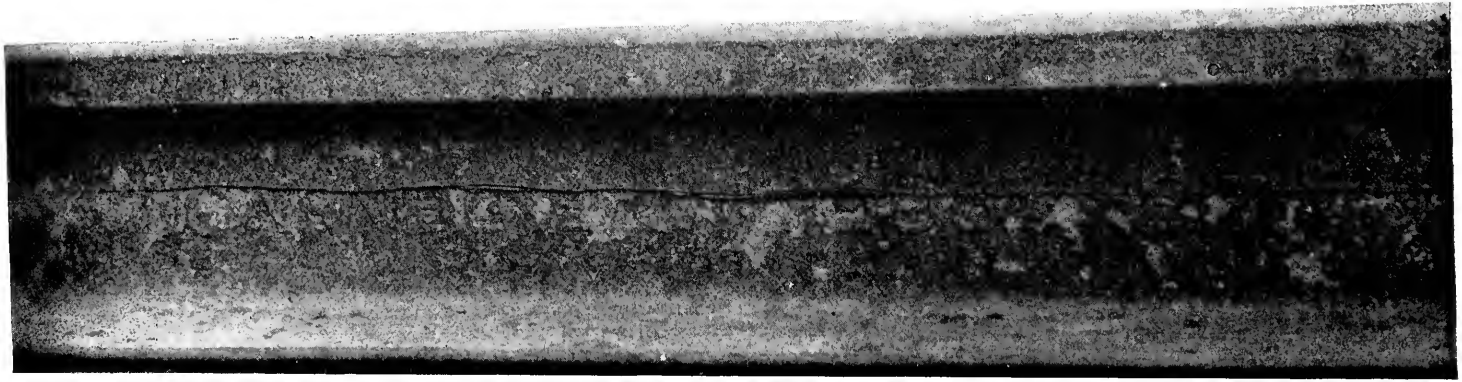
Classification: SPLIT WEB.

1. Weight per yard: 85 lbs.
2. Section: A. S. C. E.
3. Brand: Carnegie, E. T., 1904.
7. Month and year laid: May, 1904.
10. On curve or straight line: Straight line.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
22. Break square or angular: Angular.
32. Roadbed frozen: No.
37. Location of flaws and cause: Commencing 2 ft. from end, rail was split through web 18 in. and broke out through base.

REPORT OF RAIL FAILURES IN MAIN TRACKS—OREGON RAILROAD & NAVIGATION COMPANY.

Classification: SPLIT WEB.

1. Weight per yard: 75 lbs. (1906).



ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—ROCK ISLAND LINES.

Classification: SPLIT WEB.

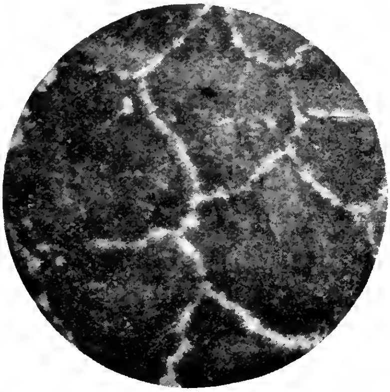
1. Weight per yard: 80 lbs.
2. Section: A. S. C. E.
3. Brand: P. S. Co.
7. Month and year laid: 1905.
10. On curve or straight line: Curve.
14a. Rail broken: Yes.
15. Rail much or little worn: Little.
35. Cause of break and description of flaws: Flaw in web of rail just under ball 22 ft. long.
37. Location of flaws and cause: Cracked web.

LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

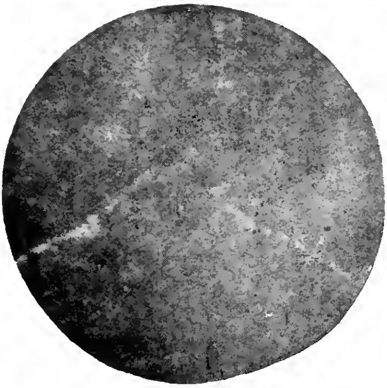
	Head.	Web.	Base.
Carbon	0.516	0.560	0.518
Manganese	0.810	0.935	0.960
Phosphorus	0.092	0.088	0.076
Sulphur	0.043	0.046	0.044

Tensile strength, 84,435 lbs.
Elastic limit, 48,350 lbs.
Elongation, 15 per cent.
Fracture, silky.

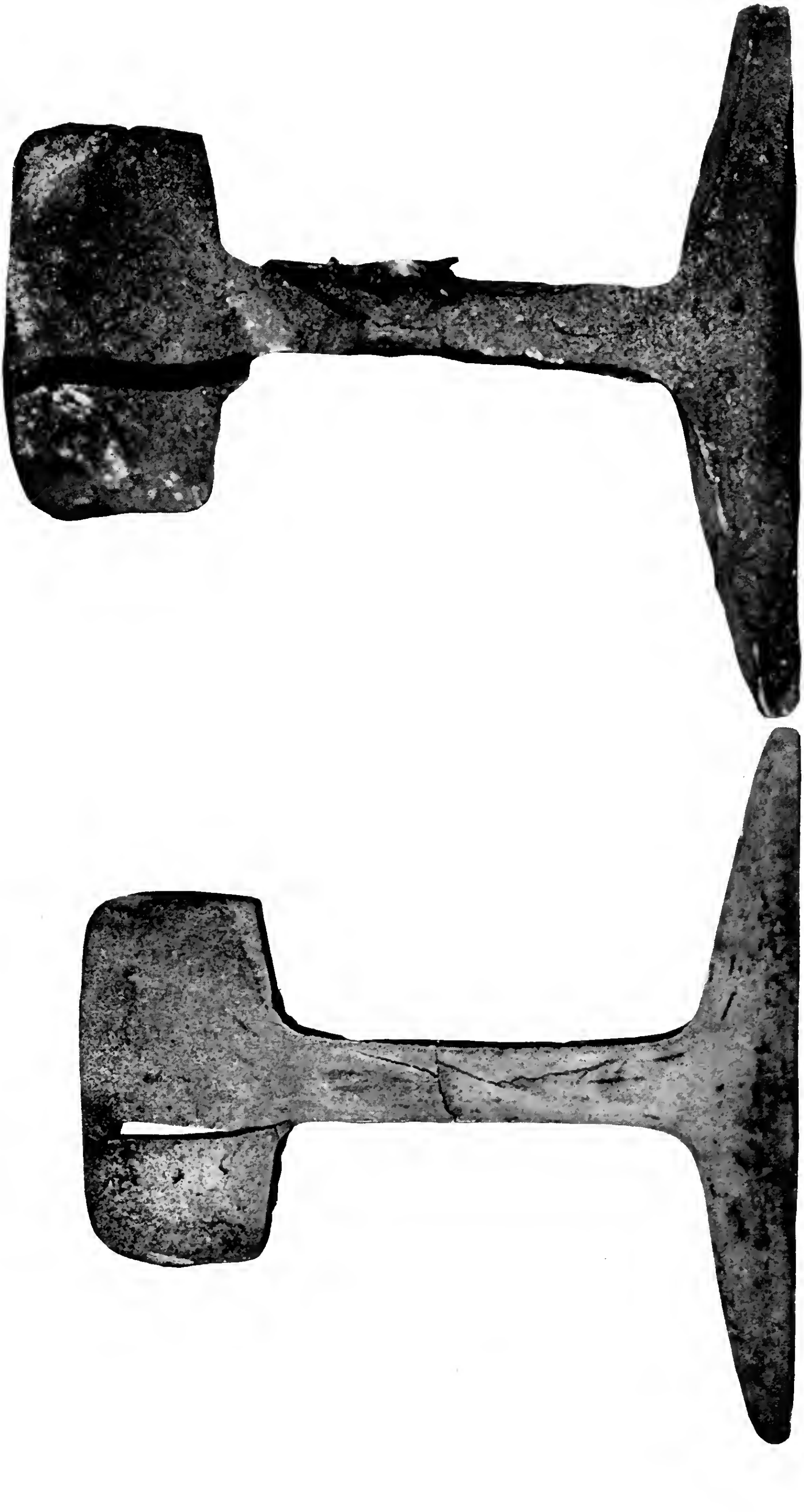
60 DIA.



200 DIA.

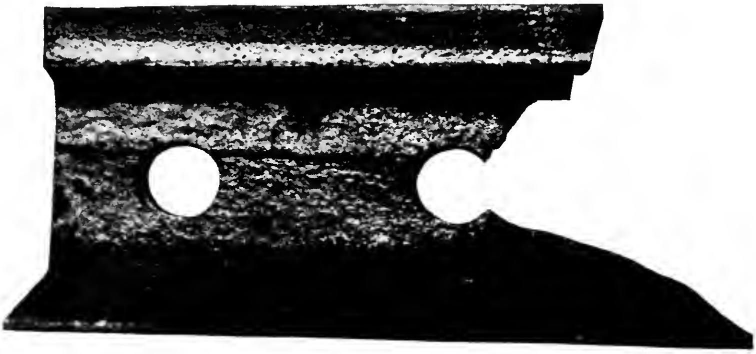


1000 DIA.



REPORT OF RAIL FAILURES IN MAIN TRACKS—ILLINOIS CENTRAL RAILROAD.

Classification: SPLIT WEB.



85-lb. Rail from Chicago Division, Mile 93. Bessemer rail rolled by Illinois Steel Company at South Chicago. Laid in 1901 and removed from the track February 6, 1909. Rock ballast; 18 ties to 30-ft. rail, 40-in. angle bar. Cause of break unknown. No chemical analysis made.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

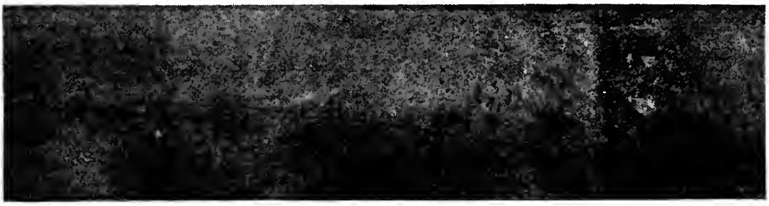
Classification: BROKEN BASE.

1. Weight per yard: 85 lbs.
2. Section: P. R. R.
3. Brand: Maryland, 2-07.
5. Rail No. or Letter: 5.
7. Month and year laid: September, 1907.
10. On curve or straight line: Curve.
14a. Rail broken: Yes.
15. Rail much or little worn: Little.
21. Break over or between ties: On edge.
22. Break square or angular: Square.
32. Roadbed frozen: No.
35. Cause of break and description of flaws: Crack in base of rail from end of rail to transverse fracture evidently cause of failure.

LABORATORY REPORT OF CHEMICAL AND PHYSICAL EXAMINATION.

	Head.	Web.	Base.
Carbon	0.604	0.533	0.60
Manganese	0.92	0.90	0.92
Phosphorus	0.091	0.074	0.091
Silicon	0.026	0.033	0.045
Sulphur	0.076	0.063	0.079

Failure apparently started from longitudinal crack in base.



ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

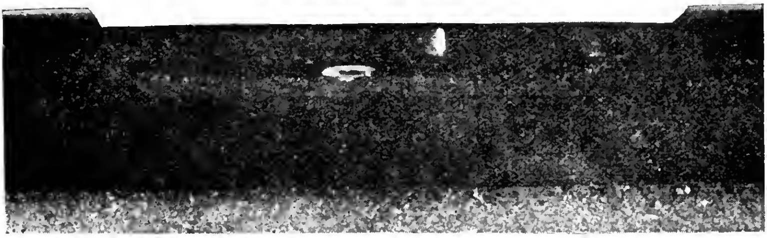
Classification: BROKEN BASE.

1. Weight per yard: 85 lbs.
2. Section: P. R. R.
3. Brand: L. S. Co., Bfo, 1907.
7. Month and year laid: September, 1907.
10. On curve or straight line: Curve.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
21. Break over or between ties: Over.
32. Roadbed frozen: Yes.
35. Cause of break and description of flaws: Longitudinal seams along center line of base.
37. Location of flaws and cause. Probably flaw where base and web join. Piece not broken off. Base cracked at two other places.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA RAILROAD.

Classification: BROKEN BASE.

1. Weight per yard: 85 lbs.
2. Section: P. R. R. Standard.
3. Brand: L. S. Co., Bfo, 852-3-1907.
7. Month and year laid: August, 1907.
10. On curve or straight line: Curve.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
21. Break over or between ties: Over.
32. Roadbed frozen: Yes.
35. Cause of break and description of flaws: 14-in. piece broken out of base of rail. Longitudinal seam along center of base.



ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

Classification: BROKEN BASE.

1. Weight per yard: 85 lbs.
2. Section: A. S. C. E.
3. Brand: Carnegie, E. T., 5-04.
7. Month and year laid: April, 1904.
10. On curve or straight line: Straight line.
14c. Rail defective: Yes.
15. Rail much or little worn: Little.
32. Roadbed frozen: No.
37. Location of flaws and cause: Two pieces broken out of base of rail, one 7 ft. from end for 10 in., and the other 8 ft. 8 in. from end for 7 in. Ties not being adzed level.

REPORT OF RAIL FAILURES IN MAIN TRACKS—PENNSYLVANIA LINES.

Classification: BROKEN BASE.

ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—SOUTHERN PACIFIC COMPANY.

Classification: BROKEN BASE.

1. Weight per yard: 75 lbs.
2. Section: S. P. Standard.
3. Brand: T. C. & I. Co.
5. Rail No. or Letter: 752.
7. Month and year laid. March, 1908.
10. On curve or straight line: Straight line.
14a. Rail broken: Yes.
15. Rail much or little worn: Little.
21. Break over or between ties: Over and between.
22. Break square or angular: Angular.
32. Roadbed frozen: No.
35. Cause of break and description of flaws: Flange at end of rail broke out about 11 in. long.
37. Location of flaws and cause: Flaw in flange at end of rail.

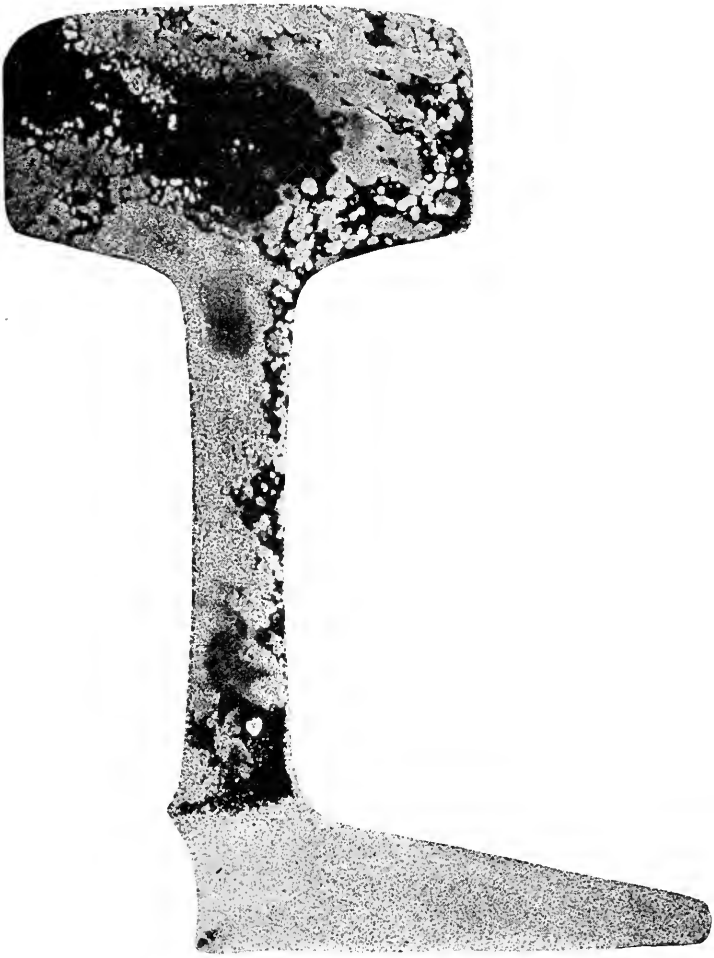
ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—UNION PACIFIC RAILROAD.

Classification: BROKEN BASE.

1. Weight per yard: 80 lbs.
2. Section: A. S. C. E.
3. Brand: Ill. Steel Co.
5. Rail No. or Letter: 28.
7. Month and year laid: 1905.
10. On curve or straight line: Straight line.

CHEMICAL ANALYSIS.

Carbon	0.483
Silicon	0.056
Sulphur	0.039
Phosphorus	0.067
Manganese	0.96



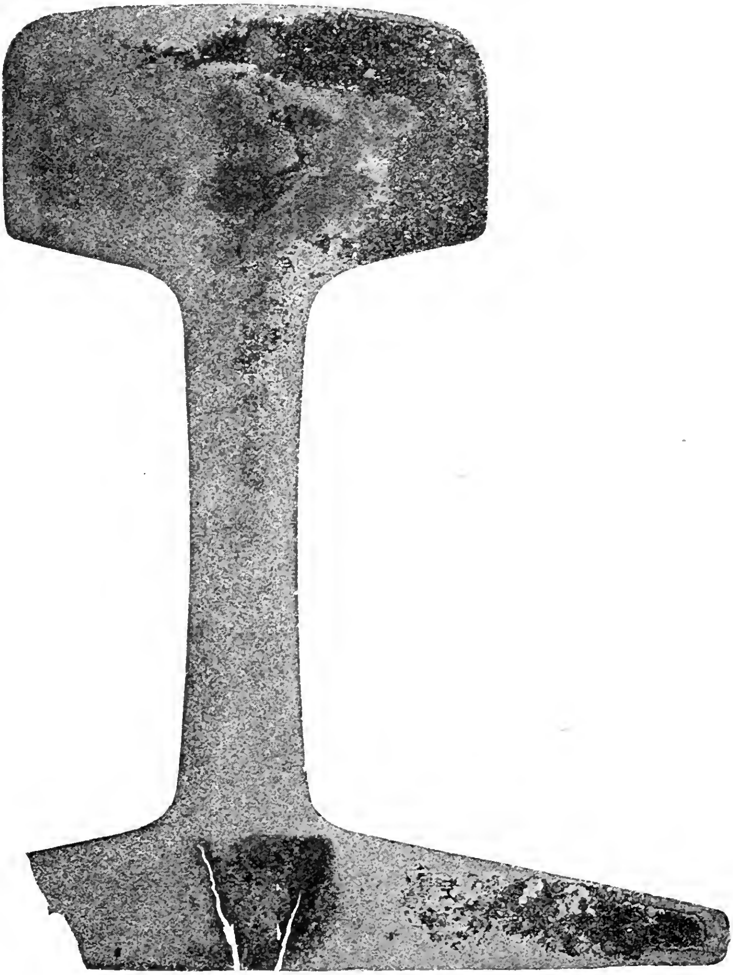
ABSTRACT OF REPORT OF RAIL FAILURES IN MAIN TRACKS—UNION PACIFIC RAILROAD.

Classification: BROKEN BASE.

1. Weight per yard: 80 lbs.
2. Section: A. S. C. E.
3. Brand: Ill. Steel Co.
5. Rail No. or Letter: 28.
7. Month and year laid: 1905.
10. On curve or straight line: Straight line.

CHEMICAL ANALYSIS.

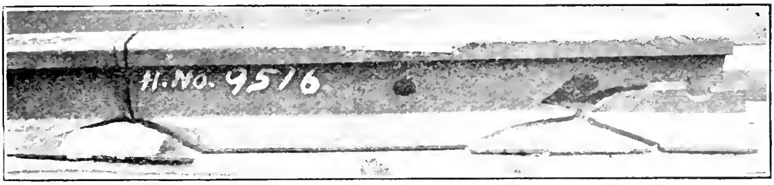
Carbon	0.504
Silicon	0.099
Sulphur	0.041
Phosphorus	0.069
Manganese	0.80



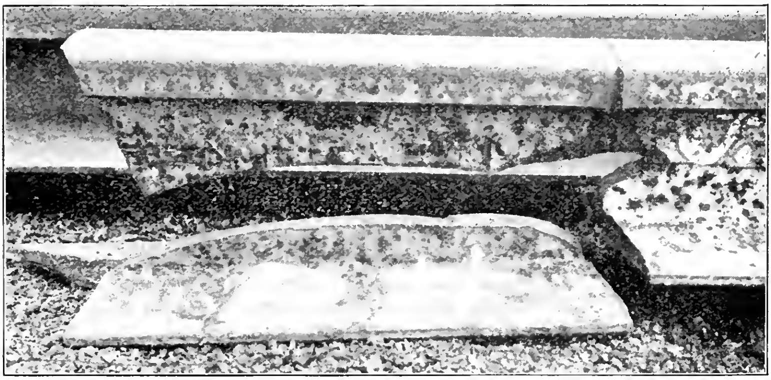
REPORT OF RAIL FAILURES IN MAIN TRACKS—ILLINOIS CENTRAL RAILROAD.

BROKEN BASE.

Classification:



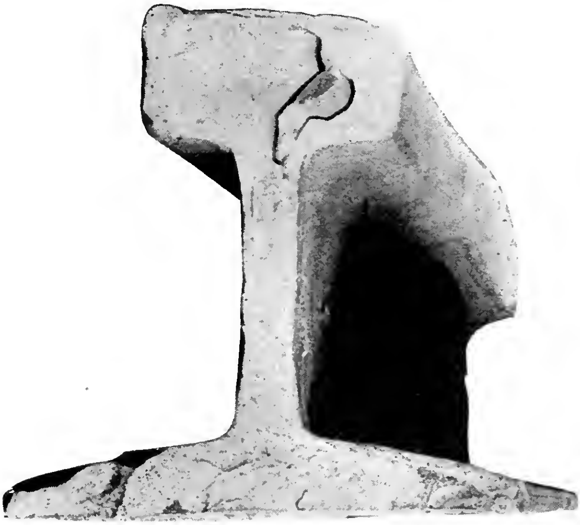
Classification: Combination of SPLIT WEB and BROKEN BASE.



85-lb. Rail from Mississippi Division, Mile 700. Open-hearth rail rolled by Tennessee Coal & Iron Company, and laid in December, 1907. This is one out of 81 rails that were found broken within a month after the rail was laid. Out of a total of 2,660 rails laid, 81 were broken in this manner. The rail was on straight track gravel ballast, good surface. The following is the chemical analysis, which shows Carbon .06 high and Phosphorus .04 high. Carbon, .71; Phosphorus, .102; Silicon, .011; Manganese, .102; Sulphur, .055.

REPORT OF RAIL FAILURES IN MAIN TRACKS—ILLINOIS CENTRAL RAILROAD.

Classification: CRUSHED OR SPLIT HEAD, showing peculiar pipe with small core.



85-lb. Rail from St. Louis Division, Mile 334. Open-hearth rail rolled by Tennessee Coal & Iron Company at Birmingham. Laid August, 1907, and removed from track October 13, 1908. Cause of failure pipe, which occurred one foot from end of rail. There were 10 in. of stone ballast, 21 ties to 33-ft. rail and Wolhaupter joint. Rail was on the inside of a curve. No chemical analysis made.

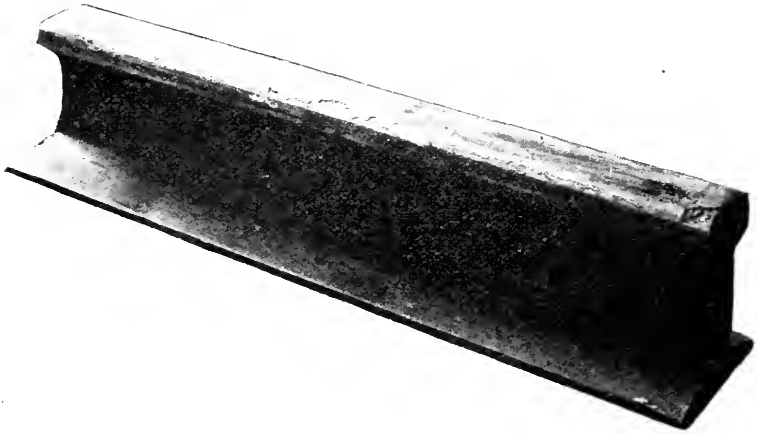
REPORT OF RAIL FAILURES IN MAIN TRACKS—ILLINOIS CENTRAL RAILROAD.

Classification: Combination of BROKEN RAIL with SPLIT HEAD.

85-lb. Rail from Tennessee Division, Mile 513. Bessemer rail rolled by the Carnegie Steel Company and laid in 1901 and broken February 17, 1908. Cause of break pipe, but rail was very hard. The following is the chemical analysis, which shows Carbon is .12 high and Phosphorus .037 high. Carbon, .700; Phosphorus, .137; Silicon, .086; Manganese, .810.

REPORT OF RAIL FAILURES IN MAIN TRACKS—ILLINOIS CENTRAL RAILROAD.

Classification: Illustrates class of rails failing, due to segregation of metal at top of head.



85-lb. Rail from the Dubuque Division, Mile 271. Bessemer rail rolled by the Illinois Steel Company in January, 1903, and laid in April, 1903, and removed from the track in February, 1908. Straight track, perfect gage and level. Cause of failure due to chipping off of the outside of the rail. The following is the chemical analysis, which comes within the specifications: Carbon, .540; Phosphorus, .091; Silicon, .121; Manganese, .910.

EXAMINATION OF TYPICAL RAIL FAILURES ON THE MICHIGAN CENTRAL RAILROAD.

One rail was selected as representing the best example that could be found for each of the classes of failures given below:

1. Broken Rail.
3. Flow of Metal.
4. Crushed Head.
5. Split Head.
6. Split Web.
7. Broken Base.

Table 1 contains data concerning the rails examined. All of the rails were manufactured under specifications, which provided for the following chemical composition:

Carbon	0.50 to 0.60 per cent.
Phosphorus not to exceed	0.10 per cent.
Silicon not to exceed	0.20 per cent.
Manganese	0.90 to 1.20 per cent.

The 1904 rail was from a lot of 15,756 tons, which has given very unsatisfactory service, the average amount of defective metal removed from the track annually of this rolling amounting to over 0.7 per cent. of the rail laid. The behavior of this particular lot of rail is noticeable by very heavy failures during the month of January, 1905. In subsequent years the failures were more evenly distributed over the entire year, showing, however, as might be expected, a some better performance during the summer months.

Of the 1905 rail, 19,288 tons was received, the average annual failures being in this case about 0.2 per cent. of the total tonnage laid, the greatest number of failures occurring during the spring months.

The 1906 rail was a lot furnished by the steel company to replace defective guaranteed rail and the amount received is too small to allow for any general conclusions being drawn from the percentages of failures.

TABLE NO. 1—RAILS EXAMINED—WEIGHT, 100 LBS., BESSEMER STEEL, A. S. C. E. SECTION.

Kind of Failure.	Date Rolled.	Date Put in Track.	Date Failed.	Kind of Ballast.
Broken Rail	Aug., 1905	Sept., 1905	Dec., 1907	Gravel
Flow of Metal	Aug., 1905	Sept., 1905	Nov., 1908	Gravel
Crushed Head	May, 1906	June, 1906	Dec., 1907	Gravel
Split Head	Aug., 1904	Sept., 1904	Dec., 1907	Gravel
Split Web				
Broken Base	Aug., 1905	Aug., 1905	Dec., 1907	Gravel

BROKEN RAIL.

The photograph shows the manner of failure of this specimen. There was no evidence of a flaw or seam, and the break has the appearance of being due to too great a stress of the metal. A chemical analysis, which was made to determine the existence of segregated metal at the fracture, gave the following composition:

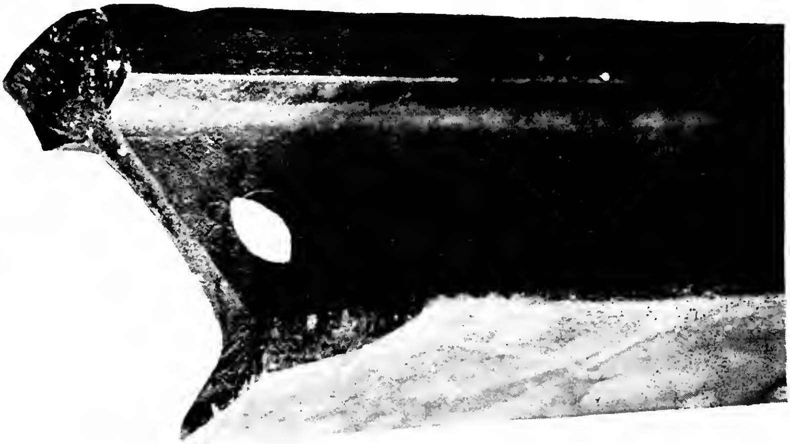
Carbon	0.581 per cent.
Phosphorus	0.091 per cent.
Silicon	0.103 per cent.
Manganese	1.009 per cent.

The physical properties of the rail were then tested. A tensile test was made on a piece cut from the center of the flange in the direction of rolling with the result shown in Table No. 2.

TABLE NO. 2—TENSILE TEST.

Size, diameter	0.726	in.
Area	0.414	sq. in
Broke at	49,690	lbs.
Stress per sq. in.	120,024	lbs.
Elastic limit	31,530	lbs.
Elastic limit per sq. in.	76,159	lbs.
Elongation in 2 in.	0.3125	in.
Elongation in per cent. of length	15.625	per cent.
Area of reduced section	0.3068	sq. in.
Reduction in per cent. of original section	7.41	per cent.

The rail was also subjected to a transverse test and the test made to complete failure. Fracture started on top of rail at point of contact and extended through a bolt hole to the base, three inches from point of support, the fracture following closely along the lines of principal stress. The rail failed very suddenly and without warning, one of the broken pieces being cast 25 ft. from the machine.



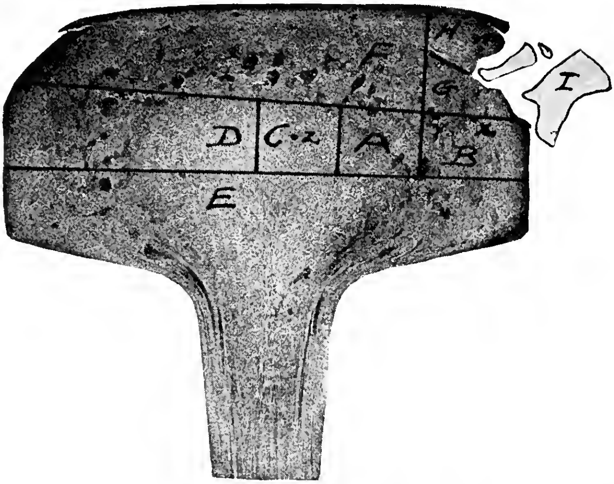
The modulus of rupture as determined by the transverse test is 126,000 lbs. per sq. in. This modulus is intermediate between the moduli of rupture of the steel in tension and compression. The chemical analysis of the rail gives 0.09 per cent. phosphorus, with 0.58 per cent. carbon. Bessemer steel of this composition should not be looked upon with favor for rail purposes, and it is probable that the failure was caused by the metal being unduly brittle.

FLOW OF METAL.

This rail was sectioned, and the section polished and etched with acid, as shown by the photograph. It shows some segregation and flow of metal as expected from the rolling. The rail was slivered, breaking off the right of the head as indicated.

The following measurements were made of the rail:

	Across Head.	Height.
At point of greatest distortion	3.41 in.	5.58 in.
At point from which section was taken	3.36 in.	5.59 in.
Balance of rail	3.02 in.	5.62 in.



The photograph shows the portions into which this section was cut and the marks by which they are identified. These were in part polished and examined microscopically for defects.

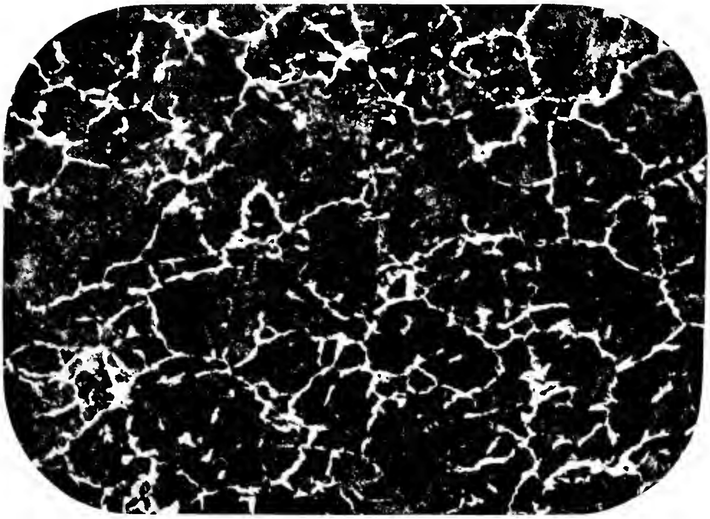


FIG. A.

Fig. A, cross-section, magnification 100, taken at point Cz, shows the grain size of the center of the head on this rail. The average of five determinations showed this to be 68,000 grains per sq. in.

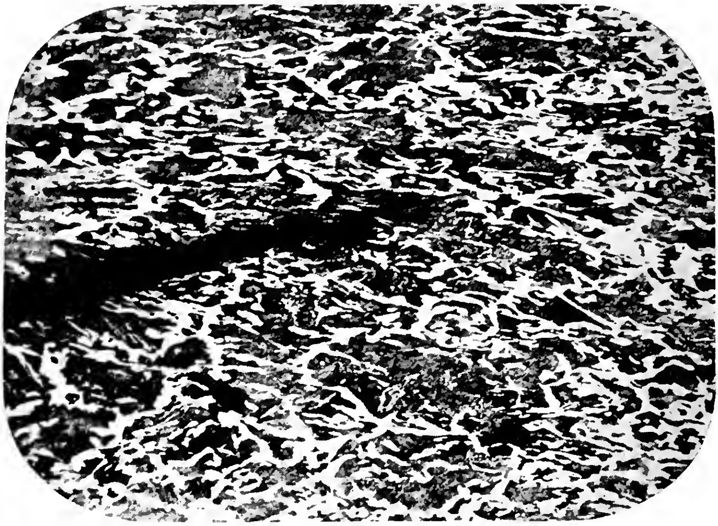


FIG. B.

Fig. B, cross-section, magnification 100, taken about the point Hw, shows the finer grain near the surface, and the distortion of the grains by wheel action. The photograph is taken at the end of a crack, and shows besides this some small cavities, which were more noticeable before etching, and which might have been minute oxide pits or pockets.

FIG. C.

Fig. C, longitudinal section, magnification 50. This was made on the top of the portion B, and the photograph made on the surface above the dot By, before etching. The metal, which is the white ground mass, is badly contaminated by slag, which is extended longitudinally by the process of rolling. These slag lines were found to some extent over the whole surface of this piece, but were worst in the neighborhood of the point indicated by the dot By. This is shown on the picture, which was taken at the edge of the localized portion.

FIG. D.

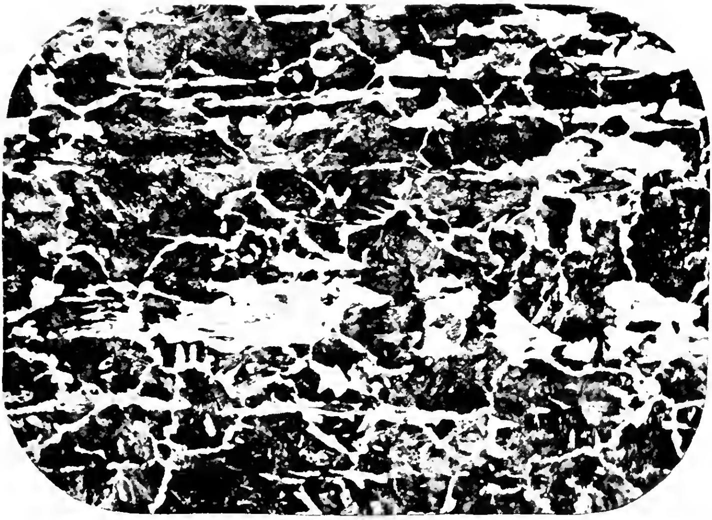


FIG. E.

Figs. D and E are longitudinal sections, magnification 100. **Fig.** D is taken at By and Fig. E at Bx. These two photographs, taken after etching the surface with acid, show that there was considerable segregation of the carbon in the neighborhood of the localized slag as well. The dark areas being due to the carbon-bearing constituent, this is found in greater abundance in D, taken in the zone of greatest slag, and in less amount in E, taken nearer the outside of the rail. On examination, the slag lines can be detected in both cases.

Chemical analysis of a sample taken at the flow showed the following composition:

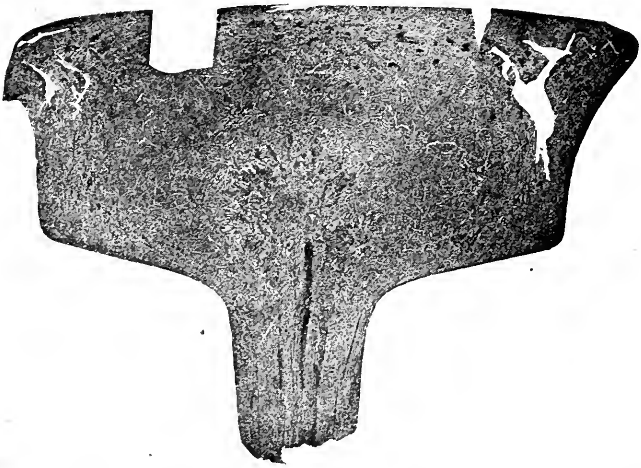
Carbon	0.488 per cent.
Phosphorus	0.065 per cent.
Silicon	0.136 per cent.
Manganese	0.849 per cent.

All of the hardening constituents are low; it is not, however, probable that this caused the rail to fail. We have ample evidence of rails low in carbon which do not flow even under heavy traffic, provided sound steel is present, with granular form fine enough to render the metal tough and strong. As shown by Figs. A and B the rail had a satisfactory texture, and there is every indication that the flow of metal was due to the presence of slag in the part that failed.

CRUSHED HEAD.

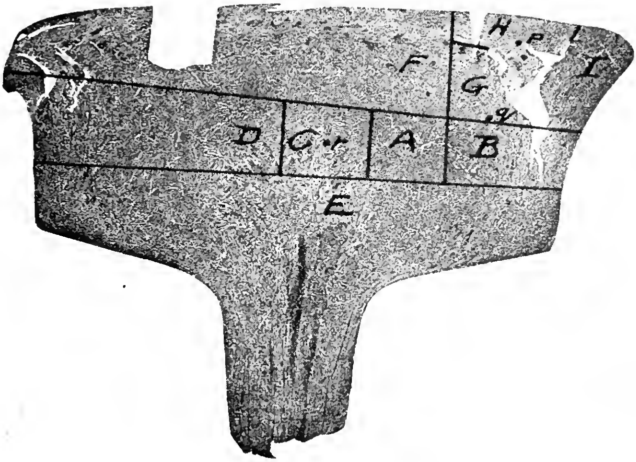
The photograph shows the appearance of this rail. The following measurements show the deformation of the head:

	Across Head.	Height.
Measurement at greatest distortion	3.31 in.	5.58 in.
Balance of rail	2.87 in.	5.70 in.



The rail was sectioned at the point of greatest distortion; the section, after being polished and etched with acid, is shown in the illustration. The cavity in the top of this view is a drilled hole, as is also the V-shaped hole to the right of it. On the side of the head a cavity, which did not show on the surface, but indicated marked breaking down of the metal, was revealed. The metal, however, is more uniform throughout this rail than was the case in Specimen No. 3.

The view below shows the portions into which the section was cut and the marks by which they are identified. Fig. A is a cross-section, magnification 100, taken at point Cr. The average of five determinations showed this to have 95,000 grains per sq. in. Before etching this showed numerous small pits on the surface.



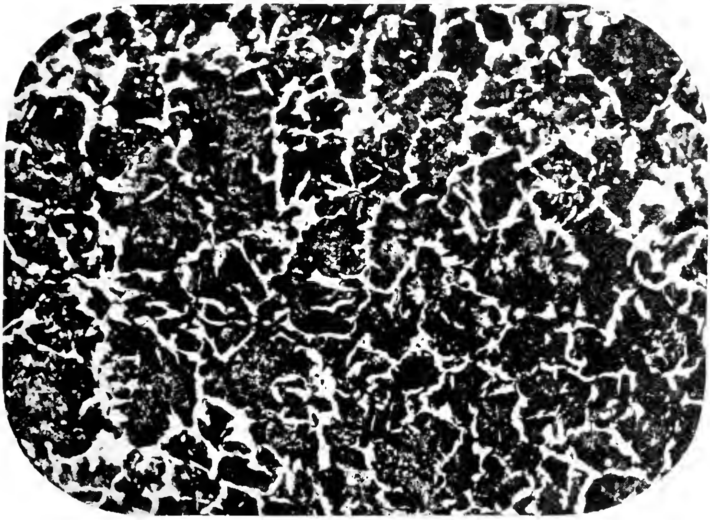


FIG. A.

Fig. B, cross-section, magnification 100. Like Fig. B, is taken at the end of the crack. It shows the finer grain, and distortion of the same, and shows as well the further distortion of the metal at the end of the crack, as a sort of tearing action. This end of the crack is at the corner of the picture, the further direction of progress of the failure is shown by the black defects extending across the photograph.

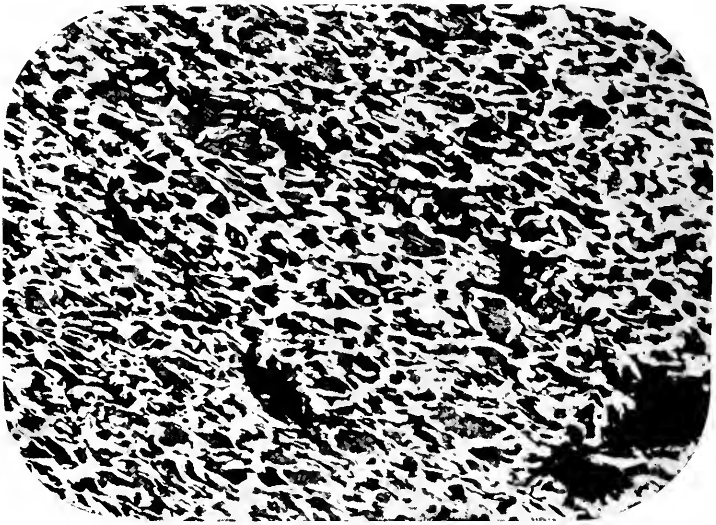


FIG. B.

A longitudinal section on this rail made on portion G showed slag lines, as in Rail No. 3, somewhat most abundant at the point q, though the number was not so great as in Rail No. 3.

The chemical analysis given below of the metal that failed showed a normal composition, and it is probable that the breaking down of the sides of the head was due to unsound metal.

Carbon	0.445 per cent.
Phosphorus	0.079 per cent.
Silicon	0.127 per cent.
Manganese	1.078 per cent.

SPLIT HEAD.

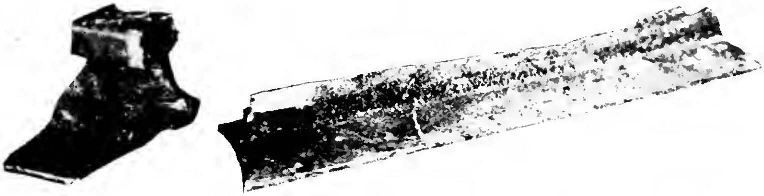
The photograph shows this rail. A chemical analysis of the metal taken from either side of the crack gave the following composition:

Carbon	0.454 per cent.
Phosphorus	0.062 per cent.
Silicon	0.116 per cent.
Manganese	0.901 per cent.

While this fracture may have originated in a thermal crack, it is more probable that it was due to imperfectly welded blowholes or slag formations extended longitudinally by the process of rolling. This lot of rails was especially noticeable for failures of this character, as well as evidence of slag seams and defects due to pipes.

SPLIT WEB—BROKEN BASE.

These failures, illustrated by the views given below, are very possibly traceable to the existence of slag (probably sulphide of manganese) streaks.



Appendix E.

CHEMICAL AND PHYSICAL TESTS OF RAIL.

(Bulletin 116.)

Conducted by Committee on Rail, at Maryland Steel Company's plant at Sparrows Point, Md., February 15, 1909.

The Committee on Rail submits, for the information of the Association, a record of the tests made on various sections of rail under the new standard drop testing machine at the Maryland Steel Company's plant, Sparrows Point, Md., February 15, 1909, by the Rail Committee and the Manufacturers' Committee, acting as a Joint Committee.

The samples of rail of the American Railway Association Section were the first that it was possible for the Rail Committee to procure. Rails of both the A. R. A. Section and the A. S. C. E. Section were tested for comparative purposes.

The tables show the chemical analysis and other characteristics of the rail and include tests made by the Scleroscope and photographs showing the character of some of the breaks, also information as to whether the rail broke under full drop of the hammer at 15 feet or at a greater height.

In addition to the tests made by the Committee of the Manufacturers and the Committee of the American Railway Engineering and Maintenance of Way Association, Dr. P. H. Dudley, of the New York Central Lines, reported some tests made by him in a letter dated February 11, 1909, to the Chairman of the Committee. The record of the tests made by Dr. Dudley is appended to the record of tests made by the Committee.

This data having been collected for the future use of the Committee, is now submitted for the information of the Association. The Committee does not give any conclusions at this time as a result of the tests.

Chas. S. Churchill, *Chairman.*

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST NO. 1

Material furnished by Illinois Steel Co. Weight per Yd. 90 Section ASCE

From South Works Plant Date rolled August, 1908.

Rolled by Illinois Steel Company Kind of Steel Bessemer

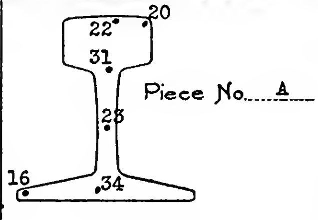
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	56967										.55	.80	.10	.03	.10		
B.	56974										.57	.91	.09	.04	.11		
C	57024	D									.58	.83	.10	.03	.09		
D	57036	D									.59	.96	.10	.03	.11		
E	57016										.55	.77	.10	.03	.08		
F	56973										.57	.84	.10	.04	.10		

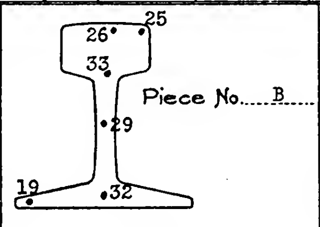
STANDARD DROP TEST.

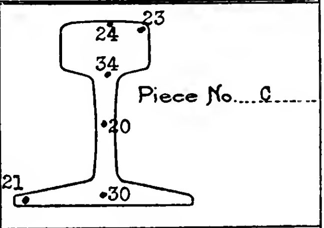
Temperature of Test Piece 70-90 Degrees.

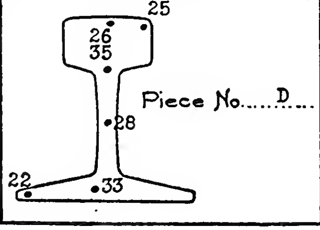
Piece	Height of Drop.						Elongation in 6 on Base.	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	1.84	1.5					.31	59600	110000	5% Silk- 95% Fine Granular
B	1.59	1.4					.25			
C	1.71	1.4					.25			
D	1.65	1.4	Broke				.31			
E	1.75	1.5					.31	60400	101800	20% Silk- 80% Fine Granular
F	1.71	1.45					.31			

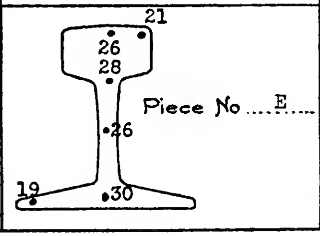
Scleroscope Test.

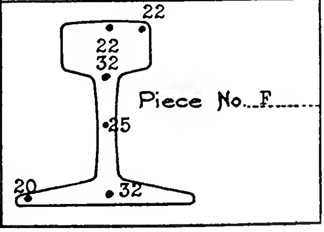












REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R.R. TEST NO. 2

Material furnished by P. & L. E. R. R. Weight per Yd. 100 Section "B" ARA

From Edgar Thompson Plant Date rolled Oct. to Dec., 1908.

Rolled by Carnegie Steel Company Kind of Steel Bessemer

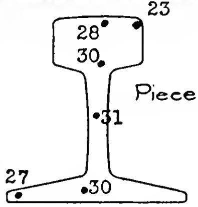
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	4098			.43	.90	.95	.07	.04			.40	.80	.10	.04	.08		
B	494-0										.48	1.11	.10	.05	.11		
C	4098			.43	.90	.95	.07	.04			.41	.75	.11	.05	.07		
D	4098			.43	.90	.95	.07	.04			.39	.74	.10	.05	.06		
E	494										.49	1.10	.10	.05	.11		

STANDARD DROP TEST.

Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation % in Base.	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	1.95	1.7					.63			
B	1.68	1.3					.31			
C	1.95	1.7					.31	-	87200	35% Silk- 65% Fine Granular
D	1.95	1.7					.31			
E	1.61	1.3					.19			
B			2.99	2.55			-			

Scleroscope Test.



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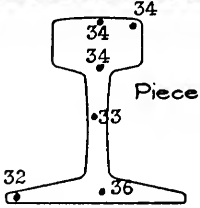

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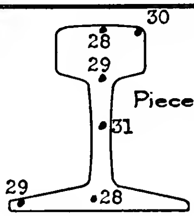
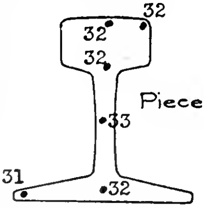


Piece No. C



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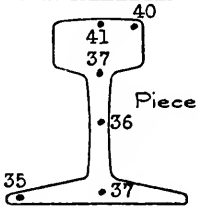
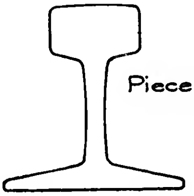


Piece No. E



Piece No.

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY **B. & O. R. R.** TEST NO. 3

Material furnished by Carnegie Steel Co. Weight per Yd. 100 Section "A" ARA

From Edgar Thompson Plant Date rolled September, 1908.

Rolled by Carnegie Steel Company Kind of Steel Bessemer

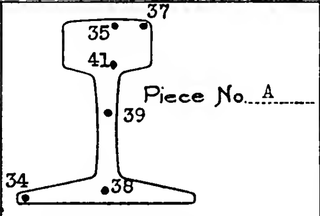
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analyisis of Heat							Chemical Analyisis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	6264			.5	.89	.09	.11	.05			.50	1.06	.10	.04	.08		
B	6264			.5	.89	.09	.11	.05			.51	1.04	.10	.05	.10		
C	6264			.5	.89	.09	.11	.05			.51	1.05	.10	.05	.10		
D	6264			.5	.89	.09	.11	.05			.51	1.00	.10	.05	.09		
E	-										.52	1.04	.10	.04	.10		

STANDARD DROP TEST.

Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation on 6" in Base.	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	Broke							66000	123800	100% Coarse Granular
B	1.56	1.25	Broke				.25			
C	1.61	1.3					.25	-	79400	100% Coarse Granular
D	1.58	1.3					.25			
E	1.58	1.3					.31			

Scleroscope Test



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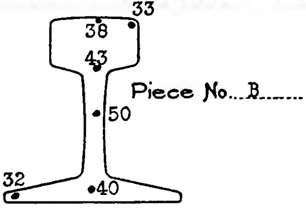

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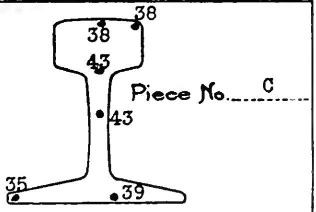

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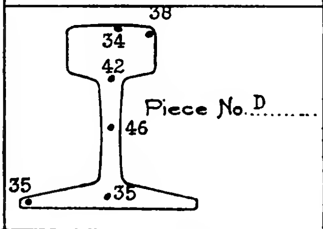

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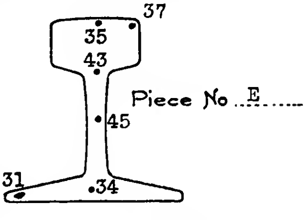

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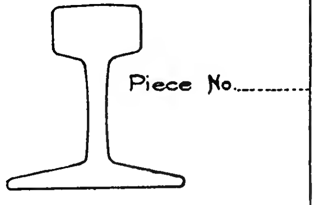


Piece No.

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST NO. 4

Material furnished by Chgo,M.& St.P.Ry Weight per Yd. 85 Section ASCE

From South Works Plant Date rolled May, 1907.

Rolled by Illinois Steel Company Kind of Steel Bessemer

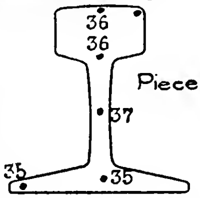
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	–										.55	.89	.11	.09	.14		
B	–										.54	.92	.11	.09	.12		
C	–										.57	.92	.10	.08	.17		
D	–										.56	.86	.11	.08	.10		
E	–										.55	.86	.11	.08	.14		
F	50265										.55	.87	.11	.09	.15		

STANDARD DROP TEST.

Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation % on in. Base.	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	1.91	1.6					.38			
B	Broke						–			Square – Medium – Granular
C	1.76	1.6					.25			
D	1.94	1.6					.38			
E	1.96	1.7	Broke				.44			Angular – Fine – Silky
F	Broke						–			Square – Fine – Silky

Scleroscope Test.



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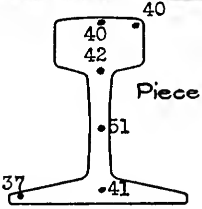

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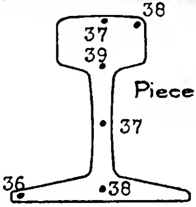

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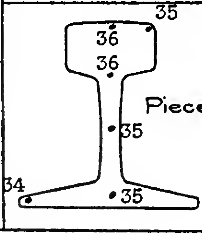

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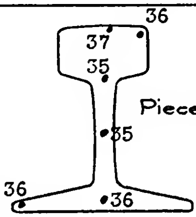

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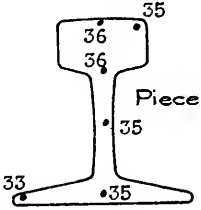


Piece No. F

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST NO. 5

Material furnished by Penna Steel Company Weight per Yd. 100 Section ASCE

From Steelton, Pa. Plant Date rolled 1908

Rolled by Pennsylvania Steel Company Kind of Steel Open Hearth

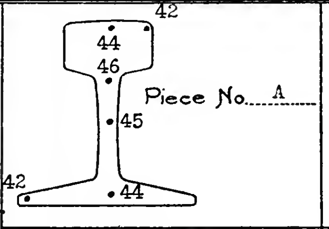
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	23687			.84	.71	.01		.02			.83	.77	.01	.03	.07		
B	22695			.82	.82	.02		.04			.85	.85	.02	.04	.10		

STANDARD DROP TEST.

Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation % on 1 in. Base	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	1.34	.9					.13			
B	1.21	.8	Broke				.25			Angular - Medium - Angular

Scleroscope Test.



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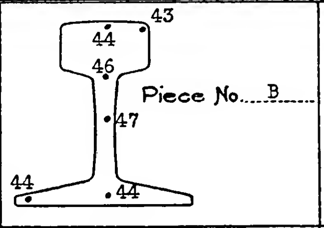

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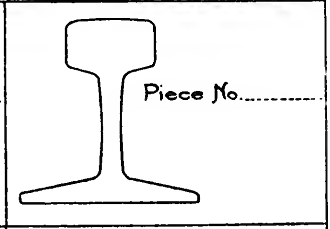

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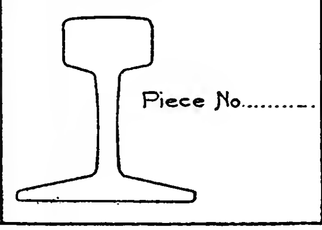

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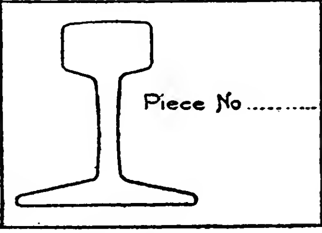

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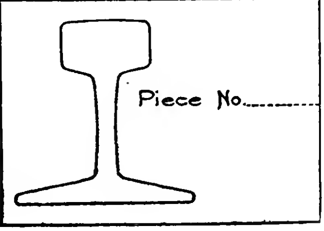


Piece No.

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST NO. 6

Material furnished by Penna Steel Company Weight per Yd. 85 Section ASCE

From Steelton, Pa. Plant Date rolled 1908

Rolled by Pennsylvania Steel Company Kind of Steel Manard

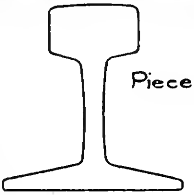
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	3631	1.18	12.6	.08	.21	.03											
B	3630	1.16	13.4	.06	.26	.03											

STANDARD DROP TEST.

Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation % on in. Base	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	2.53	2.4					.69			
B	2.66	.25					.94			
B				5.2			.94			

Scleroscope Test.



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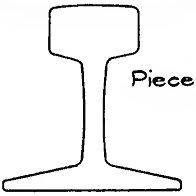

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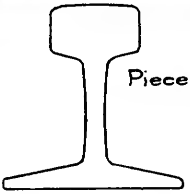

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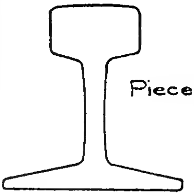

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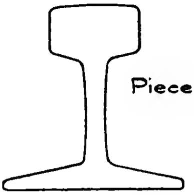

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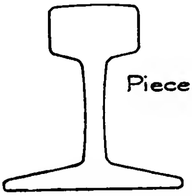


Piece No.

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O.R.R. TEST NO. 7

Material furnished by B.&.O.R.R.Company Weight per Yd. 90 Section "A" ARA

From South Works Plant Date rolled August,1908

Rolled by Illinois Steel Company Kind of Steel Bessemer

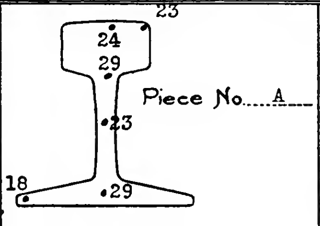
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	58364	B		.51							.49	.90	.10	.05	.13		
B	58332	D		.48							.50	.86	.09	.05	.11		
C	58288	A		.49							.54	.98	.10	.05	.13		
D	58334	C		.51							.50	.87	.10	.04	.11		

STANDARD DROP TEST.

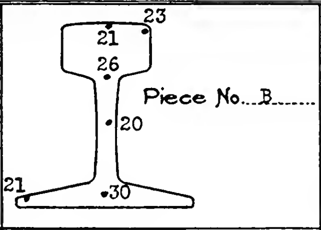
Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation in 6" on Base.	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		16-ft		17-ft					
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	1.84	1.5					.31			
B	1.84	1.5					.56			
C	1.84	1.4					.31	60000·	119800	3% Silk- 97% Fine Granular
D	1.88	1.5					.31			
D			3.3	2.8			.56			
D					4.54	4.1	.81			
					20-ft					
C					3.62	3.0	.56			

Scleroscope Test.



Piece No. A



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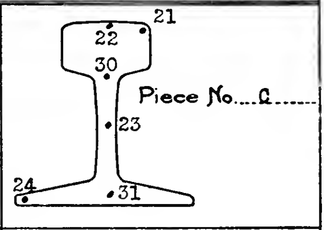
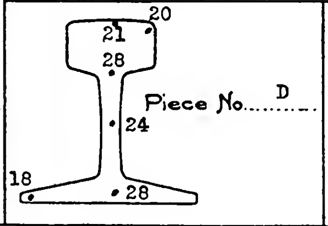


Piece No. C



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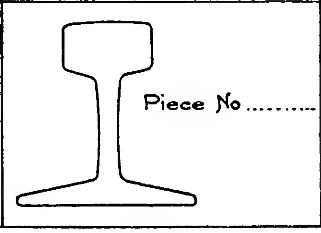

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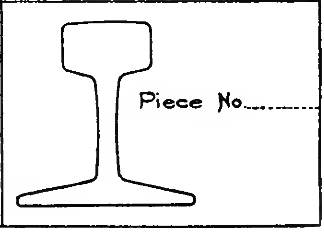


Piece No.

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST NO. 8

Material furnished by B.& O.R.R.Company Weight per Yd. 90 Section "B" ARA

From Bethlehem,Pa. Plant Date rolled August, 1908.

Rolled by Bethlehem Steel Company Kind of Steel Open Hearth

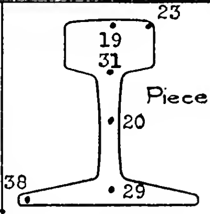
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	17414			.67	.76	.03		.05			.75	.72	.03	.04	.11		
B	23187			.65	.76	.03	.12	.05			.70	.78	.02	.02	.15		
C	21345			.70	.81	.04		.05			.70	.68	.01	.05	.12		
D	15373			.65	.76	.03		.05			.64	.74	.02	.05	.11		

STANDARD DROP TEST.

Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation in 6" on Base.	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	1.76	1.2					.31			
B	1.8	1.3					.31			Large-Angular-Coarse-Granula
C	1.9	1.4					.19			
D	1.89	1.45					.31	62000	118800	20% Silk- 80% Medium Granula

Scleroscope Test.



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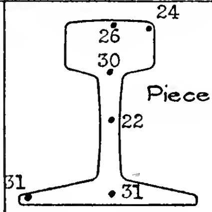

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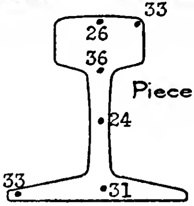

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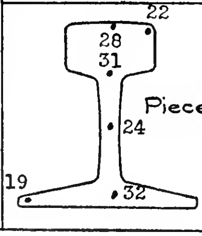

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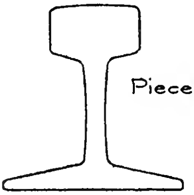

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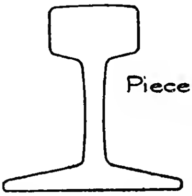


Piece No.

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R.R. TEST NO. 9

Material furnished by Manganese Steel Rail C Weight per Yd. 85 Section ASCE

From Hilburn, N.Y. Plant Date rolled July, 1908.

Rolled by Manganese Steel Rail Company Kind of Steel Manganese

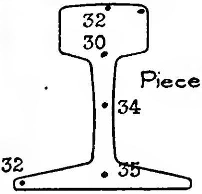
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analyisis of Heat							Chemical Analyisis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	32			.098	11.25	.08	.38	.043									
B	18			.116	12.46	.078	.39	.036									

STANDARD DROP TEST.

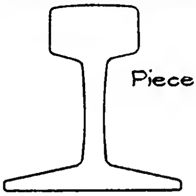
Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation in 6" on Base.	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft		25-ft					
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	2.66	2.5					.5			
B	2.59	2.4					.6			
B			5.58	5.3			1.06			
B					9.2+	9.2	1.9			

Scleroscope Test.



Piece No. A



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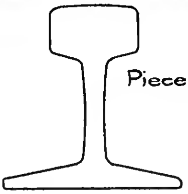

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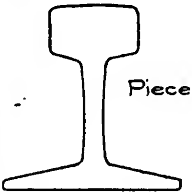

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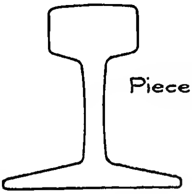

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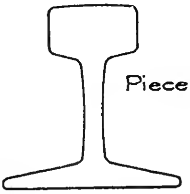


Piece No.

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST No. 10

Material furnished by B.& O.R.R.Company Weight per Yd. 85 Section ASCE

From Hilburn,N.Y. Plant Date rolled - - -

Rolled by Manganese Steel Rail Company Kind of Steel Manganese

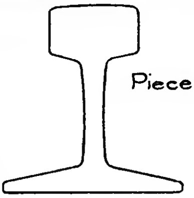
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	-																

STANDARD DROP TEST.

Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation % on in. Base	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	2.69	2.5					.56			
A			5.52	5.3			.94			

Scleroscope Test.



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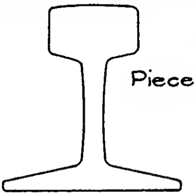

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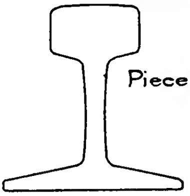

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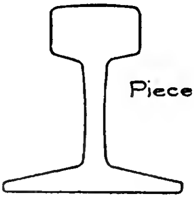

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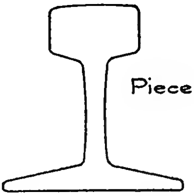

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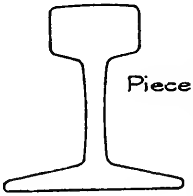


Piece No.........

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O.R.R. TEST NO. 11

Material furnished by B.& O.S.W.R.R. Weight per Yd. 90 Section "B" ARA

From Edgar Thompson Plant Date rolled August,1908.

Rolled by Carnegie Steel Company Kind of Steel Bessemer

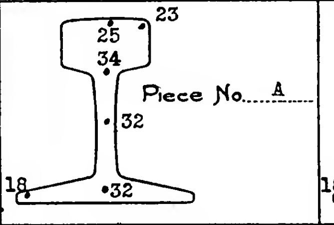
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analyisis of Heat							Chemical Analyisis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	3990	4		.46							.48	.89	.09	.05	.08		
B	3971	2		.5							.51	.85	.11	.05	.09		
C	3881	4		.49							.50	.89	.10	.07	.07		
D	3887	4		.47							.45	.75	.10	.06	.07		

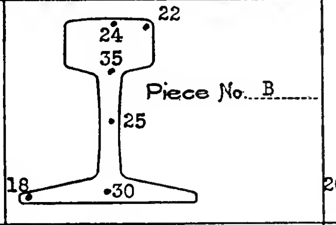
STANDARD DROP TEST.

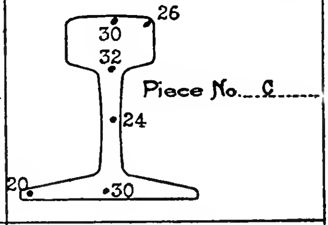
Temperature of Test Piece 70-90 Degrees.

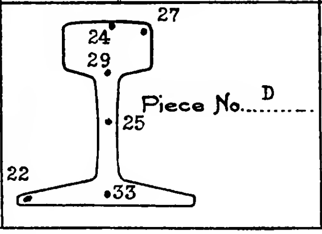
Piece	Height of Drop.						Elongation in 6" on Base.	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	Broke									Square - Fine - Granular
B	2.26	1.6	Broke				.31	64000	120800	100% Coarse Granular
C	1.99	1.7					.44			
D	2.24	1.8					.81	56000	109800	20% Silk- 80% Fine Granular

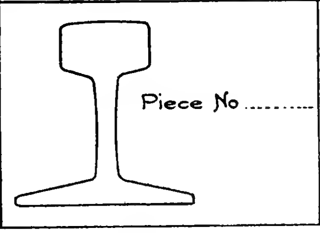
Scleroscope Test.

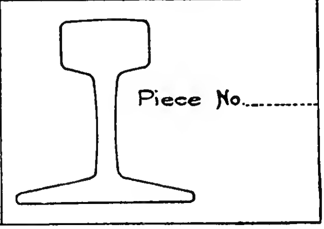












REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST NO. 12

Material Furnished by Carnegie Steel Co. Weight per Yd. 85 Section ASCE

From Edgar Thompson Plant Date rolled May, 1908.

Rolled by Carnegie Steel Company Kind of Steel Bessemer

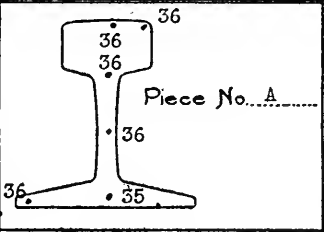
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	1958										.54	1.01	1.01	.06	.11		
B	1967										.45	.89	.09	.05	.09		
C	1952			.51	.84	.09	.09	.05			.50	.90	.09	.05	.10		
D	1950										.55	.91	.10	.05	.12		
E	1969										.45	.85	.10	.05	.10		

STANDARD DROP TEST.

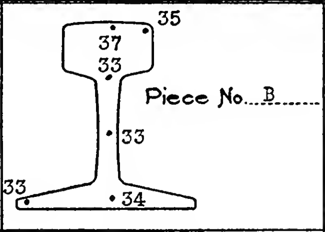
Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation % on in Base.	Elastic Limit	Tensile Strength.	Remarks. Clean Brk
	15 Ft		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	Broke						-			Angular-Medium-Granular
B	2.11	1.8	Broke				.44			Square-Medium-Granular
C	1.98	1.7					.56			
D	1.98	1.6					.38	62000	115600	5% Silk- 95% Fine Granular
F	2.21	1.9					.44			

Scleroscope Test.



Piece No. A



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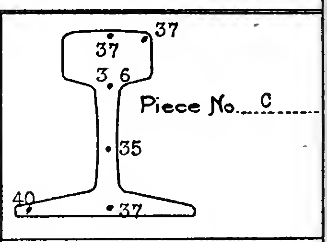

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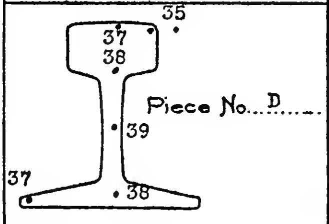

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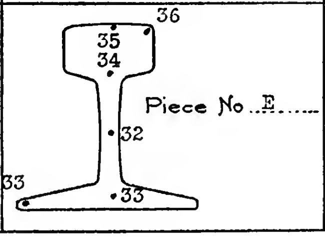

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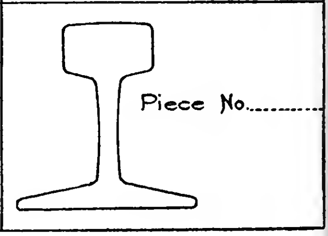


Piece No.

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST NO. 13

Material furnished by A.T.& S.F.Ry. Weight per Yd. 90 Section "A" ARA

From South Works Plant Date rolled March,1908.

Rolled by Illinois Steel Company Kind of Steel Bessemer

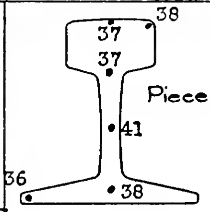
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A		A									.51	.76	.11	.06	.11		
B	35128	A									.51	.78	.10	.06	.12		
C	55481	A									.53	.85	.10	.05	.13		
D		A									.53	.88	.10	.06	.11		
E		A									.48	.80	.09	.08	.12		
F		A									.52	.82	.11	.06	.12		

STANDARD DROP TEST.

Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation in 6" on Base.	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				Flaw in base before test
A	Broke									Square - split web and base
B	1.95	1.7	Broke				.25			*
C	1.98	1.7					.31	58000	113800	100% Coarse Granular
D	1.95	1.7					.38			
E	2.05	1.8					.56			
F	2.03	1.8					.38			
										* Irregular - head medium
										granular. Web and base
										fine granular

Scleroscope Test.



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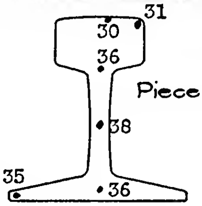

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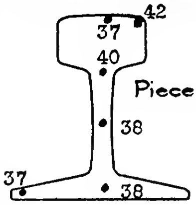

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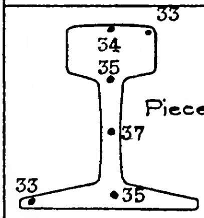

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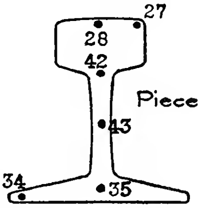

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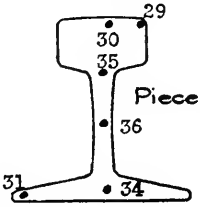


Piece No. F

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST NO. 14

Material furnished by Bethlehem Steel Co. Weight per Yd. 90 Section "A" ARA

From South Bethlehem Plant Date rolled December, 1908.

Rolled by Bethlehem Steel Company Kind of Steel Open Hearth

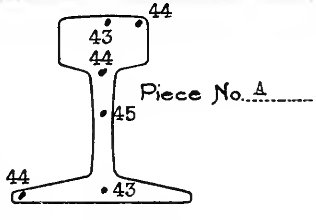
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analyisis of Heat							Chemical Analyisis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	23329	A									.73	.78	.03	.04	.10		
B	19484	A									.58	.89	.01	.04	.12		
C	19484	A									.64.	.93	.02	.04	.11		
D	19484	A									.58	.89	.02	.03	.11		
E	23329	A									.72	.86	.04	.04	.11		

STANDARD DROP TEST.

Temperature of Test Piece 90-90 Degrees.

Piece	Height of Drop.						Elongation in 6" on Base.	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		18-ft		20-ft					
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	1.66	1.1					.19			
B	1.74	1.3					.31			
C	1.74	1.3					.31	62874	113572	5% Silk- 95% Fine Granular
D	1.78	1.4					.25			
E	1.54	1.1					.19			
B			2.94	2.5			.44			
C					3.26	2.7	.56			

Scleroscope Test.



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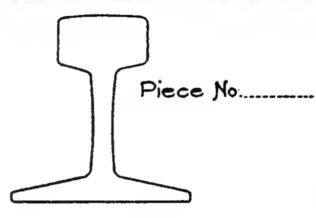

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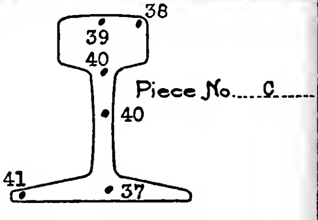

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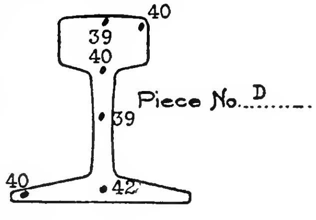

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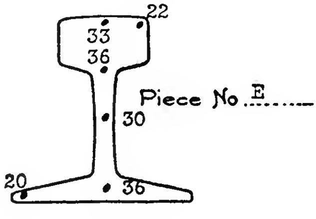

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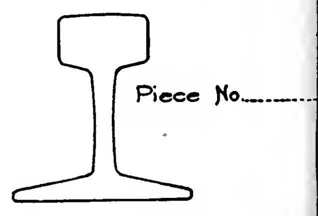


Piece No.

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST NO. 15

Material furnished by B.& O.R.R.Co. Weight per Yd. 90 Section "B" ARA

From South Bethlehem Plant Date rolled August,1908.

Rolled by Bethlehem Steel Company Kind of Steel Open Hearth

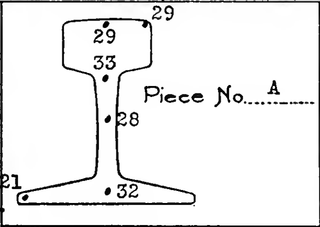
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	17411	D									.72	.76	.03	.03	.10		
B	20392	C									.77	.73	.02	.02	.10		
C	20392	C									.71	.73	.02	.04	.10		
D	20392	C									.76	.72	.01	.04	.09		
E	20392	C									.71	.75	.02	.04	.11		

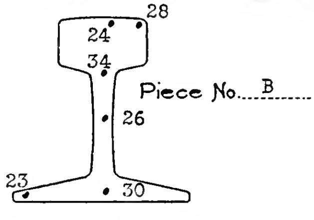
STANDARD DROP TEST.

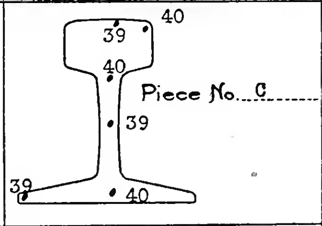
Temperature of Test Piece 70-90 Degrees.

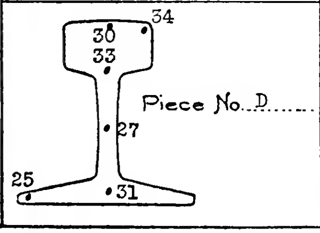
Piece	Height of Drop.						Elongation % on 6" in Base	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	1.68	1.3					.25			
B	1.68	1.3	Broke				.31			
C	1.68	1.3					.25			
D	1.77	1.3					.25			
E	1.71	1.3					.31	59880	117764	25% Silk- 75% Medium Granular

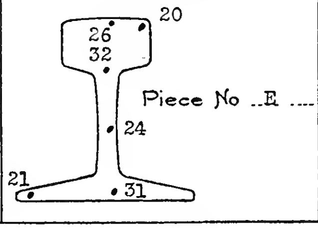
Scleroscope Test.

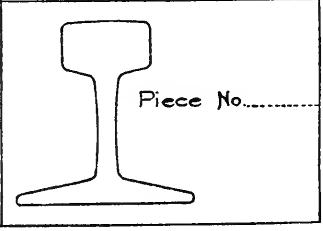












REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST NO. 16

Material furnished by Bethlehem Steel Co. Weight per Yd. 85 Section ASCE C.B.& Q.Sty

From South Bethlehem Plant Date rolled March,1908.

Rolled by Bethlehem Steel Company Kind of Steel Open Hearth

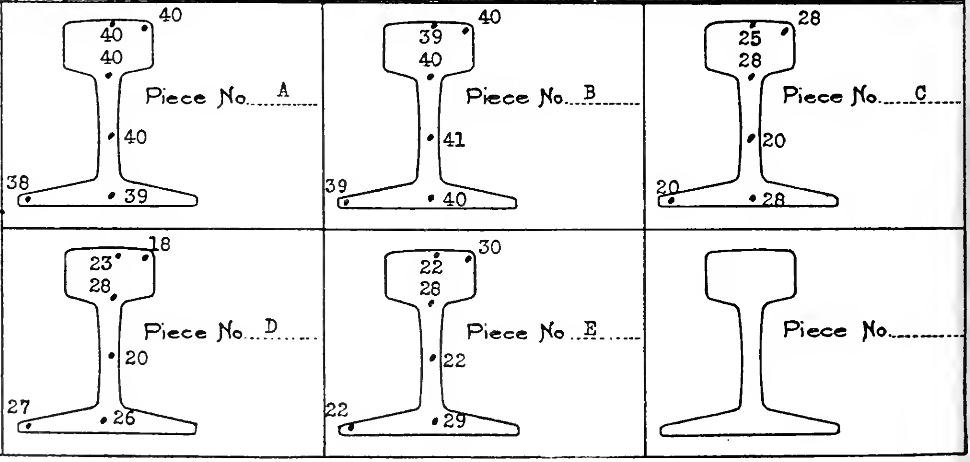
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	L-1315	C		.67	.85	.02		.03			.63	.93	.01	.03	.12		
B	L-1315	C		.67	.85	.02		.03			.63	.92	.01	.03	.10		
C	16302	E		.69	.77	.03		.05			.58	.75	.02	.04	.07		
D	16301	E									.61	.84	.01	.04	.07		
F	16302	E									.56	.92	.02	.05	.07		

STANDARD DROP TEST.

Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation on 6 in. Base.	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	1.78	1.4					.31			
B	1.71	1.4					.31			
C	2.01	1.7					.31			
D	2.08	1.7					.31			
E	Not tested						-			
A			3.81	3.0			.44			
B			3.87	3.0			.69			
C			3.91	3.5			.81			
E			2.54	2.2			.56	62000	102000	50% Silk- 50% Fine Granular

Scleroscope Test.



REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST NO. 17

Material furnished by Bethlehem Steel Co. Weight per Yd. 85 Section "A" ARA

From South Bethlehem Plant Date rolled April, 1908. B. of A. T. & S. F. Ry

Rolled by Bethlehem Steel Co. Kind of Steel Open Hearth

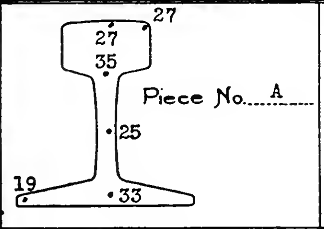
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analyisis of Heat							Chemical Analyisis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	14341	2		.66	.85	.03		.03			.75	.79	.02	.03	.10		
B	17307	2		.68	.69	.04		.07			.62	.68	.03	.06	.08		
C	23039	1		.62	.73	.04		.06			.56	.68	.03	.06	.09		
D	17307										.66	.72	.03	.07	.09		
E	14341																

STANDARD DROP TEST.

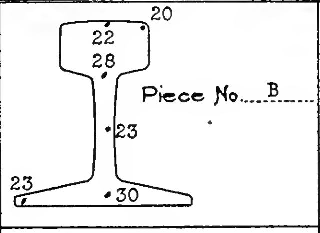
Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation % on in. Base	Elastic Limit	Tensile Strength	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	1.65	1.4					.25			
B	1.84	1.5					.31			
C	1.98	1.6					.31			
D	1.84	1.5					.25			
E	1.55	1.4					.31			
C			3.83	3.3			.56			

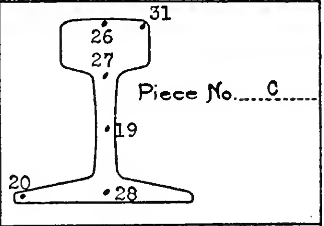
Scleroscope Test



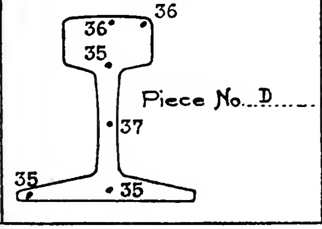
Piece No. A



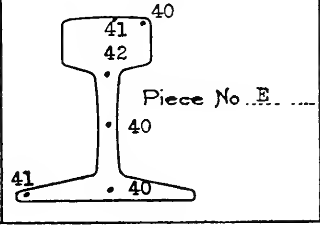
Piece No. B



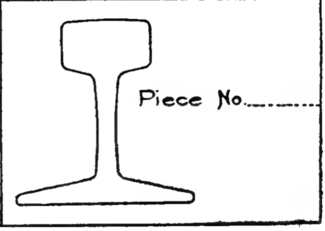
Piece No. C



Piece No. D



Piece No. E



Piece No.

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST No. 18

Material furnished by B. & O. R. R. Co. Weight per Yd. 100 Section "B" ARA

From Sparrows Point Plant

Date rolled February, 1909.

Rolled by Maryland Steel Company

Kind of Steel Bessemer

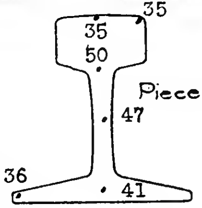
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	10511	A									.64	.89	.07	.09	.08		
B	10511	B									.58	.82	.08	.09	.09		
C	10512	C									.59	.90	.07	.09	.09		
D	10511	D									.55	.88	.07	.08	.10		
E	10509	C									.57	.78	.07	.06	.07		

STANDARD DROP TEST.

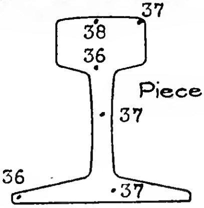
Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation in 6 on Base.	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.		20-ft							
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	1.55	1.3	Broke				.31			
B	1.51	1.2					.25			
C	1.54	1.2					.25			
D	1.54	1.2					.25			
E	1.45	1.2					.25			

Scleroscope Test.



Piece No. A



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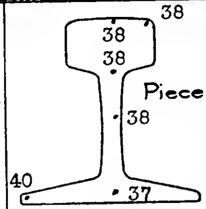
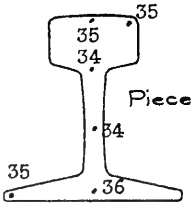
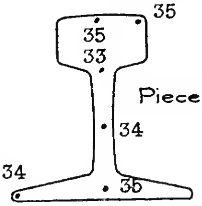


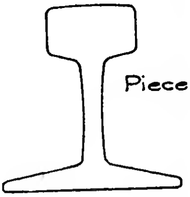
Piece No. C



Piece No. D



Piece No. E



Piece No.

REPORT OF CHEMICAL & PHYSICAL EXAMINATION OF RAIL

OFFICE OF CHIEF ENGINEER, MAINT. OF WAY B. & O. R. R. TEST NO. 19

Material furnished by B.& O.R.R.Co. Weight per Yd. 100 Section "B" ARA

From Sparrows Point Plant Date rolled February, 1909.

Rolled by Maryland Steel Company Kind of Steel Bessemer

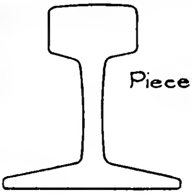
Number of Pieces	Heat Number	Position in Ingot	% of Crop	Chemical Analysis of Heat							Chemical Analysis of Test Pieces.						
				C.	Mn.	P.	Si.	S.			C.	Mn.	P.	Si.	S.		
A	10687	–															

STANDARD DROP TEST.

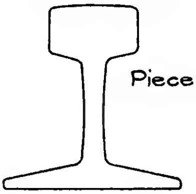
Temperature of Test Piece 70-90 Degrees.

Piece	Height of Drop.						Elongation in 6" of Base.	Elastic Limit	Tensile Strength.	Remarks.
	15 Ft.									
	Deflection.	Permanent Set	Deflection.	Permanent Set	Deflection.	Permanent Set				
A	–	.19								

Scleroscope Test.



Piece No.



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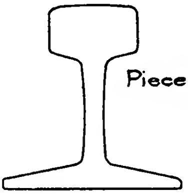

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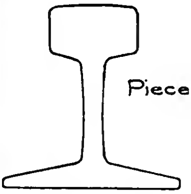

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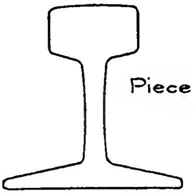

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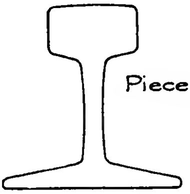

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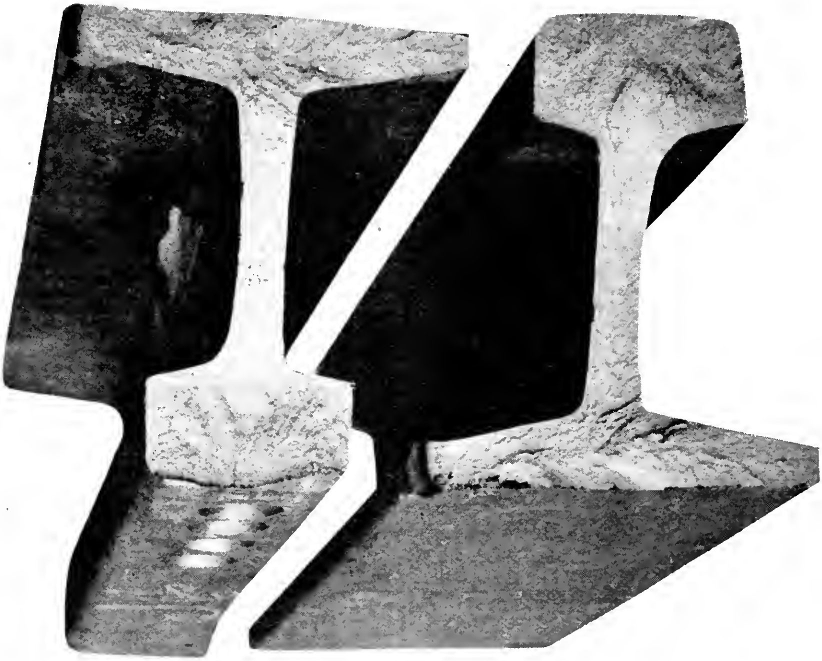
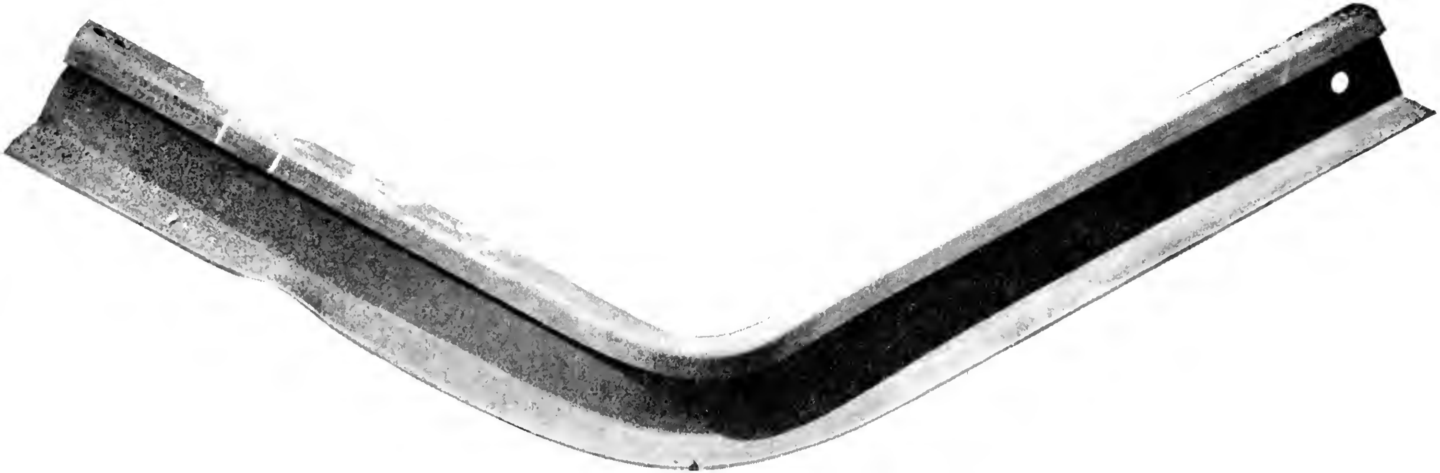


RECORD 153—TEST NO. 2-C.

Record 169—Test No. 3-A.

Record 169—Test No. 4-B.

Record 171—Test No. 4-F.



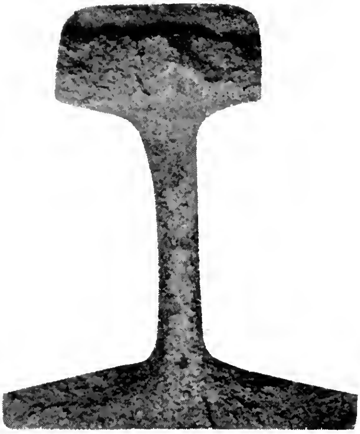
Test No. 6-B. 85-Lb. A. S. C. E. Section "Manard" Rail, Rolled at Steelton, P. S. Co. Heat No. 3630.

Test No. 6-A. 85-Lb. A. S. C. E. Section "Manard" Rail, Rolled at Steelton, P. S. Co. Heat No. 3631.

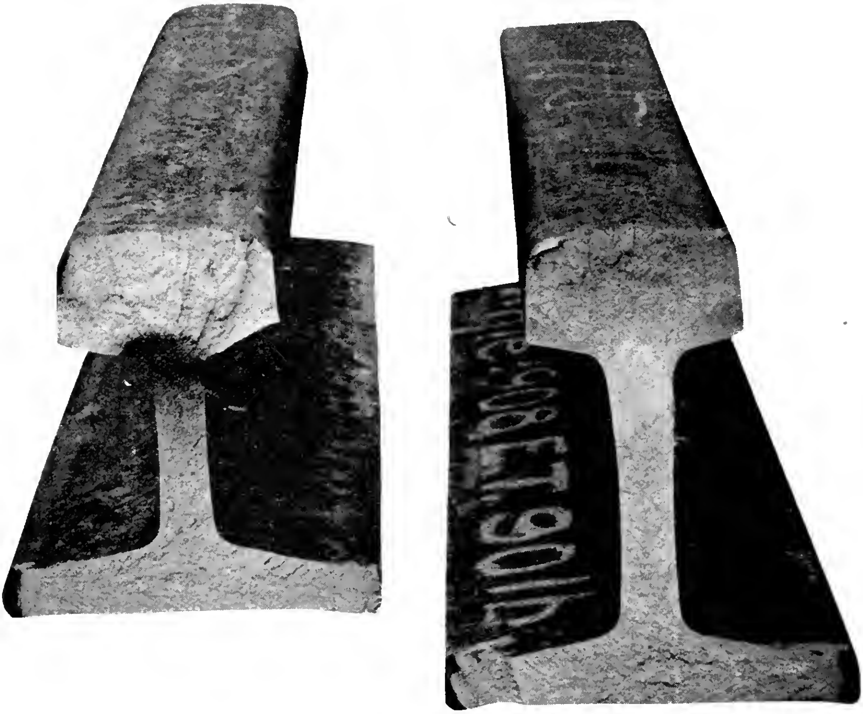
RECORD 150. TEST NO. 7-D.

RECORD 152. TEST NO. 9-A.

RECORD 155. TEST NO. 9-B.



Record 168. Test No. 11-A.



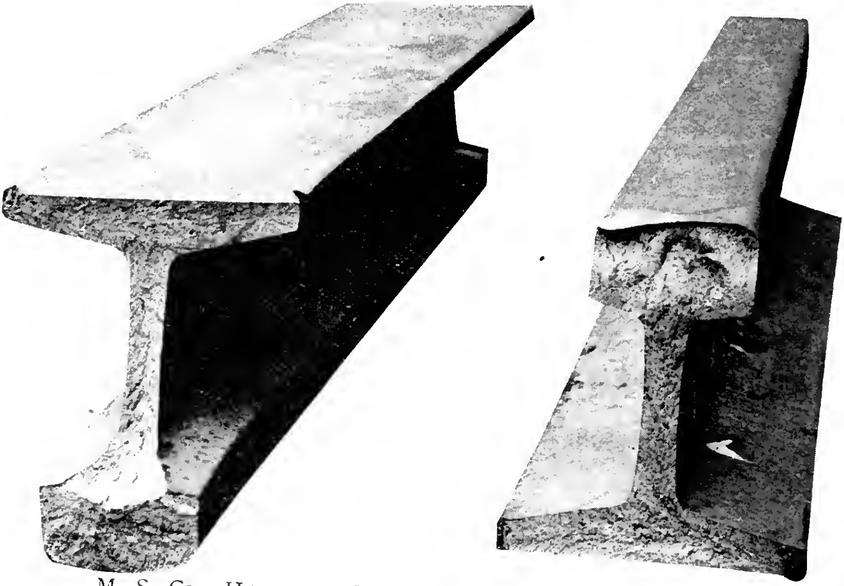
Record 152. Test No. 11-D.

Record 170. Test No. 12-A.

Record 168. Test No. 13-A.

Record 150. Test No. 14-E.

RECORD 153. TEST NO. 15-A.



M. S. CO. HEAT 10509-E. M. S. CO. HEAT 10511-D.

RECORD 151.

Record 154. Test No. 16-A.

Record 151. Test No. 16-B.

Record 154. Test No. 17-B.

DROP TESTS MADE BY DR. P. H. DUDLEY.

Mr. Geo. W. Kittredge handed me his notes of the drop tests made by the Committee at Sparrows Point, and I have calculated approximately the inch-pounds of work of the drop in bending the sections from the data for all of the unbroken tests. I thought this would be of interest to the Committee to add to their notes. The tabulations include sufficient data to identify each specimen as originally numbered upon the Committee's tests.

The drop-testing machine, when the measurements of the elastic as well as the permanent deformations of the section are made under a given fall of the hammer, enables a number of interesting results to be obtained in reference to the physical and mechanical properties of the metal and section as rolled:

First—The deflection under the drop is least where the permanent set is the greatest, i. e., the elastic properties of the section will be small and the plastic properties large. The section will have greater ductility than stiffness.

Second—The deflection under the drop increases and the permanent set of the section decreases as its mechanical properties or the physical properties of the metal are augmented, or when both in combination are used.

Third—The inch-pounds of work of the same drop to bend the section will increase as the combined total amount or the elastic and permanent deformation is reduced. This fact furnishes desirable comparisons between the sections as manufactured.

The consideration and adjustment of the relationship between the elastic and plastic properties in sections of a given weight of metal for safe and efficient service and slow rates of wear are some of the complicated problems which have been studied and selections made which render possible the development of the present heavy traffic. The ores available when those solutions were made in 1890 have since been exhausted, and readjustments are required to sustain the progress in transportation already attained, and the work has been assigned to the Committee for consideration, investigation and recommended practice as a solution of the varied problems.

The tabulation of the inch-pounds of work to deform the sections will be of service in the work and will be more interesting when the chemical composition of the steel becomes available to insert with the other data of the tests. (Note: This is now supplied in this report.—Secretary.) The butts on the base were stamped for six one-inch spaces and the elongation measured for the entire six inches and from that I have stated the average per cent. The maximum elongation for the two or three inches directly under the drop would be from two to three per cent. greater in most cases, and should have been measured to show that the new standard drop with the five-inch radius of the die of the hammer increases the maximum elongation per inch over the larger radius of the dies of the older drop-testing machines replaced.

The inch-pounds of work for rail No. 1, 90-lb. section "A" A. R. A., M. I. 38.70, average higher than for rail No. 2, 100-lb. "B" A. R. A., M. I. 41.30, showing that as rolled the physical properties were lower, i. e., the elastic limits were not as high. Rail No. 3, 100-lb. "A" A. R. A., M. I. 48.94, indicates, by the large number of inch-pounds of work of the drop to deform the section, its large mechanical properties. The Manard rail No. 6 and the Manganese rails Nos. 9 and 10, with their ductility and resistance to abrasion combined with the difficulty to break them, the inch-pounds of work by the drop to deflect and produce the permanent sets are the lowest of any of the rails tested. The elastic limits in both the Manard and Manganese rails, the inch-pounds show, are low, apparently under 30,000 lbs. per inch. It is said the elastic limits can be augmented. The inch-pounds of work under the drop average the highest in rails No. 18, 100-lb. "B," A. R. A., M. I. 41.30. The carbon in those rails was about .55 of 1 per cent., and the phosphorus probably about .085 or less. These have high elastic properties in the metal, and is the only series of tests where the letters refer to the exact position of the rails in the ingot; "A" designating the top rails and "B" the next below, etc.

The permanent set of all the rails under the 15-ft. drop for the expenditure of only 30,000 ft. pounds of energy is large, yet several specimens broke, one in test No. 3, also one in Nos. 4, 11, 12 and 13, making five in all, showing that the apparent ductility was not accompanied by uniform toughness.

I estimate that the expenditure under the new drop of only 30,000 ft. pounds for 100-lb. rails for the cold climates is too small. The 18-ft. drop, or 36,000 ft. pounds of energy, would produce an elongation of the metal corresponding about to the 20-ft. fall of the older drops, and be safer for the tests of all rails which are to be used in the northern latitude of this country. The 18-ft. drop has been inserted in most of the Manufacturers' Specifications for the new Standard Drop Testing Machines for 100-lb. sections.

The inch-pounds of work of the drop in testing the 100-lb. rails for the New York Central Lines, which have withstood the service of fifteen to sixteen years with comparatively few breakages, ranged from 380,000 to 480,000 inch-pounds. The greater number of these were over 400,000 inch-pounds. We are accepting rails with the high phosphorus at the present time in 100-lb. sections in which the inch-pounds of work of the drop are much less than for those rails which were high in carbon and only .06 in phosphorus. . . . .

CALCULATIONS OF THE INCH-POUNDS OF WORK OF THE DROP TESTS ON RAILS MADE AT SPARROWS POINT, FEBRUARY 15, 1909, BY P. H. DUDLEY FROM MR. GEO. W. KITTREDGE'S NOTES.

Rail No. 1. Kind of Steel, Bessemer. Brand, Illinois. Weight, 90-lb. Section, "A," A. R. A. M. I. 38.70.

Piece	Drop 15′		Inch-Pounds of Work of the Drop	Elongation on Six In.	Average Per Cent.
	Deflec.	Perm. Set			
A	$\frac{11}{32}$	1.5	197,652	$\frac{5}{16}$	5
B	$\frac{3}{16}$	1.4	227,000	$\frac{4}{16}$	4
C	$\frac{5}{16}$	1.4	213,765	$\frac{4}{16}$	4
D	$\frac{4}{16}$	1.4	220,182	$\frac{5}{16}$	5
E	$\frac{4}{16}$	1.5	207,714	$\frac{5}{16}$	5
F	$\frac{5}{16}$	1.45	191,189	$\frac{5}{16}$	5

Rail No. 2. Kind of Steel, Bessemer. Brand, Carnegie. Weight, 100-lb. Section, "B," A. R. A. M. I. 41.30.

A	$\frac{4}{16}$	1.7	186,615	$\frac{10}{16}$	5
B	$\frac{6}{16}$	1.3	210,955	$\frac{5}{16}$	5
C	$\frac{4}{16}$	1.7	186,615	$\frac{5}{16}$	5
D	$\frac{4}{16}$	1.7	186,615	$\frac{5}{16}$	5
E	$\frac{5}{16}$	1.3	227,000	$\frac{3}{16}$	5

Rail No. 3. Kind of Steel, Bessemer. Brand, Carnegie. Weight, 100-lb. Section, "A," A. R. A. M. I. 48.94.

A	Broke				
B	$\frac{5}{16}$	1.25	232,770	$\frac{4}{16}$	4
C	$\frac{5}{16}$	1.3	226,625	$\frac{4}{16}$	4
D	$\frac{9}{32}$	1.3	227,000	$\frac{4}{16}$	4
E	$\frac{9}{32}$	1.3	227,000	$\frac{5}{16}$	5

Rail No. 4. Kind of Steel, Bessemer. Brand, Illinois. Weight, 85-lb. Section, A. S. C. E. M. I. 30.00.

A	$\frac{5}{16}$	1.6	186,570	$\frac{6}{16}$	6
B	Broke				
C	$\frac{5}{32}$	1.6	206,541	$\frac{4}{16}$	4
D	$\frac{11}{32}$	1.6	187,549	$\frac{6}{16}$	6
E	$\frac{5}{16}$	1.65	185,929	$\frac{7}{16}$	6
F	Broke				

Rail No. 5. Kind of Steel, Open-Hearth. Brand, Pennsylvania. Weight, 100-lb. Section, Special 6 in. Boston Elevated. M. I.

A	$\frac{7}{16}$	.9	272,676	$\frac{4}{16}$	4
B	$\frac{13}{32}$	.8	320,000	$\frac{4}{16}$	4

Rail No. 6. Kind of Steel, Manard. Brand, Pennsylvania. Weight, 85-lb. Section, A. S. C. E. M. I. 30 .00.

Piece	Drop 15′		Inch-Pounds of Work of the Drop	Elongation on Six In.	Average Per Cent.
	Deflec.	Perm. Set			
A	1/8	2 .4	144,572	11/16	9
B	5/32	2 .5	143,177	9/16	15

Rail No. 7. Kind of Steel, Bessemer. Brand, Illinois. Weight, 90-lb. Section, "A," A. R. A. M. I. 38 .70.

A	11/32	1 .5	199,711	5/16	5
B	11/32	1 .5	199,711	5/16	5
C	7/16	1 .4	198,700	5/16	5
D	3/8	1 .5	194,300	5/16	5

Rail No. 8. Kind of Steel, Open-Hearth. Brand, Bethlehem. Weight, 90-lb. Section, "B," A. R. A. M. I. 32 .30.

A	9/16	1 .2	206,546	5/16	5
B	8/16	1 .3	202,000	5/16	5
C	8/16	1 .4	191,474	3/16	4
D	7/16	1 .45	192,729	5/16	5

Rail No. 9. Kind of Steel, Manganese. Brand, Manganese. Weight, 85-lb. Section, A. S. C. E. M. I. 30 .00.

A	5/32	2 .5	137,315	8/16	8
B	3/16	2 .4	140,470	10/16	9

Rail No. 10. Kind of Steel, Manganese. Brand, Manganese. Weight, 85-lb. Section, A. S. C. E. M. I. 30 .00.

A	3/16	2 .5	135,829	9/16	9

Rail No. 11. Kind of Steel, Bessemer. Brand, Carnegie. Weight, 90-lb. Section, "B," A. R. A. M. I. 32 .30.

A	Broke				
B	21/32	1 .6	161,111	5/16	5
C	20/32	1 .65	160,240	7/16	6
D	7/16	1 .8	162,898	13/16	6

Rail No. 12. Kind of Steel, Bessemer. Brand, Carnegie. Weight, 85-lb. Section, A. S. C. E. M. I. 30 .00.

A	Broke				
B	5/16	1 .8	173,430	7/16	7
C	9/32	1 .7	182,000	9/16	8
D	6/16	1 .6	184,176	6/16	6
E	5/16	1 .9	165,637	7/16	7

Rail No. 13. Kind of Steel, Bessemer. Brand, Illinois. Weight, 85-lb Section, "A," A. R. A. M. I. 33 .00.

Piece	Drop 15′		Inch-Pounds of Work of the Drop	Elongation on Six In.	Average Per Cent.
	Deflec.	Perm. Set			
A	Broke				
B	4/16	1 .7	186,615	4/16	4
C	9/32	1 .7	182,000	5/16	6
D	4/16	1 .7	186,615	6/16	6
E	4/16	1 .8	182,050	9/16	6
F	9/32	1 .75	182,050	6/16	6

Rail No. 14. Kind of Steel, Open-Hearth. Brand, Bethlehem. Weight, 90-lb. Section, "A," A. R. A. M. I. 38 .70.

A	9/16	1 .1	218,855	3/16	3
B	7/16	1 .3	209,183	5/16	3
C	7/15	1 .3	209,183	5/16	5
D	6/16	1 .4	204,873	4/16	5
E	7/16	1 .1	236,277	3/16	4

Rail No. 15. Kind of Steel, Open-Hearth. Brand, Bethlehem. Weight, 90-lb. Section, "B," A. R. A. M. I. 34 .00.

A	3/8	1 .3	216,925	4/16	4
B	3/8	1 .3	216,925	5/16	6
C	3/8	1 .3	216,925	5/16	6
D	15/32	1 .3	206,390	4/16	4
E	13/16	1 .3	213,764	5/16	6

Rail No. 16. Kind of Steel, Open-Hearth. Brand, Bethlehem. Weight, 85-lb. Section, "C. B. & Q." A. S. C. E. M. I. 30 .00.

A	3/8	1 .40	205,384	5/16	5
B	5/16	1 .40	212,643	5/16	5
C	5/16	1 .7	181,104	5/16	5
D	6/16	1 .7	175,494	5/16	7

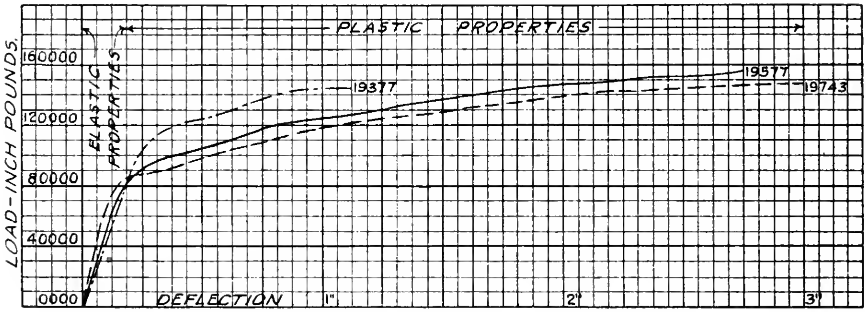
Rail No. 17. Kind of Steel, Open-Hearth. Brand, Bethlehem. Weight, 85-lb. Section, "A," A. R. A. M. I. 33 .00.

A	4/16	1 .4	220,181	4/16	4
B	11/32	1 .5	187,566	5/16	6
C	6/16	1 .6	184,239	5/16	6
D	11/32	1 .5	187,566	4/16	4
E	5/16	1 .4	212,526.	5/16	6

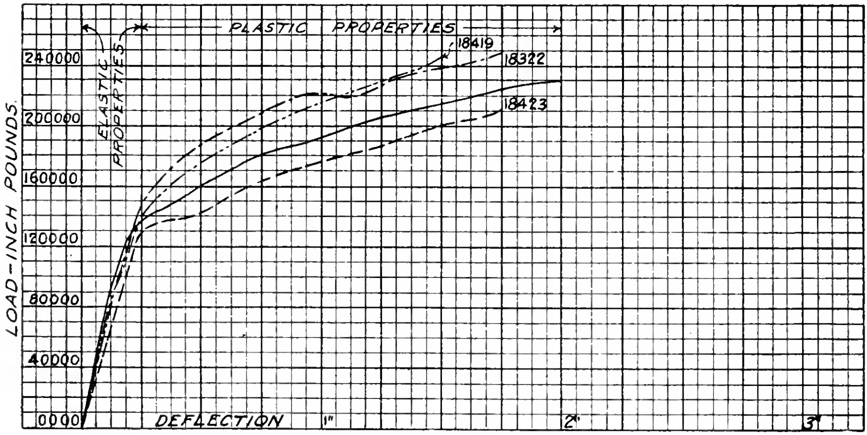
Rail No. 18. Kind of Steel. Bessemer. Brand, Maryland. Weight, 100-lb. Section, "B," A. R. A. M. I. 41 .30.

A	4/16	1 .3	234,258	5/16	6
B	5/16	1 .2	240,410	4/16	4
C	11/32	1 .20	221,390	4/16	4
D	11/32	1 .2	221,390	4/16	4
E	4/16	1 .2	250,499	4/16	4
	3/16	.19	66,000	1 ft. drop carbon .55.	

TRANSVERSE DEFLECTION CURVES OF RAIL SECTIONS
IN A TESTING MACHINE.
Tests made by P. H. Dudley



80LB. RAIL, $5\frac{1}{8}''$ HIGH-DUDLEY SECTION M. I. 28.50. 3 TESTS.



100LB. RAIL, 6" HIGH-DUDLEY SECTION M. I. 48.50 4 TESTS.

In the drop tests made by Dr. P. H. Dudley the specimens were stamped before testing on the head and base at the center with a spacing bar with seven (7) conical points, making six (6) one (1) inch spaces, in order to show the percentage of compression or elongation per inch of the metal in the section. A two (2) foot bar with three points was used to get total compression or elongation under the drop when required.

The die striking the metal of the head prevents the inch-long section immediately under the die from compressing uniformly with the sections on either side. When a butt breaks it is often bruised on the base, closing or distorting the records of the previous blow; this is shown in Test No. 42. Wood was placed in the space in subsequent tests and as a consequence the butts were not as severely bruised.

Test No. 41 is from 100-lb. rail.

Test No. 42 is from 100-lb. rail, open-hearth steel.

Tests Nos. 62 and 63 are from different ingots of the same heat: also tests Nos. 64 and 65.

Tests Nos. 62 and 64 are designated as cold-rolled, being held thirty seconds before the last pass.

DROP TESTS MADE ON LACKAWANNA STEEL COMPANY'S NEW STANDARD DROP-TESTING MACHINE, BUFFALO, N. Y., NOVEMBER 2, 1908.

Sec. 1001. (Dudley 6 in. 100-lb. M. I. 48.5). Rolled August, 1908.

Average Chemical Composition: C. .51, Mn. 1.00, Si. .13, S. .07, P. .096. Butts spaced per inch for 6 in. in length on Head and Base and for 1 ft. marks each side of the center before testing.

Compression and Elongation measured for each inch, and the totals for 6 and 24 in.

Test No. 41—Special F. T. Steel.

Heat No. 13,569.

								Totals for	
		1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	6 in.	24 in.
1st Blow Def'n, 1.58 in......									
	Head Comp..	.97	.95	.92	.95	.93	.97	.32	.43
	Base Elong..	1.04	1.06	1.07	1.08	1.05	1.05	.35	.53
2d Blow Def'n, 2.65 in....									
	Head Comp..	.95	.88	.88	.92	.87	.94	.56	.74
	Base Elong. .	1.07	1.10	1.11	1.11	1.10	1.07	.57	.90

Note.—Broke through head in third inch near third point, broke through base ¾ in. left of first point, and ⅛ in. right of seventh point. A piece was detached from base.

Permanent set of butt between supports.

Ordinates measured in hundredths of inches every two inches from zero (one end over the supports) to 36 in., the span between centers of supports.

0	2 in.	4 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.	18 in.
0	.20	.40	.60	.78	.96	1.13	1.28	1.44	1.58
	20 in.	22 in.	24 in.	26 in.	28 in.	30 in.	32 in.	34 in.	36 in.
	1.44	1.27	1.08	.88	.70	.54	.35	.18	0

The ordinates at 10 and 12 in. indicate the butt—top crop—was not perfectly straight before testing.

Test No. 42—Open-Hearth Steel, Section 1001.

Average Chemical Composition: C. 165, Mn. 76, Si. .12, S. .05, P. .03.

Heat No. 8205.

		1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Totals for 6 in.	Totals for 24 in.
1st Blow Def'n, 1.64 in.	Head Comp. .	.95	.93	.96	.94	.93	.97	.32	.42
	Base Elong. .	1.06	1.08	1.09	1.09	1.07	1.07	.43	.63
2d Blow Def'n, 1.74 in.	Head Comp. .	.95	.91	.95	.93	.94	.98	.36	.45
	Base Elong. .	1.06	1.11	1.08	1.07	1.08	1.06	.46	.64

Note.—Broke through head in third inch near fourth point; broke through base in second inch near third point.

Mn. and Si. too low and both raised for subsequent heats.

Permanent set of butt between supports.

Ordinates measured in hundredths of inches every two inches from zero (one end over the supports) to 36 in., the span between centers of supports.

0	2 in.	4 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.	18 in.
0	.20	.40	.60	.79	.99	1.18	1.36	1.53	1.64
	20 in.	22 in.	24 in.	26 in.	28 in.	30 in.	32 in.	34 in.	36 in.
	1.52	1.34	1.19	.95	.75	.55	.37	.17	0

The ordinates show that the 5-in. radius of the die, for the same height of fall, concentrates the energy of the blow in a less length of metal than the former larger radii of the dies, the central ordinate being greater as well as the maximum compression and elongation of the metal per inch.

DROP TESTS, LACKAWANNA STEEL COMPANY'S PLANT, BUFFALO, NOVEMBER 14, 1908.

Sec. 801. (Dudley 5⅛ in. 80-lb. M. I. 28.50.) Rolled October 27, 1908.

Average Chemical Composition: C. 46, Mn. .96, Si. .12, S. .08, P. .095.

Test No. 62—Ordinary Bessemer Steel.

Heat No. 23,248 = "Cold" Rolled. Held 30 seconds before finishing pass.

		1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Totals for 6 in.	Totals for 24 in.
1st Blow Def'n, 2.34 in.	Head Comp. .	.94	.90	.95	.90	.95	.98	.40	.55
	Base Elong. .	1.08	1.10	1.12	1.07	1.08	1.05	.50	.75
2d Blow Def'n, 4.28 in.	Head Comp. .	.87	.86	.89	.85	.90	.96	.67	.91
	Base Elong. .	1.16	1.18	1.22	1.15	1.13	1.09	.94	1.41
3d Blow Def'n, 4.30 in.	Head Comp. .	.87	.86	.89	.85	.90	.96	.67	.91
	Base Elong. .	1.16	1.20	1.23	1.15	1.15	1.09	.98	1.50

Note.—Broke through head in second inch near third point; broke through base in center of fourth point.

Test No. 63—Ordinary Bessemer Steel.

Heat No. 23,248 = "Hot" Rolled. Not held before finishing pass.

								Totals for	
		1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	6 in.	24 in.
1st Blow Def'n, 2.33 in.									
	Head Comp. .	.93	.89	.96	.90	.95	.97	.40	.52
	Base Elong. .	1.08	1.08	1.13	1.07	1.08	1.06	.50	.73
2d Blow Def'n, 4.32 in.									
	Head Comp. .	.85	.86	.89	.84	.91	.96	.68	.92
	Base Elong. .	1.17	1.19	1.23	1.15	1.13	1.08	.95	1.41
3d Blow Def'n, 4.35 in.									
	Head Comp. .	.85	.87	.88	.84	.90	.96	.70	.96
	Base Elong. .	1.18	1.20	1.25	1.15	1.14	1.09	1.00	1.49

Note.—Broke through head in second inch near third point; broke through base in center of third point.

Sec. 801. (Dudley 5⅛ in. 80-lb. M. I. 28.50.) Rolled October 27, 1908.

Average Chemical Composition: C. 45, Mn. 98, Si. 13, S. .07, P. .094.

Test No. 64—Ordinary Bessemer Steel.

Heat No. 23,263 = "Cold" Rolled. Held 30 seconds before finishing pass.

								Totals for	
		1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	6 in.	24 in.
1st Blow Def'n, 2.25 in.									
	Head Comp. .	.93	.91	.96	.90	.95	.97	.40	.46
	Base Elong. .	1.07	1.09	1.10	1.07	1.07	1.04	.44	.68
2d Blow Def'n, 3.55 in.									
	Head Comp. .	.91	.88	.91	.83	.90	.96	.62	.84
	Base Elong. .	1.10	1.14	1.18	1.13	1.11	1.08	.73	1.07

Note.—Broke through head in fourth inch near fourth point; broke through base in center of second point.

Test No. 65—Ordinary Bessemer Steel.

Heat No. 23,263 = "Hot" Rolled. Not held before finishing pass.

								Totals for	
		1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	6 in.	24 in.
1st Blow Def'n, 2.28 in.									
	Head Comp. .	.94	.90	.96	.90	.93	.97	.41	.54
	Base Elong. .	1.07	1.09	1.11	1.08	1.07	1.06	.48	.72
2d Blow Def'n, 4.25 in.									
	Head Comp. .	.85	.86	.88	.84	.91	.96	.70	.92
	Base Elong. .	1.17	1.20	1.21	1.18	1.13	1.08	.95	1.37
3d Blow Def'n, 4.85 in.									
	Head Comp. .	.78	.82	.85	.85	.92	.96	.79	1.06
	Base Elong. .	1.20	1.23	1.24	1.18	1.14	1.09	1.08	1.55

Note.—Broke through head in center of second inch; broke through base in center of second point.

Appendix F.

(Bulletin 116.)

GENERAL INFORMATION CONCERNING THE SCLEROSCOPE AND ITS USE ON THE BALTIMORE & OHIO RAILROAD.

By A. W. Thompson, Chief Engineer Maintenance of Way.

One of the physical characteristics of the iron and steel most necessary to a railroad is hardness. This quality is necessary in a rail to support the traffic, and in the machine shop to secure a longer life and quicker action of tools. Methods of determining both the comparative and actual hardness of the metals have been rather meager until recently.

One of the older machines, called the "Sclerometer," which was called an instrument of precision for determining the degree of hardness of a metal, was operated as follows: The piece to be examined was placed with one surface exactly horizontal upon a delicate carriage movable below a vertical rod, which ended in a diamond or hard steel point. The rod was attached to an arm of a lever and the weight was determined, which must be placed above in order that a scratch should be made upon the given surface as the carriage moved.

One of the later methods employed is called the Brinell method, which uses a ball about ¾-in. in diameter under pressure of about 50 tons. The penetration of this ball into the metal determines its hardness, and it is expressed in terms of the pressure divided by the area of the spherical surface of the cavity.

Another method of determining hardness is that of Hughes and Kryloff. This operation is based upon the principles relating to iron and steel, that their magnetic capacity is directly proportionate to their softness or molecular freedom; and, again, that the resistance to a feeble external magnetic force is directly as the hardness or molecular rigidity; then if the form and size of a piece of steel remains the same, the variation in the magnetic capacity indicates every slight change in its composition.

The latest apparatus for determining hardness is known as the Scleroscope, and the features and general description of this machine are most easily understood by reference to the diagram of the instrument and description.

The development of this machine seems to have been made possible by the discovery of an alloy sufficiently hard to test our hardest steel, and still having some of the qualities of elasticity, etc., of the steel itself.

The instrument is one of precision, and the little hammer is carefully guided by means of a finely fitting glass tube. The bulb at the top of the machine, when quickly pressed, expels the air from the glass tube. When released it creates a vacuum, which lifts the hammer. This is the sole purpose of the vacuum. The hammer is then caught on a swinging hook and is not released until the bulb attached to the plunger is pressed, which unlocks this hook. At the same time it will be noted that a light pressure should be put upon the glass tube to hold it steady, and air admitted to the tube. The hammer does not fall in the vacuum.

Why this machine measures hardness is not known, but from the description given in the catalogue it is plain that it is not the elasticity of the metal that is measured.

This instrument is entirely in the experimental stages, but seems to be the best development to date. One of the most important features is the extreme hardness and homogeneous texture of the hammer. It shows no crystals on the surface, and has none of the brittleness of a jewel or of a diamond. It seems that a great deal must depend upon this particular point, for in such a delicate instrument of precision the accuracy might be questioned unless the composition of the parts were of first quality, as the calculation of the actual strain produced must be subject to considerable error. It is claimed that a force of 75,000 pounds per square inch is obtained by the fall of this hammer from practically a height of 10 inches. The rebound of the hammer is used to measure the hardness of the metal, and the scale shown on the glass tube is simply for comparative purposes and has no direct numerical value. This scale has 140 graduations, and a test of very hard steel has resulted in a rebound to the point marked 110, while soft brass results in a rebound to the point marked 12, and lead is about 2 per cent of hard steel. This shows a wide range of the ability of the machine to measure hardness, and it is valuable if it proves to be accurate.

Practice is necessary to read the scale, although the eye is assisted by a magnifying glass and a pointer, which can be set at approximately the rebound expected. The following table taken from the manufacturer's catalogue shows a test representing as nearly as possible the scale values of different kinds of metal, and by use of this table may be obtained some idea of the comparative values of the particular piece examined:

	Degree of Hardness.
Lead, cast	2
Babbitt metal, cast	4 to 9
Brass, soft, cast	7 to 10
Brass, hard, cast	15 to 25
Brass, rolled	26
Copper, cast	6

	Degree of Hardness.
Copper, rolled	14 to 20
Zinc, cast	8
Zinc, rolled	20
Nickel, cast	27
Silver, pressed	34
Iron, hot rolled	18
Iron, cold rolled	25 to 35
Iron, gray, cast	30
Iron, gray, chilled	50 to 90
Steel, tool, annealed (carbon)	30 to 35
Steel, tool, not annealed (carbon)	40 to 50
Steel, tool, hardened (carbon)	90 to 110
Steel, high speed, hardened	70 to 105

NOTE.—These figures are subject to variations, owing to nature of composition or compression of metals.

In testing very thin pieces of metal it seems that great care should be taken to secure a very uniform bearing on the bedplate of the machine, otherwise there will be some giving or bending of the sheet of metal examined, causing a less rebound than if this same metal should be tested in a piece whose mass was much greater.

The cost of this machine is given as $115, and some discount can be secured, but it is undoubtedly the best development of a machine for testing hardness that at present exists. Its range is wide, and with proper care the soft parts of the same piece of metal can undoubtedly be accurately determined. This machine has been used in the office of Mr. J. R. Onderdonk, Engineer of Tests of the Baltimore & Ohio Railroad, and several sections of rail, car wheels and tool steel have been examined, prints of which sections, together with explanation, are attached to this report.

The sections which have been used are good comparatively, but not enough sections have been tested with this instrument to say anything definite, and it will be only after experiments have been made with our new rails and the new instrument that conclusions will be drawn which can be relied upon.

In each of the individual sections the line of the harder metal is clearly brought out and the effect of the cold rolling of the extreme edge is noticeable, while the harder part of the general section is the center of the head near the junction with the web, down through a small strip in the center of the web to a small circular area at the junction of the web and the base.

The test of titanium rail is particularly interesting, as this is the latest of the alloy steels to be put upon the market, and is attracting considerable attention. The variation in hardness in this section is not as marked as in other rails, and is directly opposite, in that the soft part is at the top of the rail; however, this matter is still in its infancy, and the information is given only for what it is worth as a step toward the future study of these alloys and the means of testing their physical qualities.

THE SCLEROSCOPE.

The principle of the "Scleroscope" (Greek sclero = hardness) consists of dropping a tiny little plunger hammer from a fixed height onto the surface of the material whose hardness is to be measured. This hammer, after striking, by no other force except its own weight (about 40 grains) and momentum, always rebounds to variable heights, depending on the hardness or amount of resistance to penetration offered by a metal, hardened steel, carbon or other material.

Without the proper scientific shape and area of striking point, and also proportionate weight of the indicator hammer, a device as the one in question may indicate the surface elasticity of solid bodies as in the hardened and tempered steels and glass and to a slight extent in the softer metals. In the perfected scleroscope this is, however, not the case, for, as it were, the surface is always broken or indented by the impact of the drop hammer, no matter how hard the steel may be. And these dents may be seen with a magnifier or without on softer metals. To thus indent hardened steel requires enormous pressure. According to very careful tests and measurements the striking force of the drop hammer varies with the hardness of the metal, etc. In lead, a force of 12 lbs. constant pressure is required to imitate an indentation equal to one made by the drop in testing for hardness; in hardened steel the pressure is over 100 lbs., or 20,000 times the weight of the hammer itself. The area of the point is about 1-25.00 part of a square inch, and is convex, meaning that not more than half of this area comes in contact in testing hardened steel. Thus 1-5000 inch, multiplied by the measured impact of 100 lbs., would represent a pressure of 500,000 lbs. per square inch exerted by the scleroscope on hard steel.

This force is ample to exceed the elastic limit of the hardest and strongest steel in existence.

OPERATION.

In operating, the first thing requisite is the control of the drop hammer. Thus, to bring it to the starting point at the top, the rubber bulb A (Fig. 2) is pressed and released suddenly enough to suck the plunger hammer up so that it will catch without a knock. This catch and release mechanism consists of a pendulum hook anchored in the round cap B, the hook lowers down into the center of the glass tube containing the hammer so that it may engage with the latter. The said hammer has a notched recess for the hook on its top and both are kept in clasp by a spring in the said cap, and this spring is adjusted by headless screw No. 1 in the cap B. Setscrew No. 2, on the opposite side, opposes it, and thus is the means for adjusting the hook in the glass for the best position to catch and release. The release which allows the hammer to drop for the indicating rebound consists of a cylinder C, the bulk H and a piston in the former which acts on the hook stem as described.

Making a Test.—After the instrument has been set plumb by aid of the bob rod D and the knurled thumbscrew E, we are ready for work. Raise up the shoe F by the lever G and insert the sample (if

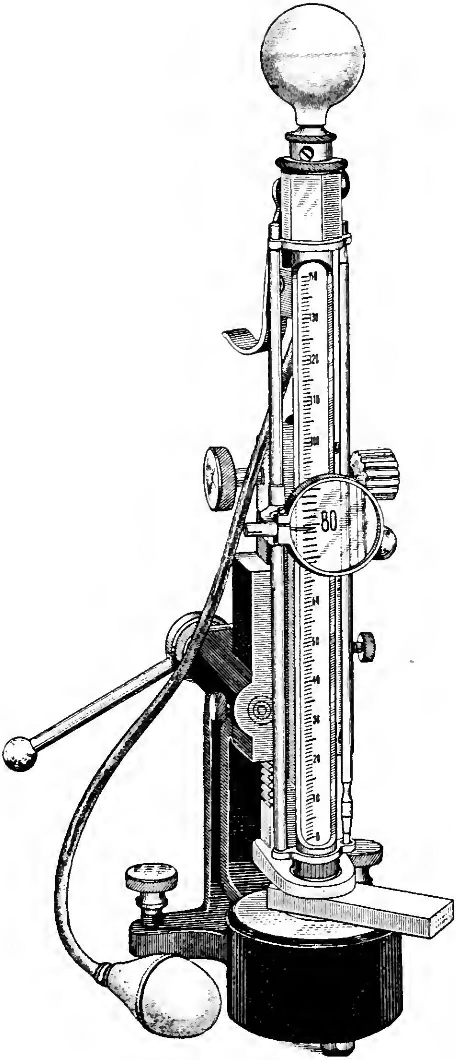


FIG. I. SCLEROSCOPE.

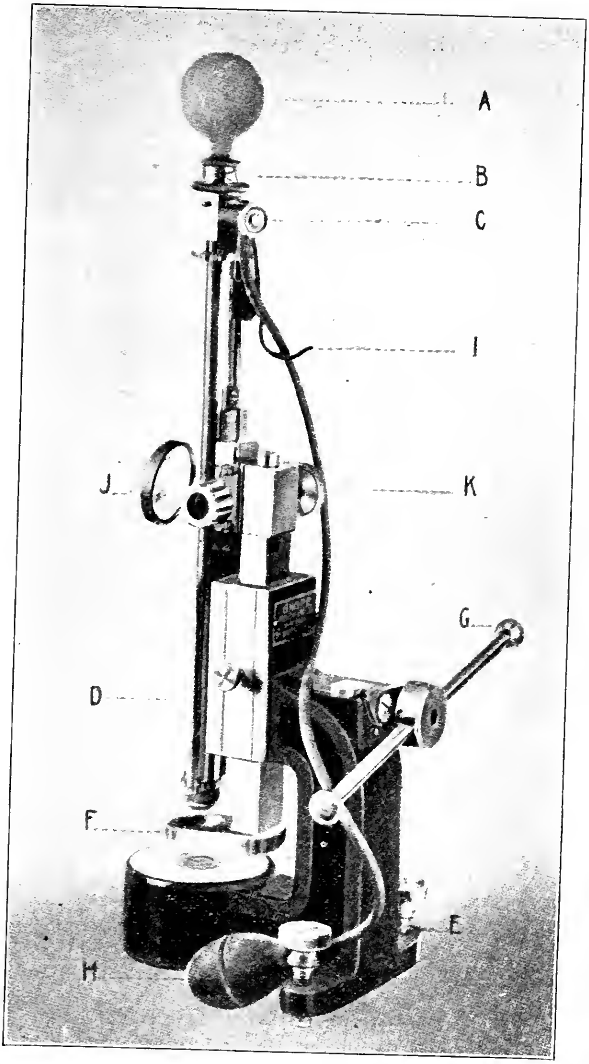


FIG. 2. SCLEROSCOPE.

flat or parallel) so that it will come central with the instrument. Now take bulb H in the right hand and at the same time bear with it with some pressure on the lever G. With the other hand (thumb) press on the hook valve I; this opens the tube so that no vacuum can be formed when the hammer descends. Now press the bulb H. The hammer has dropped and rebounded to a certain height, but you are not perfectly sure just at what figure or degree the rebounding stopped (the first alone is noticed). Now repeat the operation, but be careful not to let the hammer strike the same spot. You will now have the range of the hardness of the sample, and with the second or third hit you will be able to read very accurately.

In reading, *the top of the hammer is taken as the indicator.* When the light is right, as from above, there will be reflection on the slant of the polished hammer, and which enables the operator to read with the greatest ease owing to the lingering impression in the eye of what appears to be a streak of light rising and ending with the rebound.

When a special spot is to be tested raise the instrument by the knob J so that it may be placed central with the hole in the shoe F, through which the hammer point passes, and test as before.

USE OF THE SWING ARM.—As there are many large pieces and often odd-shaped parts or samples which cannot be tested very well in the self-contained machine, as per Figs. 1 and 2, a swing arm is provided. This device is set up near a bench vice, as follows:

Straighten out the arm so that its vertical post will extend about 2 inches beyond the stationary jaw of the vise (smooth jaws preferred) and screw down firmly on the work bench. Detach the scleroscope from its regular frame by the setscrew K, and then place it on the swing arm post as in Fig. 3. The latter must be set level and can best be done by the plumb bob on the instrument.

To test clamp sample in the vise, and always have the surface as nearly level as possible. If the sample is not parallel, or if it is a finished tool, a set of copper or lead jaws should be used. A drill is tested by smoothly grinding a little flat on its point and clamp upright. Almost anything imaginable can thus accurately be tested by a little practice and the use of judgment.

For testing large pieces, as punches, dies and other large parts weighing more than 1 lb., a surface plate may be used in connection with the arm, and this is kept near to the vise.

FREE-HAND WORK.—In some instances it is desirable to carry the instrument to the work, especially if it is very large and heavy, as castings or inserted or attached parts of a machine. For this purpose a dovetailed finger attachment is provided. To attach remove the instrument from its dovetailed pinion block by knob J, withdraw it, and then slide on and clamp the finger ring near the top in place of it. By passing the index finger through the ring and with the thumb on the hook valve I a pistol grip is effected and it is very easy to make free-hand tests. The instrument is kept still and nearly vertical as possible by aid of the plumb bob D.

USE OF THE LENS.—The scleroscope is provided with a lens and a needle, which together may be adjusted to any part of the scale, and is used as follows: Suppose we wish to test a piece of metal and wish to read very positively slight differences.

The rebound is to a given figure, as the first test shows. By now setting the needle at this figure it is seen that slight variations above or below are easily noted. The lens is used principally on soft metals.

CAUTION IN TESTING.—In testing sheets and flats for very accurate readings the scale should be removed, and care should be taken, especially if it is hardened steel. A little practice will enable the operator to tell by the hollow sound whether or not his work is properly mounted.

Small tools, as taps, drills, reamers and other frail or irregular shaped pieces of small size, should be clamped in a lead or copper-jawed bench vise, or in a special device if many similar pieces are measured. When only a very small surface can be found to test, as on the teeth of cutters, drill points, etc., the spot can be located by allowing the hammer point to rest on it before drawing it up.

Never let the hammer point hit the same spot, or too near, as on the margin of a previous one. In the former case the reading will be too high and in the latter it will be too low. This means that the piece or the instrument must be moved a trifle for each drop that is made.

When metals such as brass castings have very large crystals slight variations may be noticed. In these instances several tests may be made and the average adopted as the final figure. Mild steels often must also be tested a few times across the bar owing to the streaks or veins of high and very low carbon combinations, sometimes perhaps due to improper mixing in manufacture. Like before, the average must be accepted.

In hardened steel there will be little variation if the job is perfect and there is no decarbonization as is likely in the low carbon steels, 0.65 to 1.00 per cent. Cyanide hardening, as is often done on low carbon steels, is apt to show wide variations. This is also the case if steel has been quenched at too high a heat, and the scale will prevent uniform hardening or simultaneous temper drawing in spots. In taking averages on hardened steel the low reading spots, which can be scratched also with the file, are usually not taken into account.

THE PLASTER MOUNT.—It sometimes happens that pieces very odd in shape cannot be secured very well in the ways previously mentioned. If the piece weighs one ounce or more the ragged or odd side is pressed down into the plaster dish accompanying the testing set, often by the foot F and lever G and which at the same time levels up the flat surface prepared for testing.

ADJUSTMENTS.—If there is any trouble in the catch device for the hammer, it may be remedied by slightly turning the headless screw marked No. 2 in the cap B (Fig. 2) one way or the other, and which controls the position of the catch hook and shock absorber, and also by varying the tension of the spring controlled by the screw on the opposite side.

CHANGING HAMMERS.—The knurled cap B may be removed by releasing the small setscrew on the hexagon above the release cylinder C. This permits the said cap to be lifted out, exposing the internal parts. To remove the hammer, carefully remove the instrument from its post and turn upside down. The hammers should always be carefully cleaned before inserting, to avoid the possibility of rusting.

THE MAGNIFIER HAMMER.—Owing to the very small rebound of the universal hammer in the soft nonferrous metals, there has developed a demand for a hammer with a larger point area. This enables it to rebound higher, thus magnifying the small but significant variations in hardness. Compared to the less distinct differences with the Universal hammer, they are in application to soft metals, recognized as quantitative and comparative for the said Universal indicator. These hammers are part of the regular testing set.

Use of the Curve Charts.—The curve charts which accompany the Scleroscope are intended to be used for preparing curves representing the effect of heat on the hardness of materials, such as annealing and hardening.

The principle uses for them is in the study of tool steels for hardening power; at what heat hardness is greatest or most uniform, and also for the greater or less tendency to crystallize by overheating.

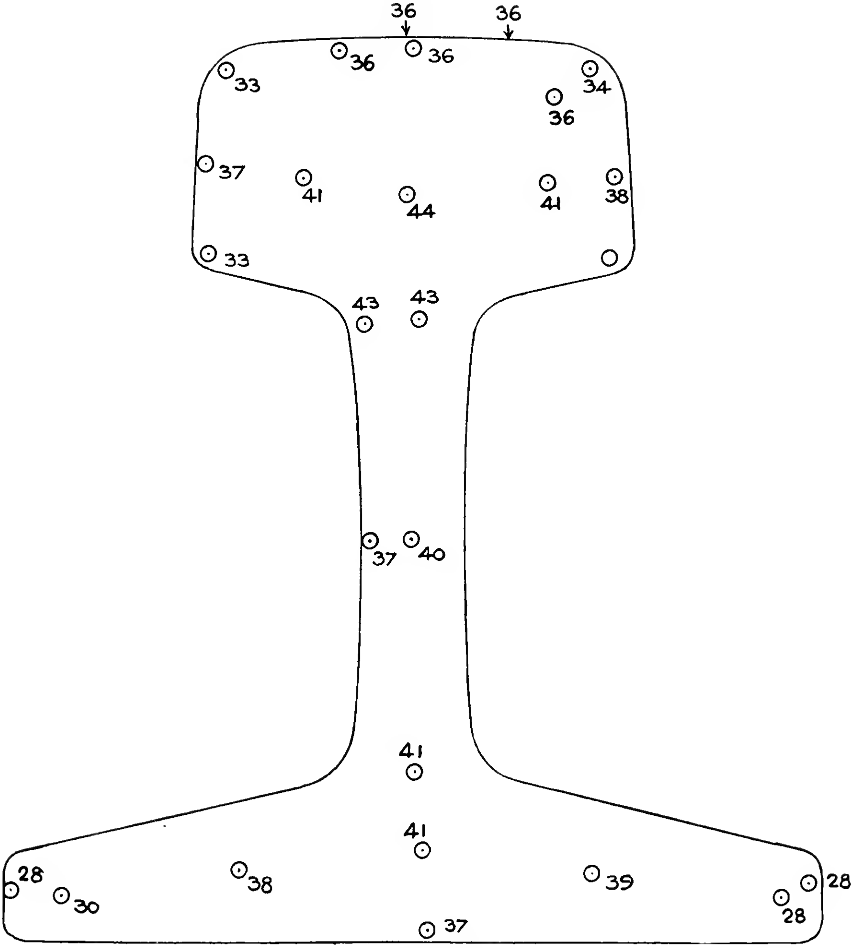
The best way to try out a tool steel thus is to saw off a piece of the stock bar weighing about 2 or 3 ounces, and which may again be cut in two. Start in by hardening one piece at a very low red and the other at a little higher. Note the color in a given room light, mark each piece with a lead pencil, and then, after grinding carefully on a fine emery wheel, test for hardness after clamping in a bench vise.

Now mark the hardness on the proper space on the chart so that it agrees with Scleroscope degrees marked thereon. To get an idea of relation of color to actual heat a pyrometer should be used, but if this is not at hand look into the sky (not the sun) through the closed eyelids. This redness is about 1350 degrees F. and enough to harden high carbon steel; a cherry red is about 1425 degrees, 1500 is a bright red, but not yellowish.

When thus the greatest hardening has been found, one of the pieces is heated to about 1800 degrees F. (a light yellow) and quenched to harden as before. This is to determine the loss of hardness through crystallization. One of the reasons is to note the sensitiveness of the steel to overheating and another is to provide a means whereby the physical strength and carbon content of the steel may be determined.

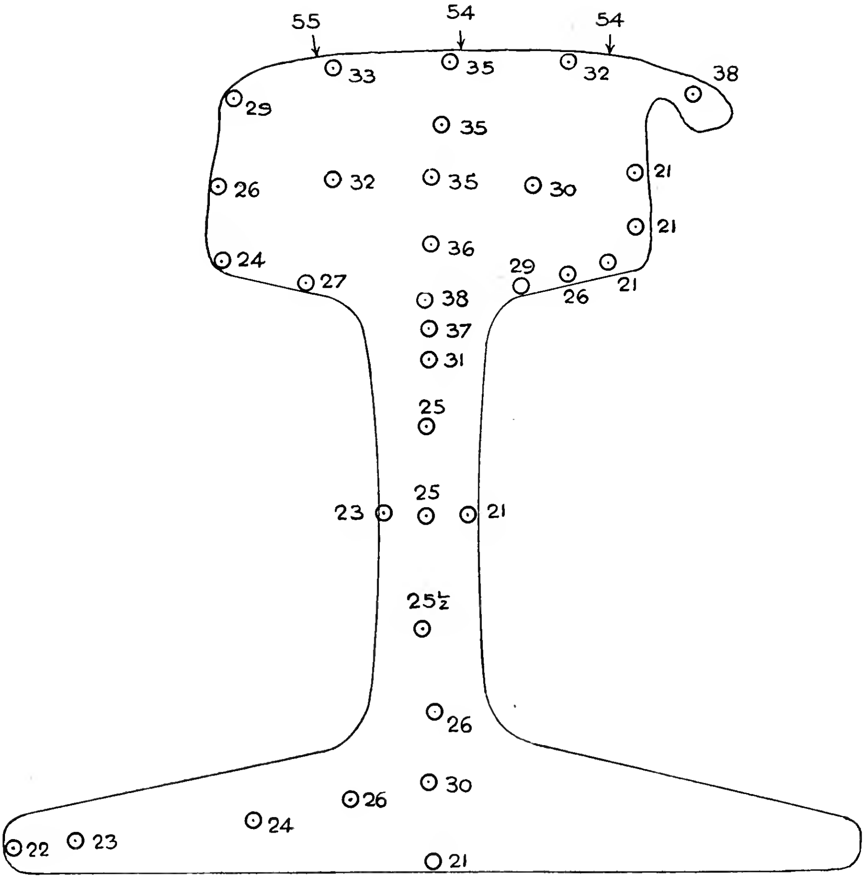
If the steel to be thus tested is a thin bar less than 1 inch square or in diameter a good way is to heat one end to a bright yellow and thus allow the heat to taper off less and less toward the other end and quench. The length should be about 4 inches. Now mark off with a lead pencil spaces ¼ inch apart and test on each division. For each divisional reading mark the hardness number on the chart, noting also what the temperature had been at each space. The result will be curves as shown in Fig. 13.

Resolving Readings of Magnifier Hammer Into Those of Universal.—When soft metals are tested for their quantitative hardness and it is desired to know approximately how they compare to hard steels, or in other words, their true position in the standard hardness scale, do the following: Draw a line with a rule on the chart extending from the corner arrow to the one farthest away from it. Now, if the magnifier hammer reads 35, follow up the horizontal line (Fig. 8) until the diagonal line is struck, then come down parallel to the vertical line to the short "Comparative" scale, and whatever figure is struck there, as in this case, 35 is resolved into 20. Thus we see that the 35 point reading was comparatively only 20 per cent. as hard as steel at 100.



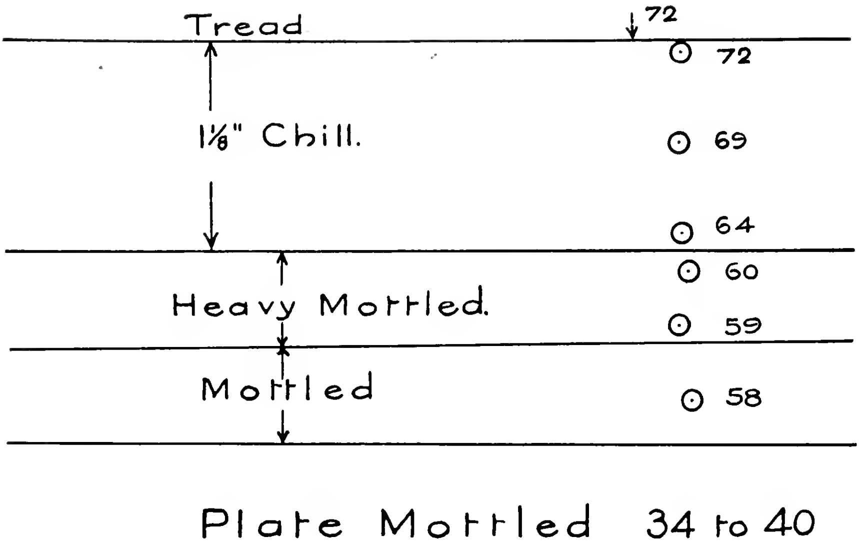
Test No. 1. 90-lb. A. R. A. Section "B" Open Hearth Steel (New) Rail, Bethlehem Steel Co. (Figures indicate the degree of hardness.)

Test No. 1 is an A. R. A. section of open-hearth rail, as rolled by the Bethlehem Steel Company, and is a new section which has not been in the track. It will be noted that the hardness on the top of the head of the rail is practically the same as the steel in the section of the rail just below the surface. The center of the head appears to be the hardest, as well as a line right down through the center of the web and base. The upper corners of the head are comparatively soft, the ends of the base, however, being very much softer than any of the rest of the rail.



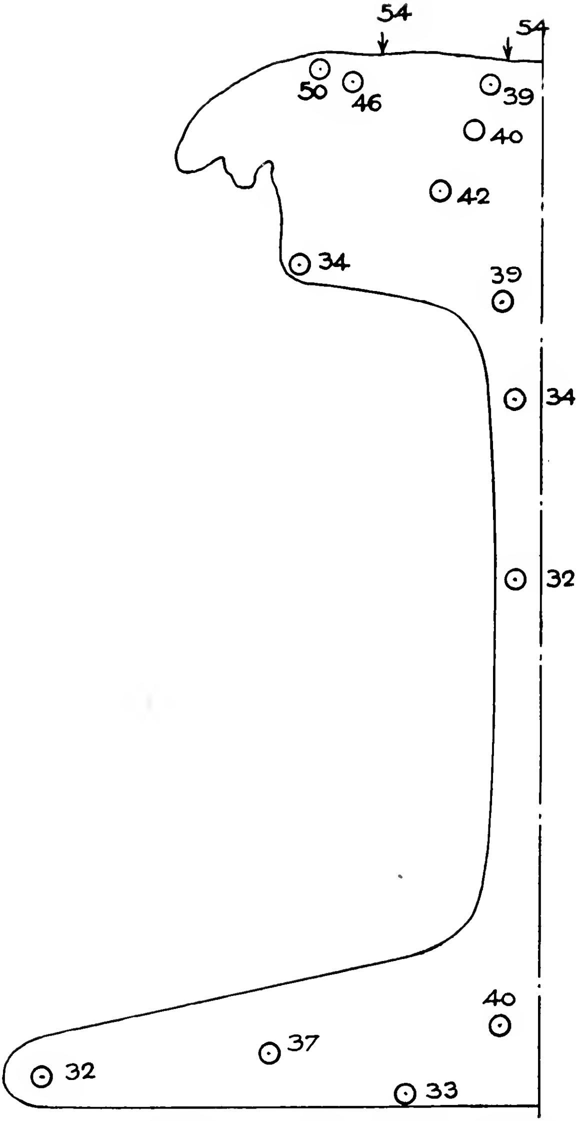
Test No. 2. 85-lb. Bessemer Steel (Old Rail), A. S. C. E. Section. (Figures indicate degree of hardness.)

Test No. 2 is on a Bessemer steel, A. S. C. E. section of 85⅝-lb. rail, which has been in service. Even with this thin base, it will be noted that the extreme edges of the base are very soft, as well as the base itself. The web is considerably softer than the open-hearth rail, the center of the head being almost ten points softer than the open-hearth. This test, however, shows the effect of the cold rolling of the rail very markedly, as will be noted that on the surface of the head the hardness is nearly twenty points harder than the steel just below the surface.



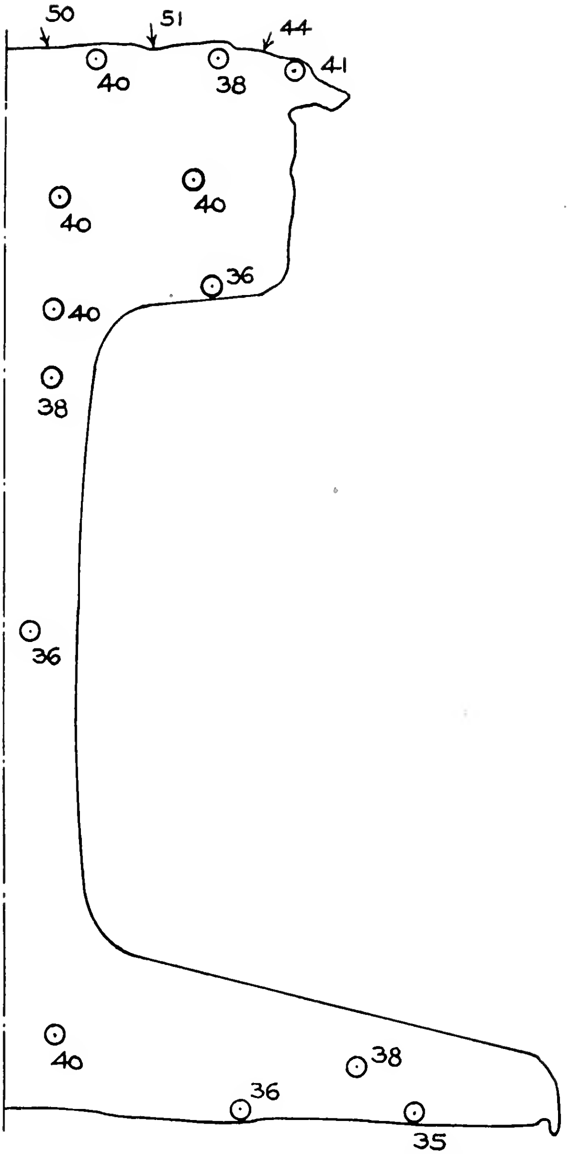
Test No. 3. Maryland Car Wheel Co. High Chilled Cast-Iron Wheel. Wheel No. 556879. Cast, 10-14-'05. 4 blows, 200 lbs. to crack; 14 blows to break; Sul. .163 per cent. Report 50483. (Figures indicate the degree of hardness.)

Test No. 3 shows a section of cast-iron chilled wheel, with a heavy chill, the chill near the surface being 72, and dropping down nearly ten points to the inner portion of the chill, the mottled iron being a little softer, and the plate, which was also mottled, being from 34 to 40.



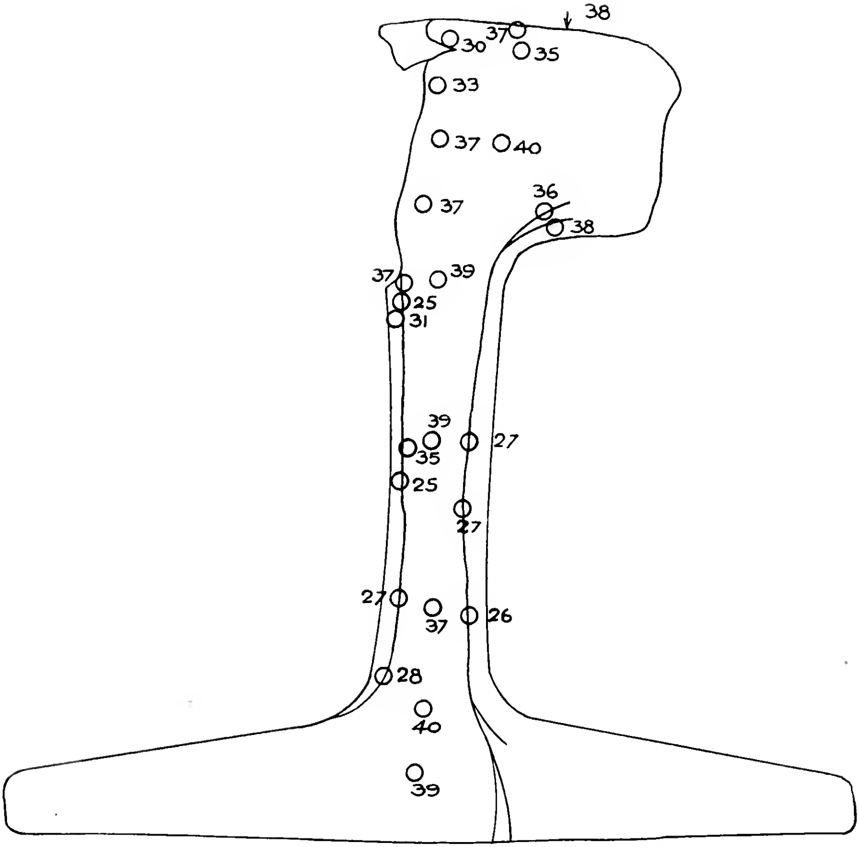
Test No. 4. Cambria Steel Co. Corrugated Bessemer Rail Rolled in 1905. Low Spot, Location 6. Report P-42798. Carbon, .50 per cent.; Sul., 048 per cent.; Phos., 094 per cent.; Mn., 1.029 per cent.; Si., 287 per cent. (Figures indicate the degree of hardness.)

Tests Nos. 4 and 5 are the sections from corrugated rail, showing extremely high silicon and look like the grain of wood after being etched. There was nothing in the analysis to show any difference in the high and low portions of this rail, the metal having flowed



Test No. 5. Cambria Steel Co. Corrugated Bessemer Rail, Rolled in 1905. High Spot, Location 4. Report P-42798. Carbon, .49 per cent.; Sul., .051 per cent.; Phos., .096 per cent.; Mn., .98 per cent.: Si., 287 per cent. (Figures indicate the degree of hardness.)

over. From the hardness of this rail it will be noted that there is no appreciable difference in the hardness of the high and low portions, all of which seems to indicate that the corrugation is due to the flexure of the roadbed rather than to the quality of the material in the rail.



Test No. 6. 85-lb. A. S. C. E. Section; Rolled at Edgar Thompson Works; 8-'08; Heat No. 3236. Top Rail. Defect discovered 10-30-'08. Newark Division. (Figures indicate the degree of hardness.)

Test No. 6 shows an A. S. C. E. section lately rolled by the Edgar Thompson Works, and put in the track on the Newark Division, and removed very shortly afterward, on account of the head breaking down. On etching this section it showed porous metal running down both sides of the web, as shown in the fine lines on the illustration. One of these lines of porous metal, it will be noted, runs right into the lower portion of the fracture where the head broke off. In testing this rail, it will be seen that along these lines of porous metal the steel is exceptionally soft, while at either side it runs from six to twelve points harder. This rail was not in the track very long, and it will be observed there is very little difference in the hardness at the top of the rail from the metal just below, showing that it had received very little cold rolling effect.

Test No. 7.

Test No. 7 shows the relative hardness of some new steel tires, grade No. 1 and No. 3, as well as the chemical analysis and physical tests.

Tire Steel—Standard Steel Works Company.

Heat, 4,099. Grade No. 1.

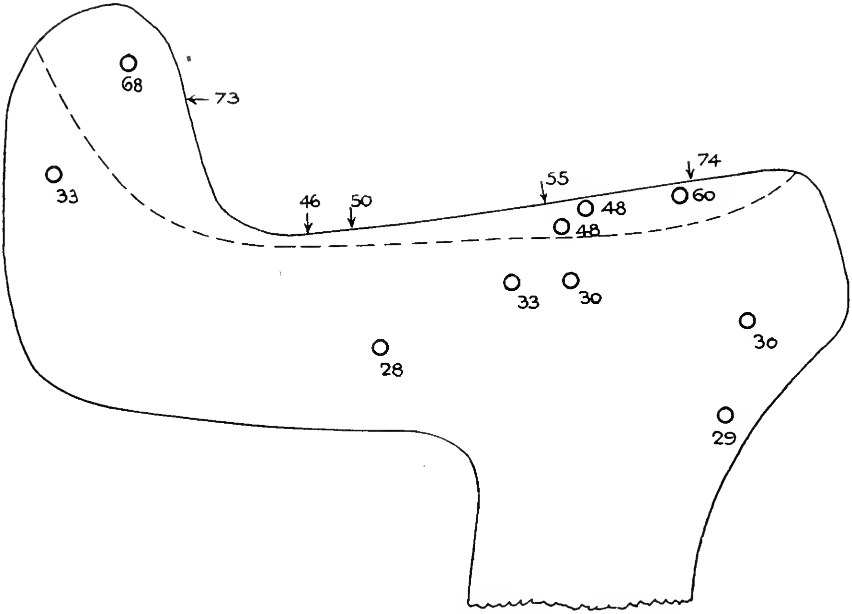
Area, 400. Tensile strength, 112,700. Elongation, 4 inches—17 per cent. Degree of hardness, 33.

Chemical analysis: Carbon, 0.54; sulphur, 0.042; phosphor, 0.047.

Heat, 4,202. Grade No. 3.

Area, 400. Tensile strength, 134,000. Elongation, 10.5 per cent. Degree of hardness, 42.

Chemical analysis: Carbon, 0.61;. sulphur, 0.039; phosphor, 0.047.



Test No. 9. Low Chill Cast-Iron Wheel. Grey Iron Plates.

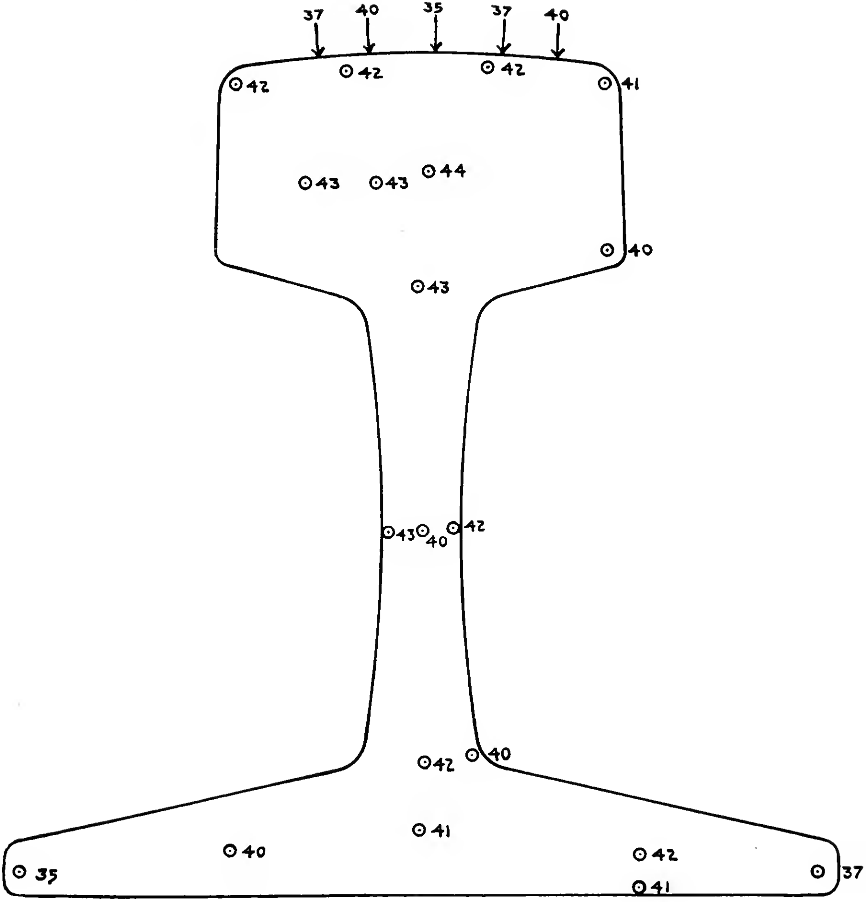
Tests Nos. 8 and 9.

Test No. 8 shows the hardness of some self-hardening, high-speed steel, while test No. 9 shows the hardness of a low chill cast-iron wheel. This wheel failed on account of wearing through the chill near the throat, and it will be noted that where the chill is almost worn through it is very much softer than up on the flange, or out near the rim. The mottled iron just below the chill runs from 30 to 33, which is considerably softer than the mottled iron shown on test No. 3. This wheel had a gray iron plate, which runs about 29, as against 34 to 40 on the mottled plates shown on test No. 3.

Test No. 8.

Crookes, Roberts & Co. Argus self-hardening tool steel. Tire tool, 2½x1½ in.

Cutting edge, degree of hardness, 82; opposite end, degree of hardness, 63.



Test No. 10. New Titanium Rail.

Test No. 10 shows the comparative hardness on different lines on experimental Titanium rails now laid on Kessler's Curve, Cumberland Division. This test indicates a skin of soft metal across the top of the head, but as soon as this is penetrated the hardness is reached which compares favorably with any part of the whole section, and this variation of one point on the scale might easily be due to the personal equation in reading when making the test, so that, as far as these rails show comparatively, the rail seems to be of very even hardness.

DISCUSSION OF SCLEROSCOPE TESTS.

By J. P. Snow.

Fig. B S is a section of a Bessemer rail rolled at Buffalo several years ago. The rail broke in service with a very square break. Polished and etched it showed very high segregation. The web of the rail was blistered and slivered in rolling to some extent, showing plainly its unsound character. The test shows great lack of uniformity, there being a difference of 14 points in the scleroscope readings at different locations in the head. The experimenter says, "This condition is rather characteristic of the rails of Bessemer origin."

Fig. B is a section of a Bessemer rail rolled at Buffalo in 1908. It is a crop from the top end of a top rail. The batch was held 2½ minutes after being recarburized before teeming.

Although the specimen was from the top of the ingot there is a differnece of but 3 points in the readings throughout the head.

The section, where polished and etched, showed rather dimly marked segregation. The head and base when planed into and etched showed some dark streaks in the head and light streaks and fissures in the base. The top of the head for ⅛-in. depth was sound.

The experimenter says: "The section as a whole is more uniform than is usually to be found in top, middle or bottom rail of a Bessemer 'ingot.'"

Fig. O is a section of open-hearth rail rolled at Bethlehem in 1908. It shows a difference of 6 points in the head, but down the center the difference is but 3 points. In sawing the rail very hard nodules were encountered at various points, especially at the junction of the web and base. The Scleroscope did not seem to indicate this feature, and it is possible that the difficulty in sawing arose more from toughness than from hardness. The open-hearth rails now being rolled at Gary are difficult to drill and saw on account of their toughness. The experimenter says: "The wearing surface is slightly harder than the material about ⅜-in. inward. This condition is just as we should expect to find in a good homogeneous rail." The rail is a 90-lb. "B" A. R. A. section, rolled for the Baltimore & Ohio Railroad. It will be interesting to learn how it proves under traffic.

Fig. M is a section of Manard rail rolled at Steelton. It shows a difference of 3 points in the head, and in fact but 3 points over its entire area. It was impossible to cut this specimen with saws, planer tools or drills, but the Scleroscope readings are not high. It may be that the resistance of certain spots in the open-hearth specimen above was due to toughness similar to that of this specimen.

These tests go to show the value and the limitations of the Scleroscope as a rail testing device. Segregation is an ever-present evil in melt-made carbon steel. Its effect is to concentrate the hardeners at the central part of the head and web. The instrument seems to detect the presence of these hardeners with considerable precision; and it may be possible to fix upon a maximum variation for the purpose of a specification that can be allowed and that will be reasonable. The tests are quickly made and are inexpensive. They might result in detecting badly segregated rails that would not be found by the drop test.

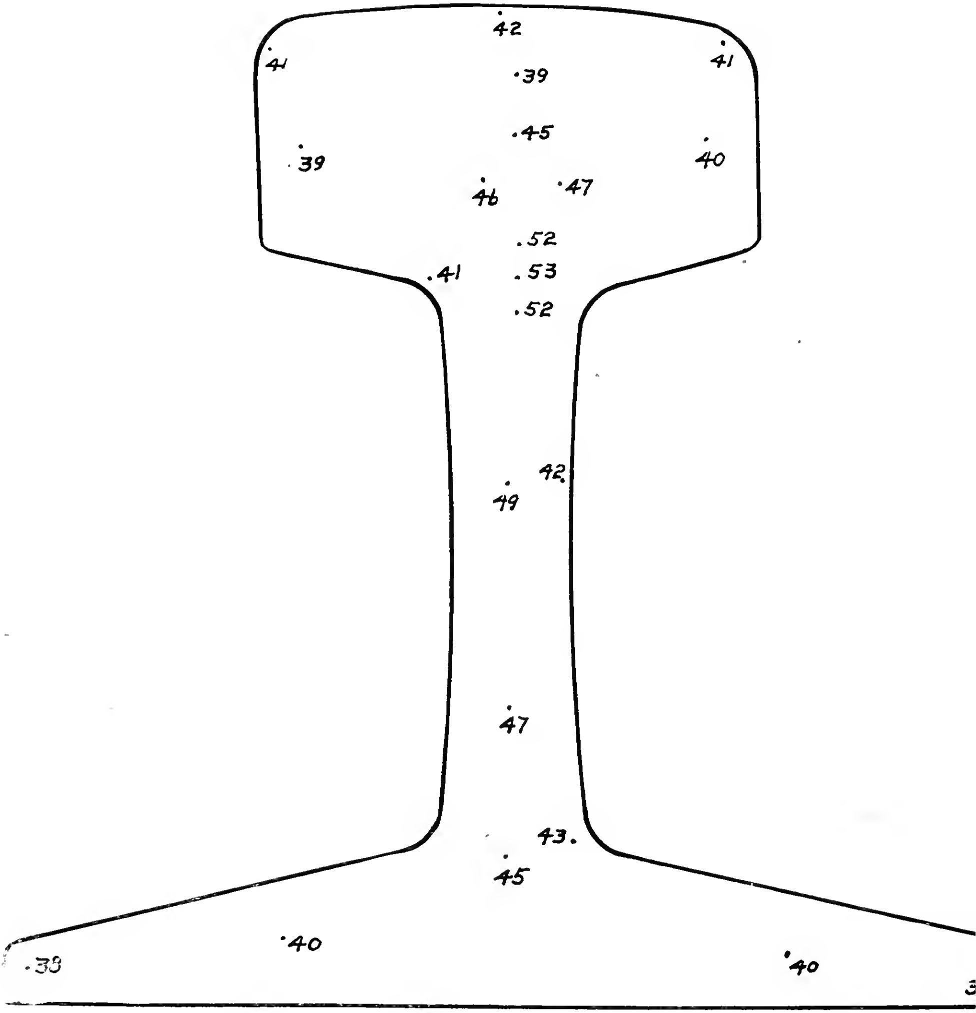


FIG. B. S.

As a test of the wearing qualities of rails, the description above shows that the instrument has its limitations. The Manard rail resists wear much better than either the open-hearth or Bessemer, while the

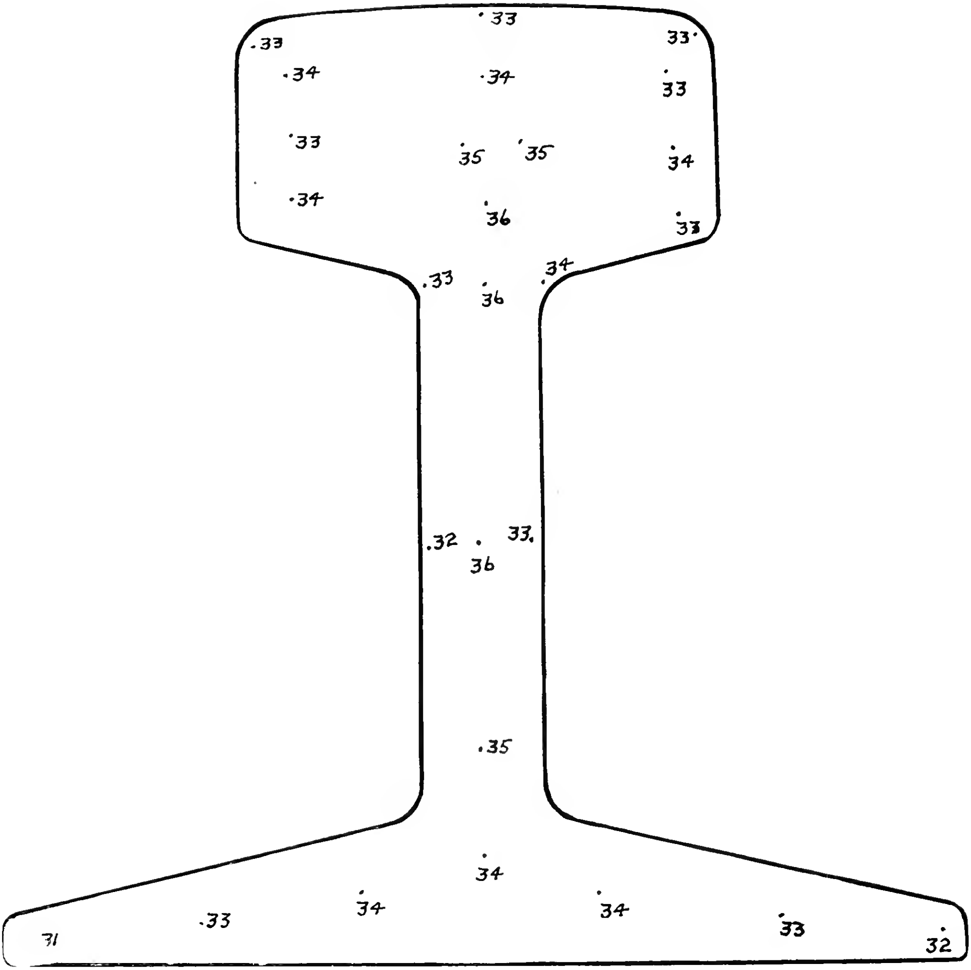


Fig. B.

readings on it are low. The highest readings on the Bessemer rail were on metal known to be unsound and of very poor wearing qualities. These facts show that the readings of the instrument have no absolute relation to resistance to abrasion.

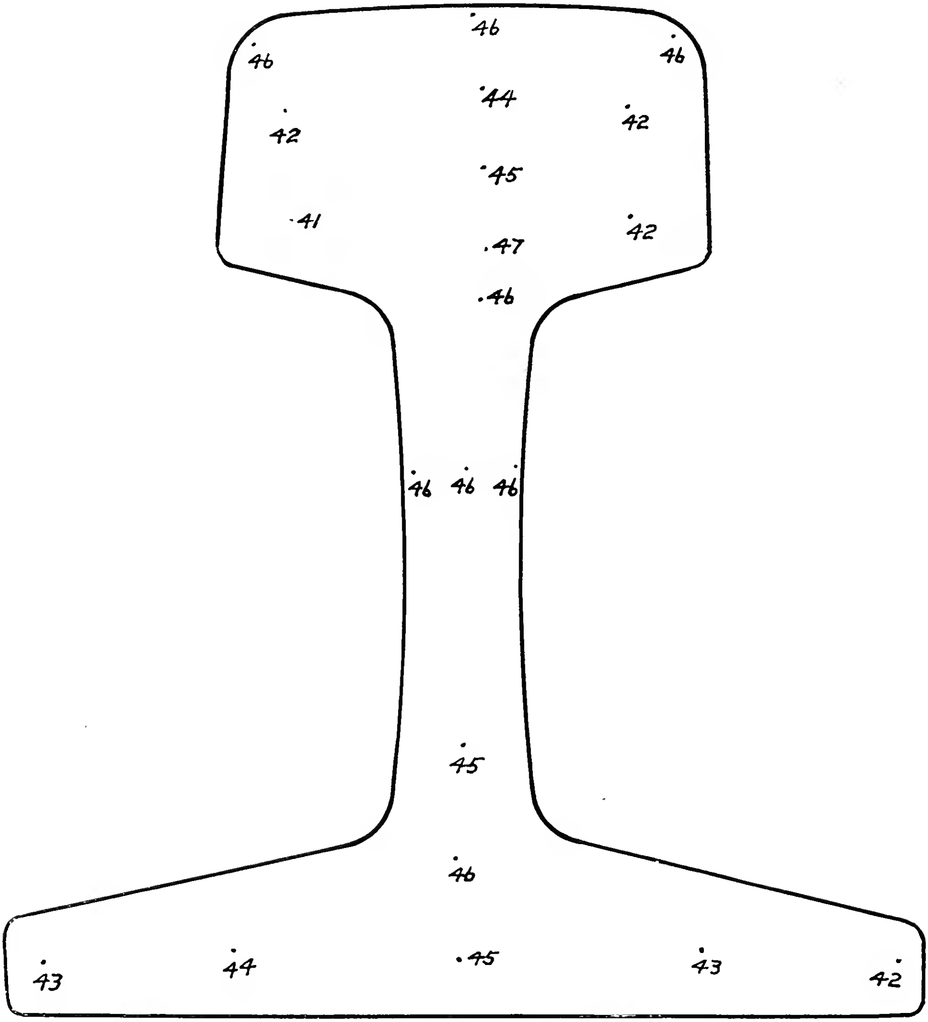


Fig. O.

The tests were made by Mr. J. H. Gibonney, Chemist for the Norfolk & Western Railway, under the direction of Mr. Chas. S. Churchill, Chief Engineer.

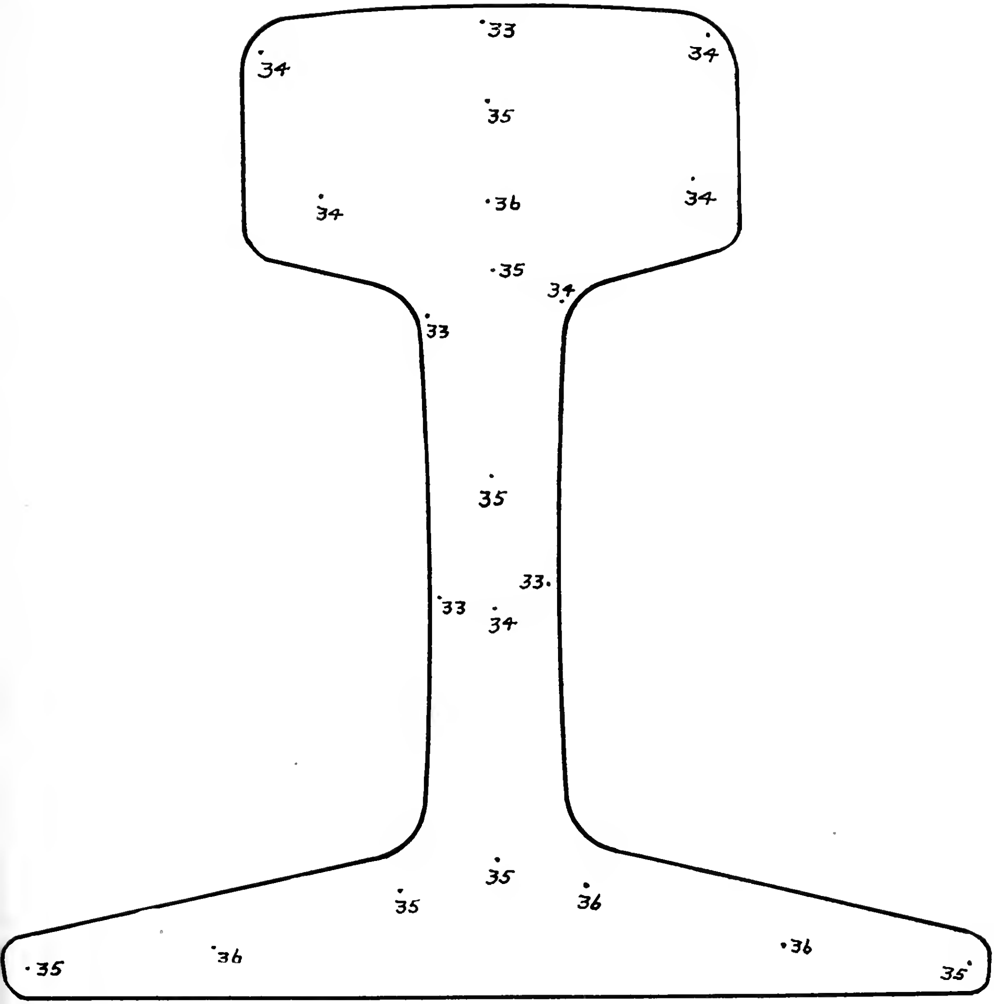


Fig. M.

Appendix G.

THE USE OF TITANIUM RAIL ON THE BALTIMORE & OHIO RAILROAD.

(Bulletin 111.)

By A. W. Thompson, Chief Engineer Maintenance of Way.

The attention of metallurgists and engineers and all users of iron and steel is being directed toward the remarkable development of alloy steel, or steel containing a percentage of various materials introduced to give it special mechanical qualities. Some of the so-called alloy steels have been known to a more or less extent for a long time. Chrome steel was introduced and extensively used for ore stamps and other purposes over twenty years ago, and about the same time nickel steel was made use of in the manufacture of armor plate. Steel containing tungsten was manufactured by Mushet, who was Bessemer's rival, and manganese steel is nearly as old as the others above mentioned. In general, however, they were confined to limited fields. More recently the use of alloy steel has been greatly extended, and some of the results from the use of these alloys, either singly or in combination, have been astonishing; that is, more than one alloy combined with the iron.

One important factor in bringing these steels into prominence was the need of a metal having exceptional strength and durability, at the same time possessing light weight and occupying small space. The use of such metals was demanded by automobile service and similar light machines which had to withstand especially severe shocks and strains. This probably led to a better knowledge of these alloys, and it was a case where the higher cost of production was not a prohibitive factor.

The requirements of steel alloy might be summed up as follows:

(1) High resistance to shock.

(2) The highest possible elastic limit.

(3) Resistance to abrasion.

(4) More generally the fulfillment of several of these requirements.

Some of the alloys best known to-day are manganese, nickel and chromium. Those fast coming into use, but which are more rare, are tungsten or wolfram, molybdenum, vanadium, uranium and titanium.

The actual effect of these alloys is not well understood even by expert metallurgists, but undoubtedly they all add valuable qualities to the steel. The older alloys, such as in the chrome vanadium, steel containing 1 per cent. to 2 per cent vanadium, have shown most remarkable properties, one of the highest tests yet obtained, after a special treatment, being a maximum breaking strength of 103 tons per square inch, the steel showing at the same time a great resistance to bending and dynamic tests, a combination of properties not usually found.

Nickel vanadium steel shows great strength, but lower resistance to bending and blows.

Manganese in steel acts as an antidote for sulphur and phosphorus and perhaps other impurities, it prevents red-shortness and tends toward the formation of close and uniform crystallization, but an excess of this alloy makes steel cold-short.

The alloy with which we are more particularly concerned in this instance is Titanium. It is practically a new alloy commercially, and. as claimed by the manufacturers, it has only been on the market since October, 1907. Titanium received its name from fanciful allusion to the Titans; its chemical symbol is Ti; its atomic weight is 48.17.

This metal is not found native, but as manufactured has a dark gray color, having a decided metallic luster resembling iron. It is found frequently combined with the protoxide iron and mixed more or less with the peroxide of the same metal. It is a widely distributed element in nature, being found in many minerals and rocks as well as in clays and soils, resulting from their decomposition, but it nowhere occurs in large quantities in any one location. It has also been detected in meteorites and the sun. It occurs combined also with oxygen, forming titanic dioxide or titanic acid and also in oxygen combinations with iron and calcium, and in some of the silicon. One of its most remarkable properties is its power of combining with nitrogen at a high temperature. Certain copper-colored cubical crystals, which are not infrequently found in the bear of blast furnaces and which were supposed to be pure titanium, were shown later to really be a combination of that element with other elements.

As titanium enters into the composition of so many iron ores, it is natural that it should have been found in many kinds of pig iron. A considerable number of patents have been taken out covering compositions of iron and steel in which titanium has played an important part. The so-called titanic steel was at one time extensively advertised as being of great excellence, but several chemists of reputation were unable to find any portion of this element after making analysis of the metal put upon the market under that name.

According to tests made by the American Foundrymen's Association and reported at their last convention, titanium strengthens cast iron. Gray cast-iron is strengthened about 50 per cent. and white cast-iron is strengthened about 20 per cent., or less. An addition of titanium alloy giving 0.5 per cent. titanium in the casting is sufficient to accomplish the full effect, although more will not be injurious. It is stated that, for titanium alloy containing as much as 10 per cent. titanium, it is well to have the carbon about 5 per cent, as it melts more easily in the ladle.

Titanium imparts valuable properties to steel, but its production commercially on a large scale is retarded because of the technical difficulties in producing the alloy.

An ore called rutile, with a high percentage of titanium, is found in our Southern States, but it has heretofore been used mostly as a pigment in potteries. The electric furnace has, however, admitted of great progress in the separation of these ores, and it is expected that it will be of great commercial value when the large bodies of ore in the Western and Eastern continents can be utilized.

The effect of titanium on steel as understood to-day is to give the metal greater density and strength. It unites with the nitrogen, and so far as is known at present, the greater proportion of the titanium appears in the slag, and very little, if any, of it is ever found in the finished material. This indicates its value to be that of a scavenger. It is applied to the hot metal just before pouring, either into the ladle or converter, and the metal allowed to stand from 3 to 15 minutes. The greatest trouble in this seems to be the haste in pouring the metal before the titanium has fully done its work. This haste in pouring is owing to the fear of the metal cooling too much.

The manufacturers claim one more result in the use of titanium, and that is freedom from blowholes and prevention of segregation.

The actual work which the titanium does is not yet fully understood, but it seems beyond question that a better final product results from its use and that a great field is open to engineers and metallurgists to bring the use of this metal under their control, and to obtain all the benefits that may result from using it in steel manufacture.

The experience of the Baltimore & Ohio Railroad with this particular alloy, used in rail, has been, of course, very limited and entirely experimental. During the month of June, 1908, 19 rails were rolled by the Maryland Steel Company, of the usual composition, to which was added 1.5 per cent. titanium alloy. This alloy was claimed to increase the elastic limit, ultimate strength, and remove a large percentage of the slag; also to make the rail less brittle and avoid extreme segregation and blowholes, leaving the metal homogeneous, tough and fine grained. The use of the alloy resulted in a rail with a composition high in carbon and phosphorus, which even then successfully passed the physical test.

The analysis made by the Maryland Steel Company of this rail shows the following:

C.	Mn.	P.	S.	Si.	N.	O.
0.701	0.92	0.086	0.048	0.079	0.004	Nil

An analysis made by our engineer of tests, Mr. J. R. Onderdonk, shows the following:

C.	Mn.	P.	S.	Si.
0.57	0.86	0.074	0.039	0.045

These analyses vary somewhat in the percentage of elements, and, as before remarked, both of them show no trace of the element titanium.

The rails above referred to are laid in the eastbound track on the east end of the Cumberland Division, on what is locally known as Kessler's Curve, between Magnolia and Paw-Paw. This eastbound track carries a heavily loaded movement. The grades are light, not over 0.4 per cent. uncompensated, but the curve is a 9-degree, having an elevation of 6.5 in. and a standard gage of 4 ft. 8¾ in. This curve has an approximate passenger traffic of 480,000 tons per year and a freight traffic of 28,300,000 tons per year. The roadbed is ballasted with broken limestone.

The analysis of the Maryland Steel Company shows that the titanium alloy has a great avidity for nitrogen, and if this is removed a high per cent. of carbon may be possible, producing a harder and yet elastic rail, giving much greater wear.

Through the kindness of Mr. Wm. F. Meredith, president of the Titanium Alloy Manufacturing Company, who controls the present process of manufacture of this alloy, there follows a reproduction of a blueprint showing a combination of tests, indicating the lack of segregation in the Bessemer ingot after treatment with ferro-titanium; also photos of treated and untreated rails, together with a set of microphotographs of the steel.

It is somewhat unfortunate that the titanium rail was laid partly on the runoff of Kessler's Curve, but any allowance can be made for whatever effect this might have when considering the following tables showing the wear.

Previous to the laying of this titanium rail on Kessler's Curve, a test had been made of high carbon open-hearth rail, rolled by the Maryland Steel Company, versus Bessemer steel rail, rolled by the Cambria Steel Company; and also a test of high carbon open-hearth steel rail, rolled by the Pennsylvania Steel Company, versus Bessemer rail, rolled by the Cambria Steel Company. The first-mentioned test was started on April 5, 1906, the rail being finally removed in August, 1907, after a life of 15½ months. The section of all these rails was 100-lb. A. S. C. E.

Rail No. 18 of the first test showed the following analysis:

High Carbon Open-Hearth.

Carbon	0.60	Phosphorus	0.018
Sulphur	0.21	Manganese	0.500

No analysis is on record of the rails of the second test.

The results of the first test are as follows:

	Wear.	Flow.
High Rail—Bessemer	0.54 sq. in.	0.051 sq. in
High Rail—High C., open-hearth	0.48 "	0.028 "
Low Rail—Bessemer	0.47 "	0.075 "
Low Rail—High C., open-hearth	0.46 "	0.048 "
Average—Bessemer	0.505 "	0.063 "
Average—High C., open-hearth	0.47 "	0.038 "

A table showing the wear in square inches of the second test, that is, the Pennsylvania Steel Company's open-hearth rail versus the Bessemer rail rolled by the Cambria Steel Company, was as follows:

Pennsylvania Steel Company.

	—High Rail—		—Low Rail—	
Time.	Wear.	Flow.	Wear.	Flow.
5 months	0.13	0.00	0.15	0.04
14.5 months	0.39	0.02	0.38	0.07

Bessemer.

	—High Rail—		—Low Rail—	
Time.	Wear.	Flow.	Wear.	Flow.
5 months	0.15	0.00	0.15	0.04
14.5 months	0.42	0.01	0.40	0.10

Average Wear.

5 months—Pennsylvania Steel Company......0.135 Bessemer....0.15
14.5 months—Pennsylvania Steel Company......0.395 Bessemer....0.41

The two previous tests have shown no decided advantage of the open-hearth rail over the Bessemer rail under such heavy traffic and such heavy curvature.

From the observation of the Titanium rail, which has been in track, the following average square inches of wear was indicated:

In 2 weeks	0.027
In 7 weeks	0.133
In 17 weeks	0.180

An examination of these figures shows that in seven weeks the Titanium rail has worn as much as the other rails in approximately five months. There is something misleading in these figures, as observation on the ground seems to show that the Titanium rail is holding up considerably better than Bessemer rail. These amounts of wear were obtained from the rail section machine, and an examination of the sections shows that on the Bessemer rail the greater proportion of the wear was on the inside of the head on the high rail and on top of the low rail, while the sections of Titanium rail show the wear to be evenly distributed across the top. This would undoubtedly be due to track conditions; that is, from the effect of the elevation of the curve, and possibly the canting of the rail, but so far these figures show that in one place or another this number of square inches has been abraded from the rail.

Some explanation of this difference of wear may be had from tests which were made with the Scleroscope, the results of which are indicated on sections contained in the report on the Scleroscope. These tests showed most clearly that the surface of the Titanium rail was much softer than the interior, and that only the "skin" of the head was of such soft material. After wearing not more than is shown by the sections taken at the end of seven weeks, the harder material would be reached, and this metal showed about six points harder than an open-hearth rail which was tested. Thus it may be found that the increased life of Titanium rail will begin to show itself after a short period within which the soft "skin" will have been worn away.

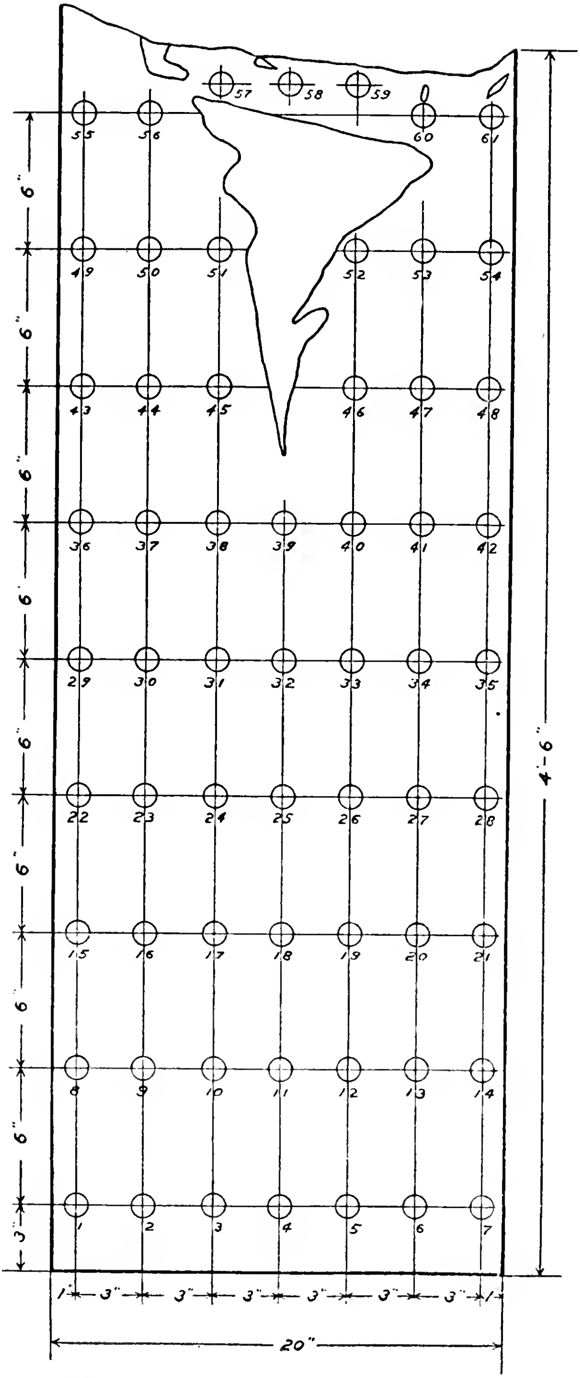
All of these tests are in their infancy as to length of time, methods and actual knowledge of the subject being investigated, and only careful records and study will result in trustworthy conclusions.

The above notes are general and are given for what they are worth, as a step toward a better understanding of the whole matter.

The test now in progress on Kessler's Curve is to be carefully followed up, and all discrepancies will be fully investigated and an explanation given as the test progresses, but up to the present time nothing absolutely definite can be stated, as the Titanium rails have been in track only about five months, or rather less than one-half the usual period of service of the ordinary Bessemer rail.

Location of Drillings from Ingot Allowed to Cool in Vertical Position.

Heat No. 73802. Two per cent. Ferro-Titanium added in Steel Ladle.



HOLES 1" DIAMETER

MOLD TEST ANALYSIS.

C.	MN.	P.	S.	SI.
.569	.86	.075	.054	.127

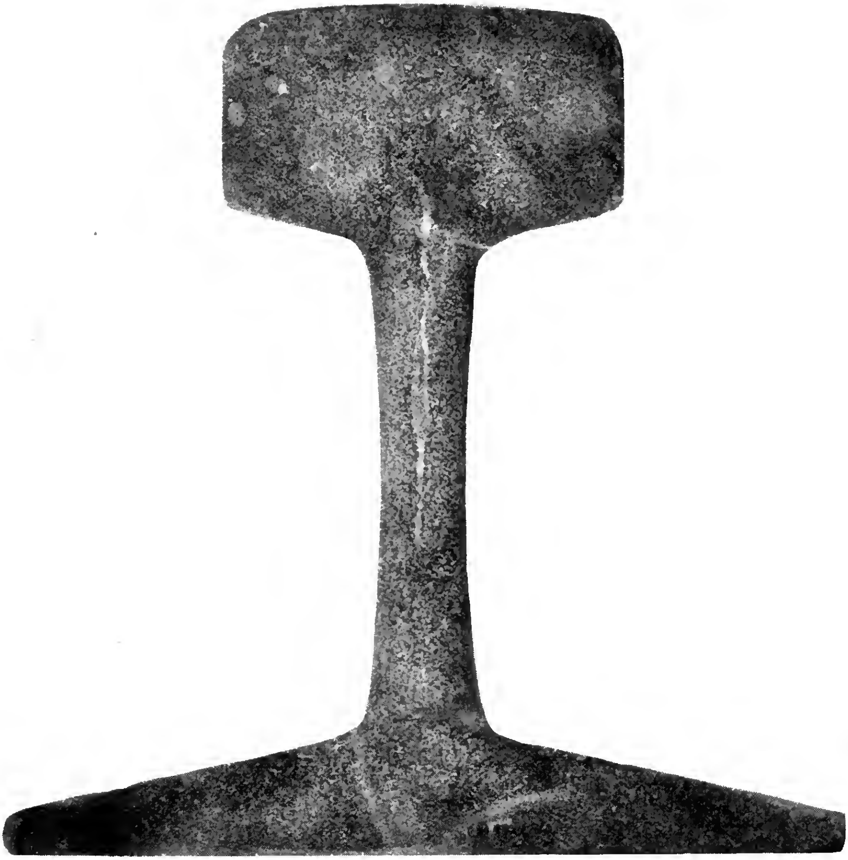
ANALYSES OF DRILLINGS FROM INGOT ALLOWED TO COOL IN VERTICAL POSITION.

Heat No. 73802.

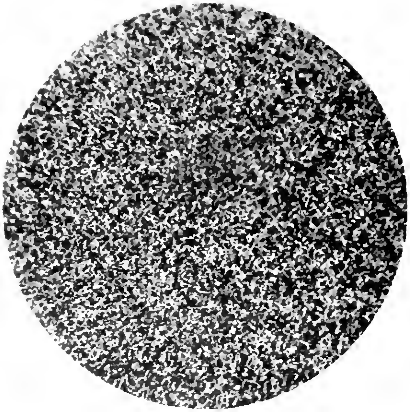
NO.	C.	Mn.	P.	.S	Si.
1	.582	.86	.074	.040	.094
2	.563	.84	.080	.041	.094
3	.556	.83	.077	.039	.094
4	.525	.82	.077	.035	.094
5	.553	.85	.076	.038	.094
6	.548	.83	.083	.040	.112
7	.566	.84	.086	.044	.112
8	.566	.85	.081	.040	.103
9	.582	.88	.085	.040	.103
10	.531	.83	.064	.034	.105
11	.453	.81	.066	.036	.103
12	.507	.81	.070	.042	.122
13	.562	.85	.078	.040	.103
14	.570	.85	.073	.034	.103
15	.565	.87	.082	.032	.122
16	.555	.63	.083	.038	.112
17	.495	.84	.067	.034	.094
18	.465	.79	.067	.032	.122
19	.501	.87	.066	.038	.103
20	.564	.88	.082	.041	.115
21	.543	.83	.080	.033	.106
22	.562	.86	.074	.040	.112
23	.576	.88	.082	.040	.103
24	.532	.91	.075	.036	.105
25	.475	.82	.061	.030	.103
26	.533	.82	.070	.035	.097
27	.585	.81	.075	.032	.103
28	.578	.76	.076	.039	.099
29	.562	.78	.076	.031	.094
30	.640	.79	.078	.040	.103

NO.	C.	Mn.	P.	S.	Si.
31	.577	.80	.072	.034	.094
32	.615	.84	.073	.039	.112
33	.580	.80	.076	.033	.103
34	.577	.76	.078	.038	.103
35	.573	.74	.078	.039	.103
36	.568	.78	.077	.042	.103
37	.561	.77	.076	.036	.112
38	.601	.71	.079	.031	.122
39	.558	.80	.064	.031	.103
40	.627	.81	.090	.044	.093
41	.608	.76	.079	.042	.094
42	.583	.75	.076	.042	.122
43	.566	.79	.077	.041	.122
44	.576	.80	.077	.035	.112
45	.652	.77	.088	.046	.112
46	.661	.86	.039	.047	.112
47	.590	.83	.080	.050	.127
48	.578	.79	.078	.041	.133
49	.577	.82	.079	.041	.122
50	.584	.83	.080	.041	.112
51	.662	.83	.089	.047	.112
52	.633	.84	.088	.045	.094
53	.591	.81	.077	.042	.094
54	.576	.83	.095	.037	.094
55	.554	.80	.081	.038	.099
56	.532	.80	.071	.036	.112
57	.529	.82	.063	.036	.103
58	.482	.84	.064	.029	.112
59	.552	.84	.061	.036	.103
60	.507	.60	.063	.033	.112
61	.582	.84	.083	.034	.112

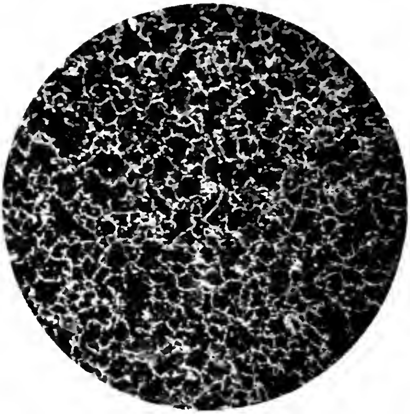
Ordinary Steel. Charge No. 693. Top of Ingot.



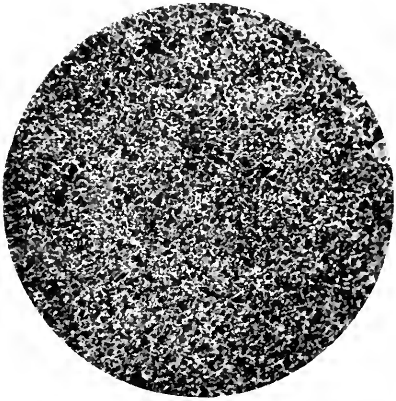
Charge No. 75828. Top of Ingot. Two per cent. of 10 per cent. Ferro-Titanium Added.



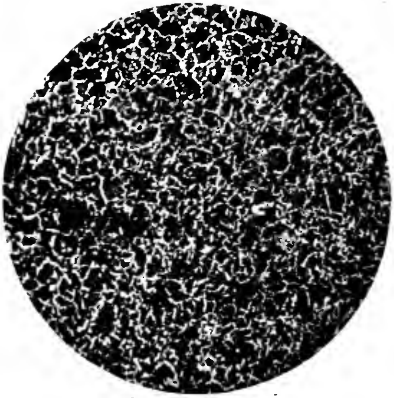
Top of Head.



Center of Head.

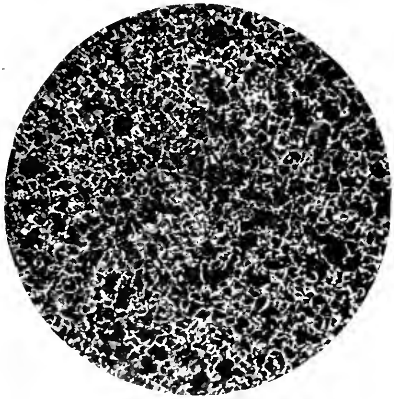


Edge of Flange.

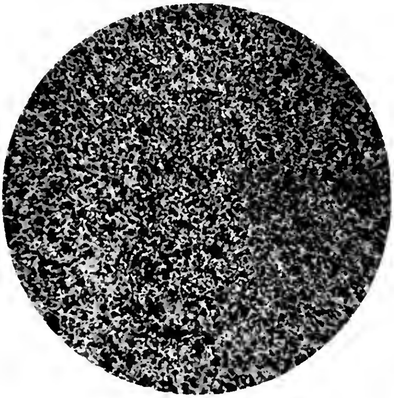


Top of Head.

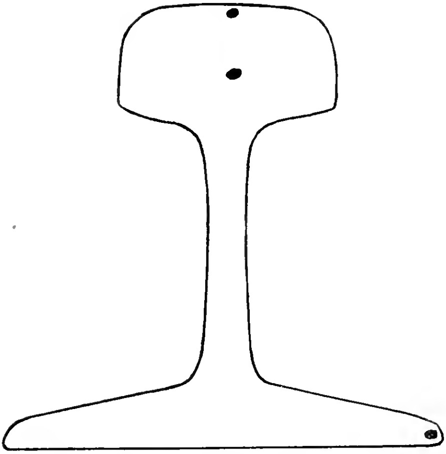
Rail from Top of Third Ingot.



Center of Head.



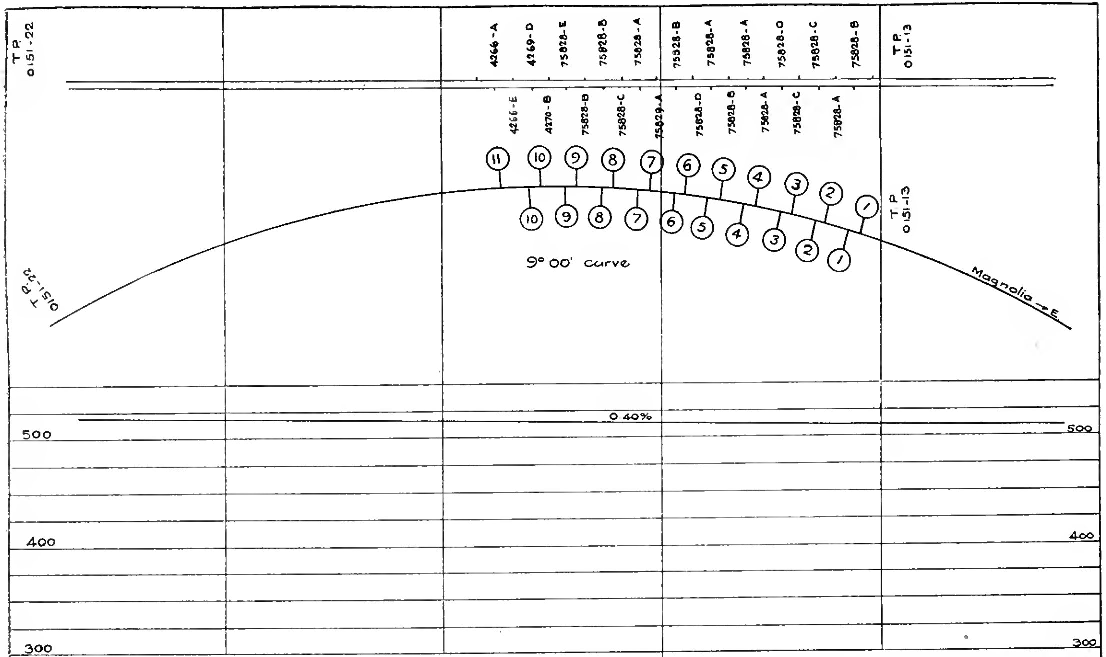
Edge of Flange.



Record 1867. Special Ferro-Titanium Steel. Location Plan of Micro-Photos. Magnification, X50.

Ordinary Steel Ingot.

Ferro-Titanium Steel Ingot.



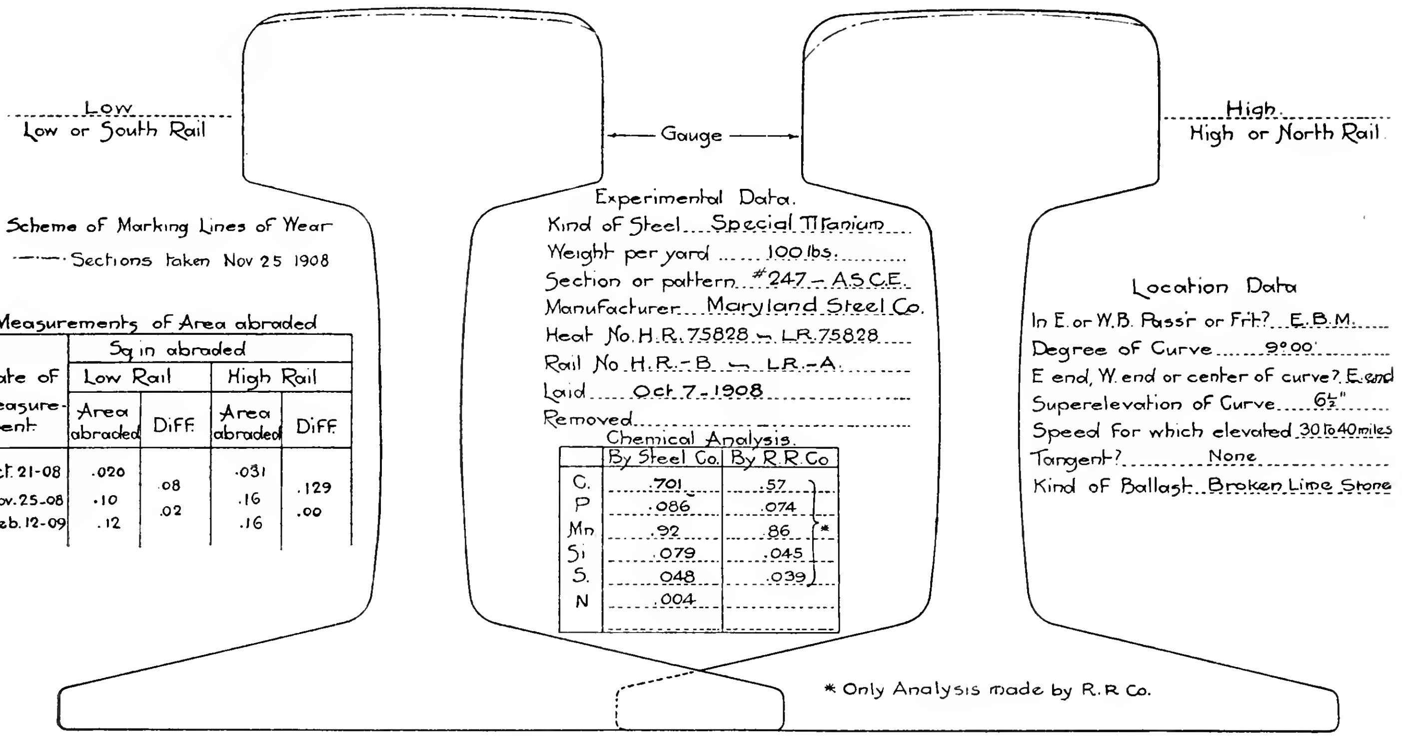
A = Titanium shown in Red B = ... shown in Yellow

Measurements made Summary by Maryland Steel Co.

Month and Year	Oct. 21 -08											
Kind of Rail	A	B	A	B	A	B	A	B	A	B	A	B
Total sq in abraded	.579		2 81									
Average sq in abraded per Section	.027		.133									
Perc. of Area abraded to total Area of Head	65%		3.2%									

1m 1-27-09 Form 986 Spl

THE BALTIMORE & OHIO RAILROAD COMPANY.
THE BALTIMORE & OHIO SOUTHWESTERN RAILROAD CO.
MAINTENANCE OF WAY DEPT.
CUMBERLAND Div.
Location Diagram of
SPECIAL TITANIUM Rails
Laid in 1908 - Oct. 7. Removed in 19 ....
Between Magnolia and Paw Paw
Office of Chief Engineer M. of W. Balto. Md.
Scale 2 in.-1m. Date Feb. 13-09.



Scheme of Marking Lines of Wear

—·—· Sections taken Nov 25 1908

Measurements of Area abraded

Date of Measurement	Sq in abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Oct. 21-08	.020	.08	.031	.129
Nov. 25-08	.10	.02	.16	.00
Feb. 12-09	.12		.16	

Experimental Data.

Kind of Steel Special Titanium

Weight per yard 100 lbs.

Section or pattern #247 – A.S.C.E.

Manufacturer Maryland Steel Co.

Heat No. H.R. 75828 – L.R. 75828

Rail No. H.R. – B – L.R. – A

Laid Oct 7 - 1908

Removed

Chemical Analysis.

	By Steel Co.	By R.R. Co
C.	.701	.57
P	.086	.074
Mn	.92	.86 *
Si	.079	.045
S.	.048	.039
N	.004	

Location Data

In E. or W.B. Pass'r or Frt? E.B.M.

Degree of Curve 9°00'

E end, W. end or center of curve? E. end

Superelevation of Curve $6\frac{1}{2}$"

Speed for which elevated 30 to 40 miles

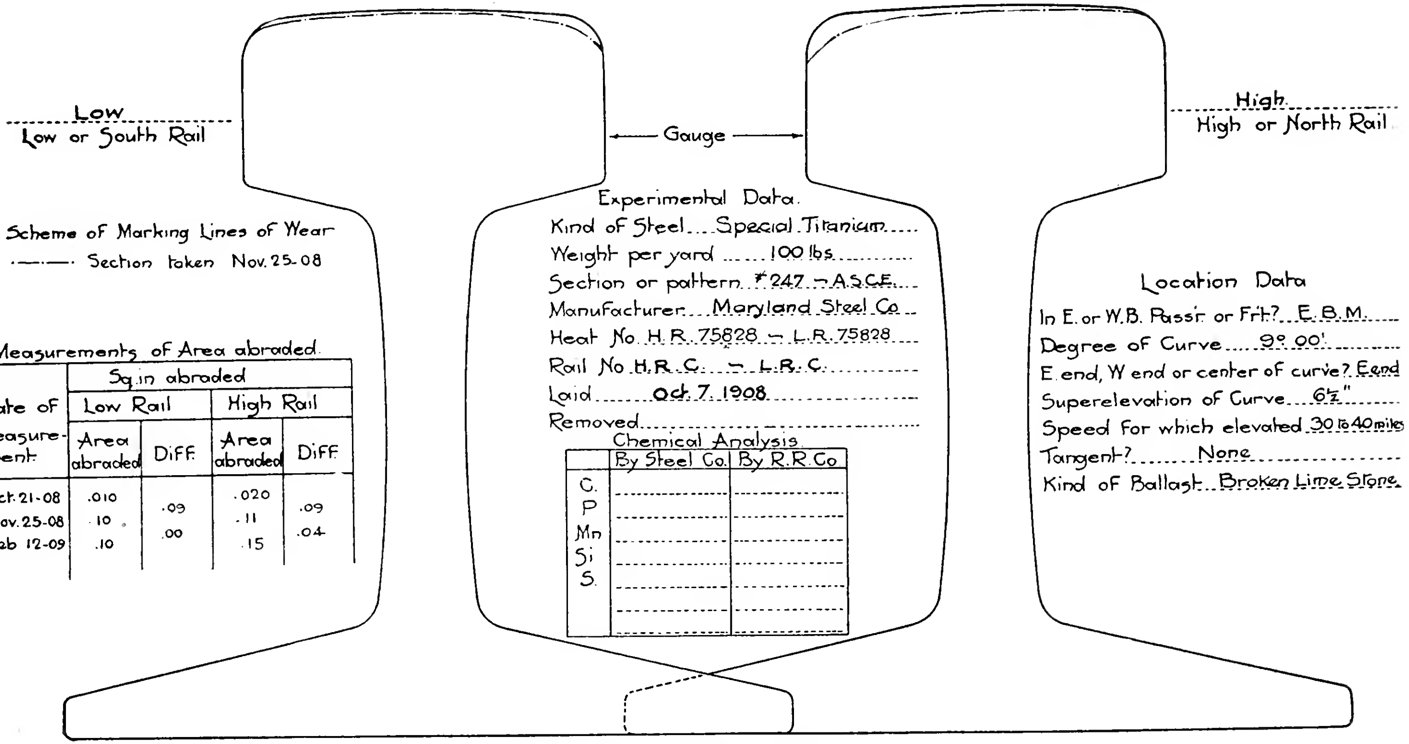
Tangent? None

Kind of Ballast Broken Lime Stone

* Only Analysis made by R.R Co.

Measurements taken at Rail Center

LOCATION IN TRACK, (1).



Scheme of Marking Lines of Wear

.—.— Section taken Nov. 25-08

Measurements of Area abraded.

Date of Measurement	Sq. in abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Oct. 21-08	.010		.020	
Nov. 25-08	.10	.09	.11	.09
Feb 12-09	.10	.00	.15	.04

Experimental Data.

Kind of Steel... Special Titanium....

Weight per yard ..... 100 lbs. ....

Section or pattern. #247 – A.S.C.E....

Manufacturer... Maryland Steel Co. ..

Heat No. H.R. 75828 – L.R. 75828 ...

Rail No. H.R.C. – L.R.C. ....

Laid .... Oct. 7. 1908 ....

Removed.................................

Chemical Analysis

	By Steel Co.	By R.R. Co.
C.		
P		
Mn		
Si		
S.		

Location Data

In E. or W.B. Pass'r or Frt.? .. E.B.M. .....

Degree of Curve ..... 9° 00'. ....

E. end, W end or center of curve? E end

Superelevation of Curve.... 6½" ....

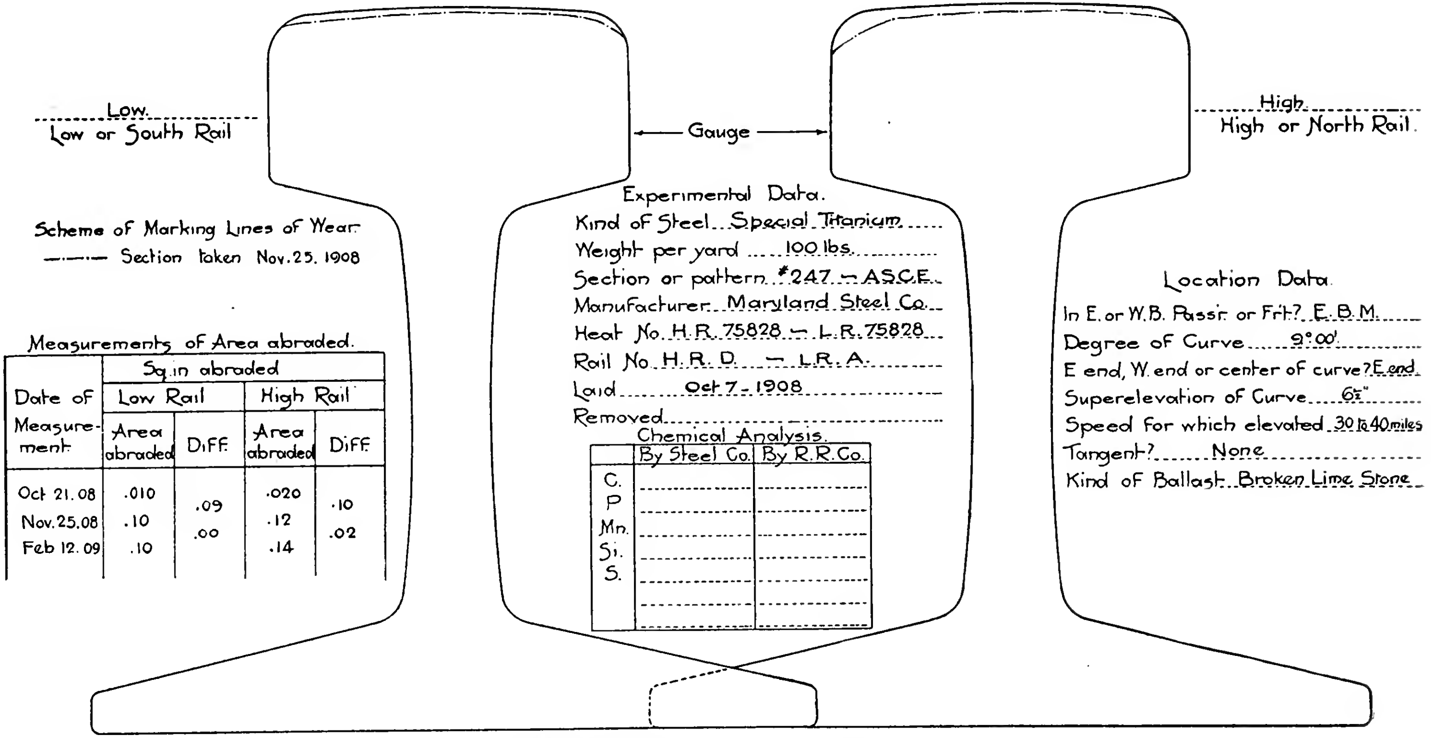
Speed for which elevated 30 to 40 miles

Tangent? .... None ....

Kind of Ballast.. Broken Lime Stone.

Measurements taken at Rail Center

LOCATION IN TRACK, (2).



Scheme of Marking Lines of Wear.
—·—·— Section taken Nov. 25. 1908

Measurements of Area abraded.

Date of Measurement	Sq. in abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Oct 21. 08	.010	.09	.020	.10
Nov. 25. 08	.10	.00	.12	.02
Feb 12. 09	.10		.14	

Experimental Data.

Kind of Steel. Special Titanium
Weight per yard ..... 100 lbs.
Section or pattern. #247 – A.S.C.E.
Manufacturer. Maryland Steel Co.
Heat No. H.R. 75828 – L.R. 75828
Rail No. H.R.D. – L.R.A.
Laid .... Oct 7 - 1908
Removed.........

Chemical Analysis.

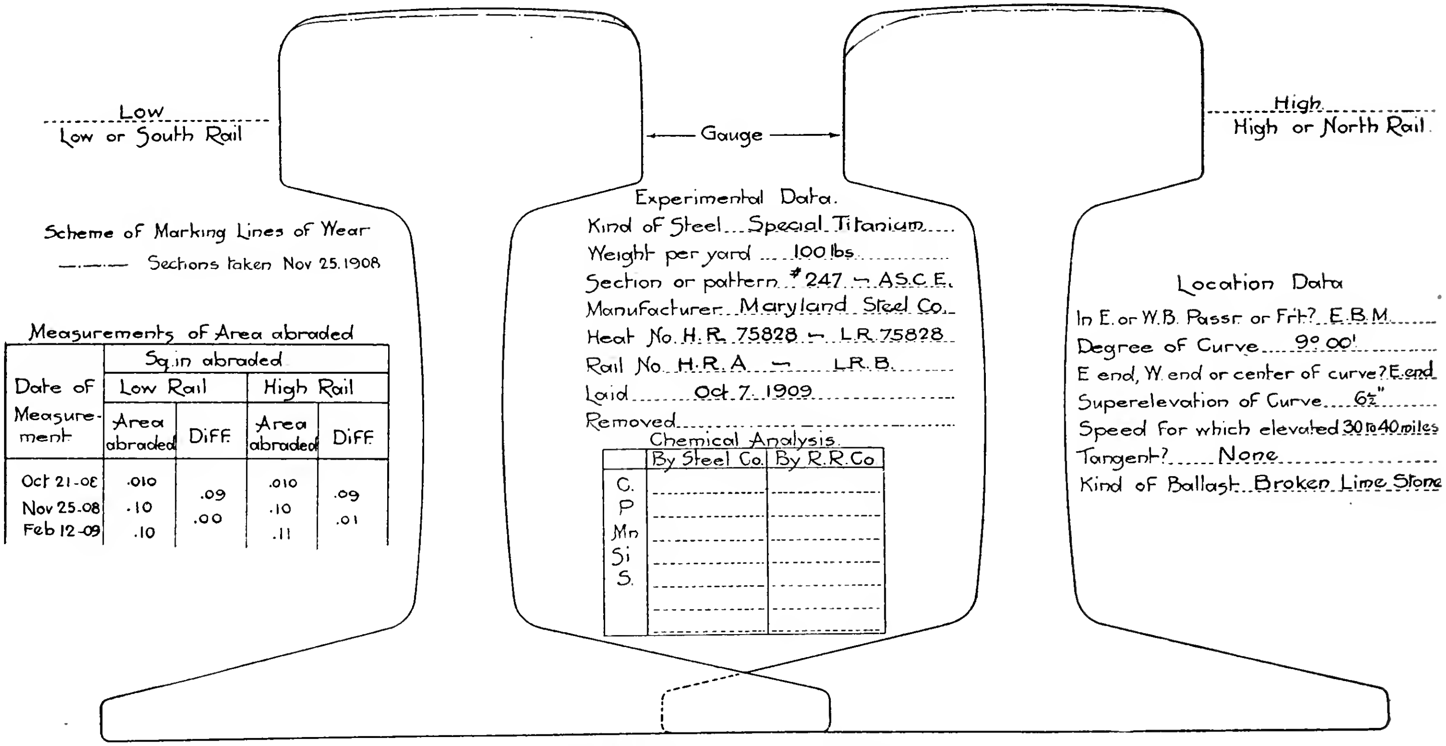
	By Steel Co.	By R.R. Co.
C.		
P		
Mn.		
Si.		
S.		

Location Data.

In E. or W.B. Passr. or Frt.? E.B.M.
Degree of Curve ..... 9°00'
E end, W. end or center of curve? E end.
Superelevation of Curve ..... 6½"
Speed for which elevated 30 to 40 miles
Tangent? .... None
Kind of Ballast. Broken Lime Stone

Measurements taken at Rail Center

LOCATION IN TRACK, (3).



Scheme of Marking Lines of Wear

—·—·— Sections taken Nov 25.1908

Measurements of Area abraded

Date of Measurement	Sq.in abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Oct 21-08	.010		.010	
Nov 25.08	.10	.09	.10	.09
Feb 12-09	.10	.00	.11	.01

Experimental Data.

Kind of Steel Special Titanium

Weight per yard 100 lbs

Section or pattern #247 – A.S.C.E.

Manufacturer Maryland Steel Co.

Heat No. H.R. 75828 – L.R. 75828

Rail No. H.R.A – L.R.B.

Laid Oct. 7. 1909

Removed

Chemical Analysis

	By Steel Co.	By R.R. Co
C.		
P		
Mn		
Si		
S.		

Location Data

In E. or W.B. Passr. or Frt.? E.B.M.

Degree of Curve 9° 00'

E end, W. end or center of curve? E.end

Superelevation of Curve $6\frac{1}{2}$"

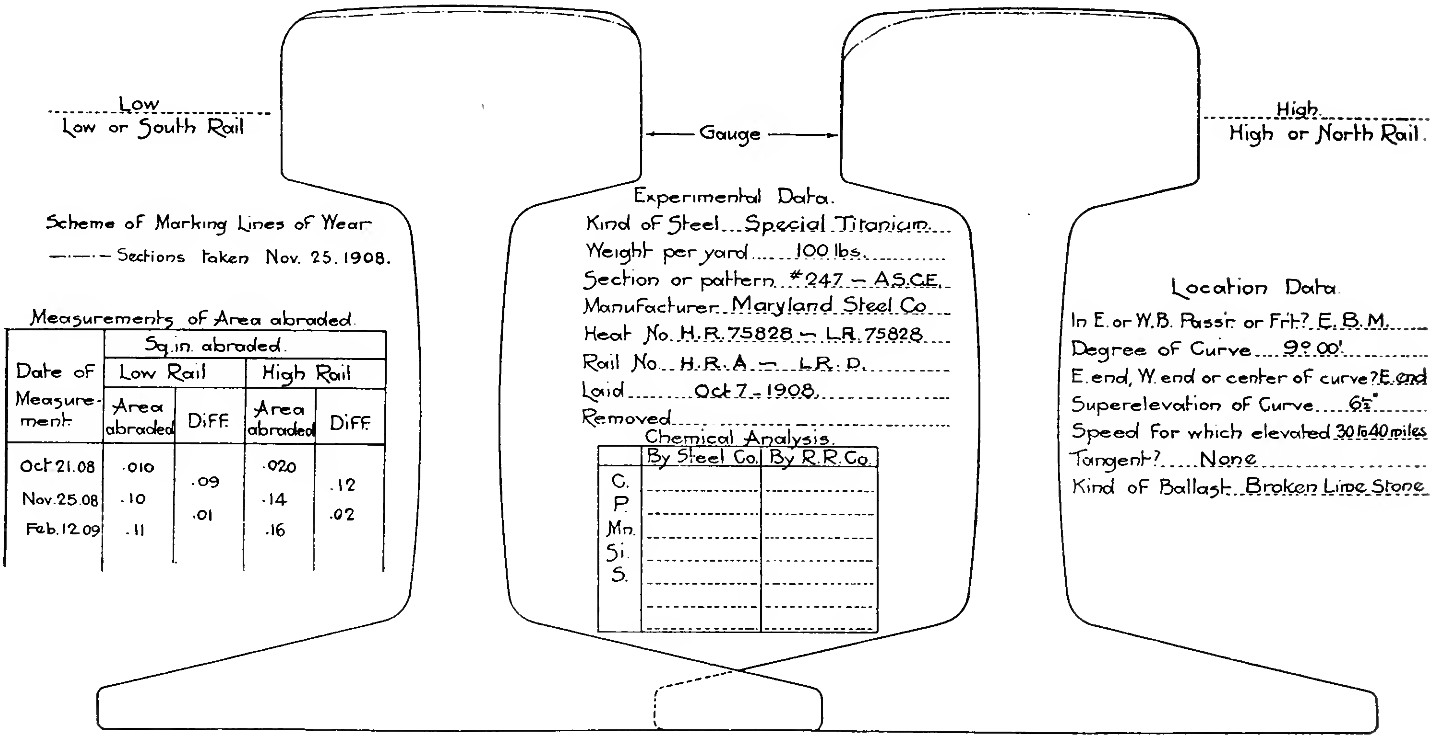
Speed for which elevated 30 to 40 miles

Tangent? None

Kind of Ballast Broken Lime Stone

Measurements taken at Rail Center

LOCATION IN TRACK, (4).



Scheme of Marking Lines of Wear

—·—·— Sections taken Nov. 25. 1908.

Measurements of Area abraded.

Date of Measurement	Sq. in. abraded.			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Oct 21.08	.010		.020	
Nov. 25.08	.10	.09	.14	.12
Feb. 12.09	.11	.01	.16	.02

Experimental Data.

Kind of Steel... Special Titanium...

Weight per yard...... 100 lbs. ....

Section or pattern... #247 – A.S.C.E.

Manufacturer.. Maryland Steel Co...

Heat No. H.R. 75828 – L.R. 75828

Rail No... H.R. A – L.R. D. ....

Laid.......... Oct 7 - 1908. ....

Removed.............................

Chemical Analysis.

	By Steel Co.	By R.R. Co.
C.		
P.		
Mn.		
Si.		
S.		

Location Data.

In E. or W.B. Pass'r or Frt? E. B. M.

Degree of Curve.... 9° 00'

E. end, W. end or center of curve? E. end

Superelevation of Curve.... 6½"

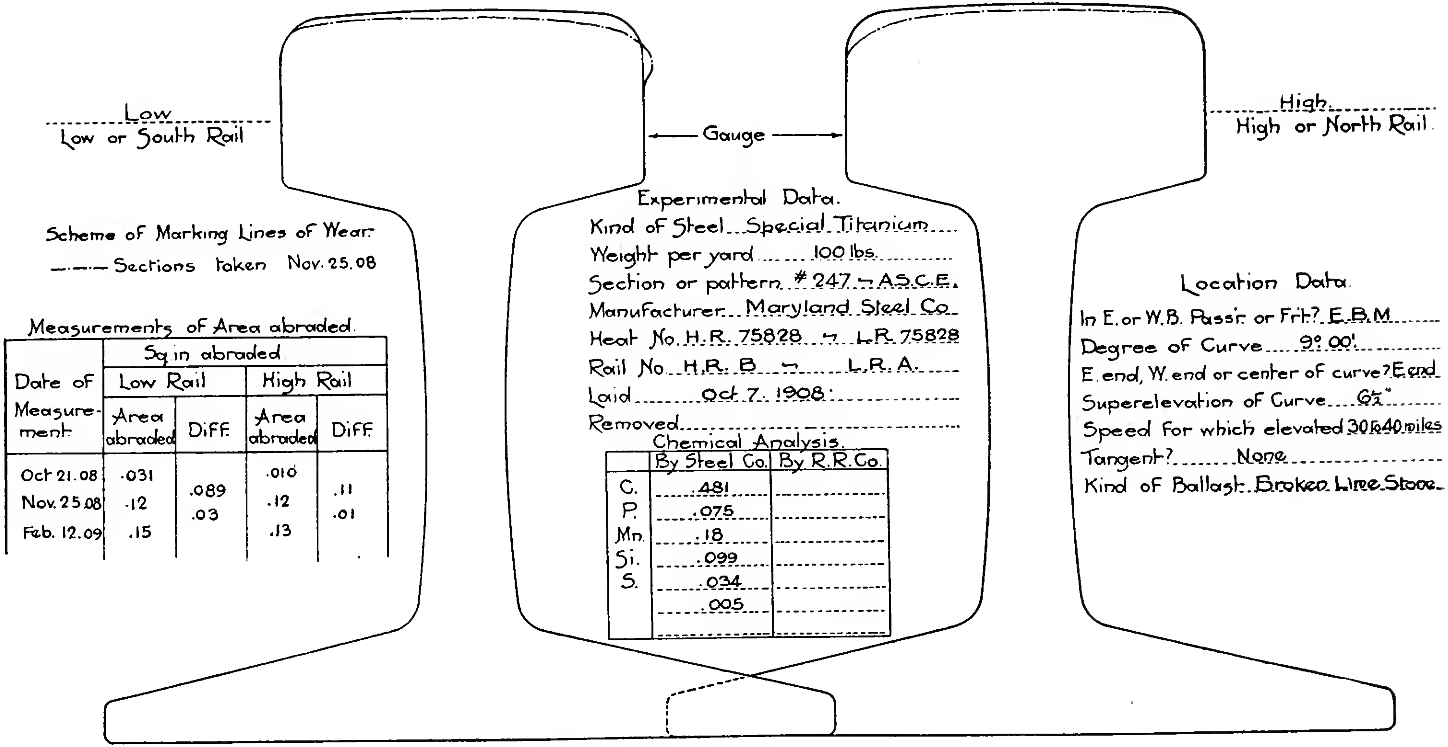
Speed for which elevated 30 to 40 miles

Tangent?..... None

Kind of Ballast.. Broken Lime Stone

Measurements taken at Rail Center

LOCATION IN TRACK, (5).



Scheme of Marking Lines of Wear.
—·—·— Sections taken Nov. 25. 08

Measurements of Area abraded.

Date of Measurement	Sq in abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Oct 21. 08	.031		.010	
Nov. 25 08	.12	.089	.12	.11
Feb. 12. 09	.15	.03	.13	.01

Experimental Data.
Kind of Steel Special Titanium
Weight per yard 100 lbs.
Section or pattern # 247 – A.S.C.E.
Manufacturer Maryland Steel Co.
Heat No. H.R. 75828 – L.R. 75828
Rail No. H.R. B – L.R. A.
Laid Oct 7. 1908.
Removed

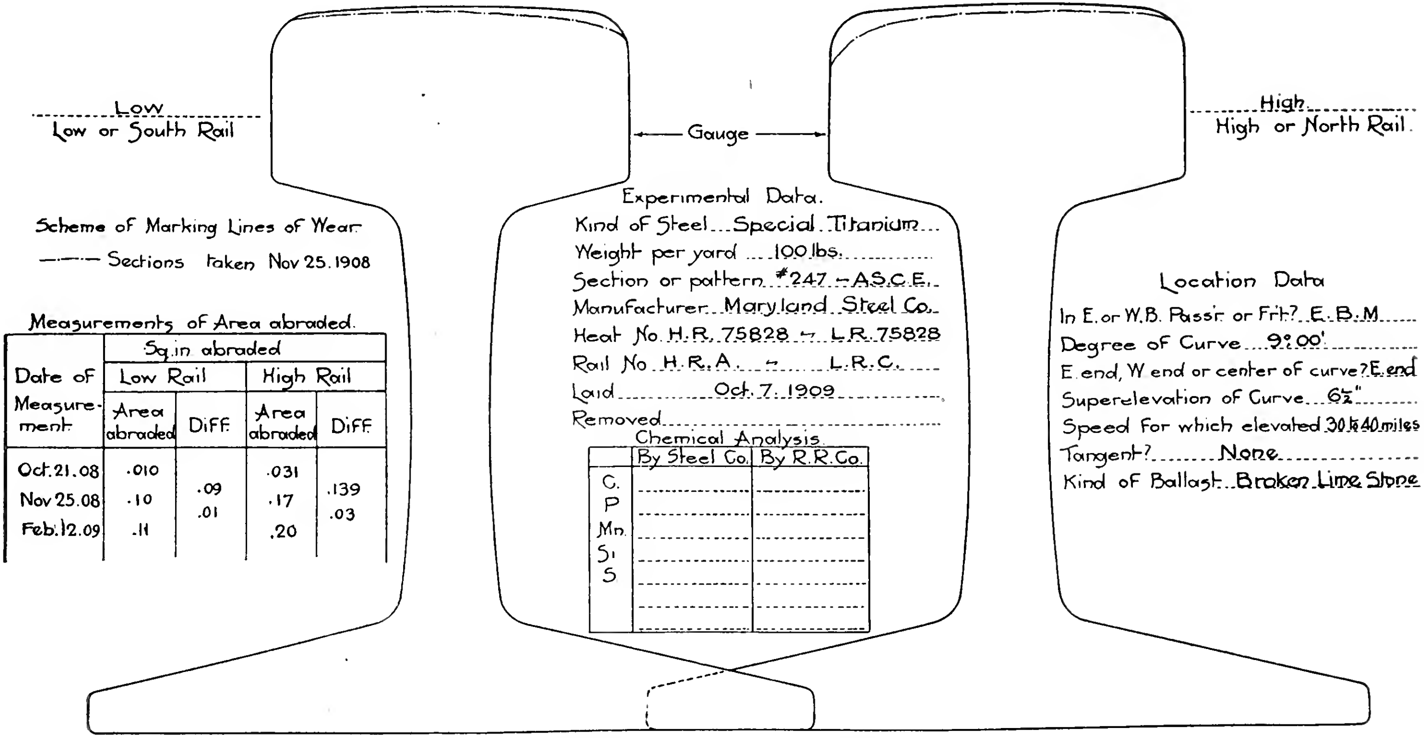
Chemical Analysis.

	By Steel Co.	By R.R. Co.
C.	.481	
P.	.075	
Mn.	.18	
Si.	.099	
S.	.034	
	.005	

Location Data.
In E. or W.B. Pass'r or Frt? E.B.M.
Degree of Curve 9° 00'.
E. end, W. end or center of curve? E end
Superelevation of Curve 6½"
Speed for which elevated 30 to 40 miles
Tangent? None
Kind of Ballast Broken Lime Stone

Measurements taken at Rail Center

LOCATION IN TRACK, (6).



Scheme of Marking Lines of Wear

—·—·— Sections taken Nov 25. 1908

Measurements of Area abraded.

Date of Measurement	Sq. in abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Oct. 21. 08	.010		.031	
Nov 25. 08	.10	.09	.17	.139
Feb. 12. 09	.11	.01	.20	.03

Experimental Data.

Kind of Steel ...Special Titanium...

Weight per yard ....100 lbs. ....

Section or pattern ..#247 – A.S.C.E..

Manufacturer ..Maryland Steel Co..

Heat No. H.R. 75828 – L.R. 75828

Rail No. ..H.R.A. .. " ... L.R.C. ....

Laid ....Oct. 7. 1909 ....

Removed ....

Chemical Analysis.

	By Steel Co.	By R.R. Co.
C.		
P		
Mn.		
Si		
S		

Location Data

In E. or W.B. Pass'r. or Frt.? ..E.B.M....

Degree of Curve ...9°00'..........

E. end, W end or center of curve? E. end

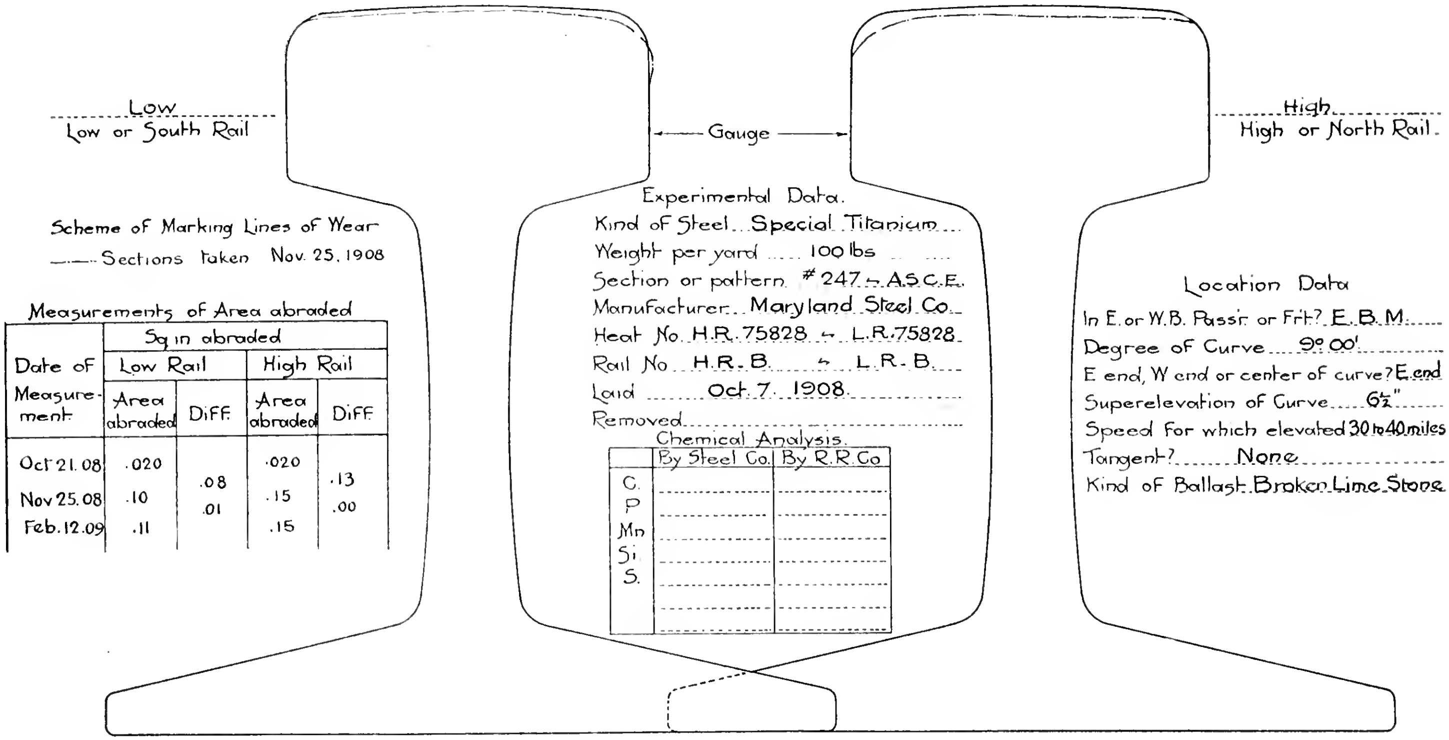
Superelevation of Curve ..$6\frac{1}{2}$"........

Speed for which elevated 30 to 40 miles

Tangent? ....None..........

Kind of Ballast ..Broken Lime Stone

LOCATION IN TRACK, (7).



Scheme of Marking Lines of Wear
—·— Sections taken Nov. 25. 1908

Measurements of Area abraded

Date of Measurement	Sq in abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Oct 21.08	.020		.020	
Nov 25.08	.10	.08	.15	.13
Feb. 12.09	.11	.01	.15	.00

Experimental Data.
Kind of Steel Special Titanium
Weight per yard 100 lbs
Section or pattern #247 – A.S.C.E.
Manufacturer Maryland Steel Co.
Heat No. H.R. 75828 – L.R. 75828
Rail No. H.R.B. – L.R.B.
Laid Oct. 7. 1908.
Removed

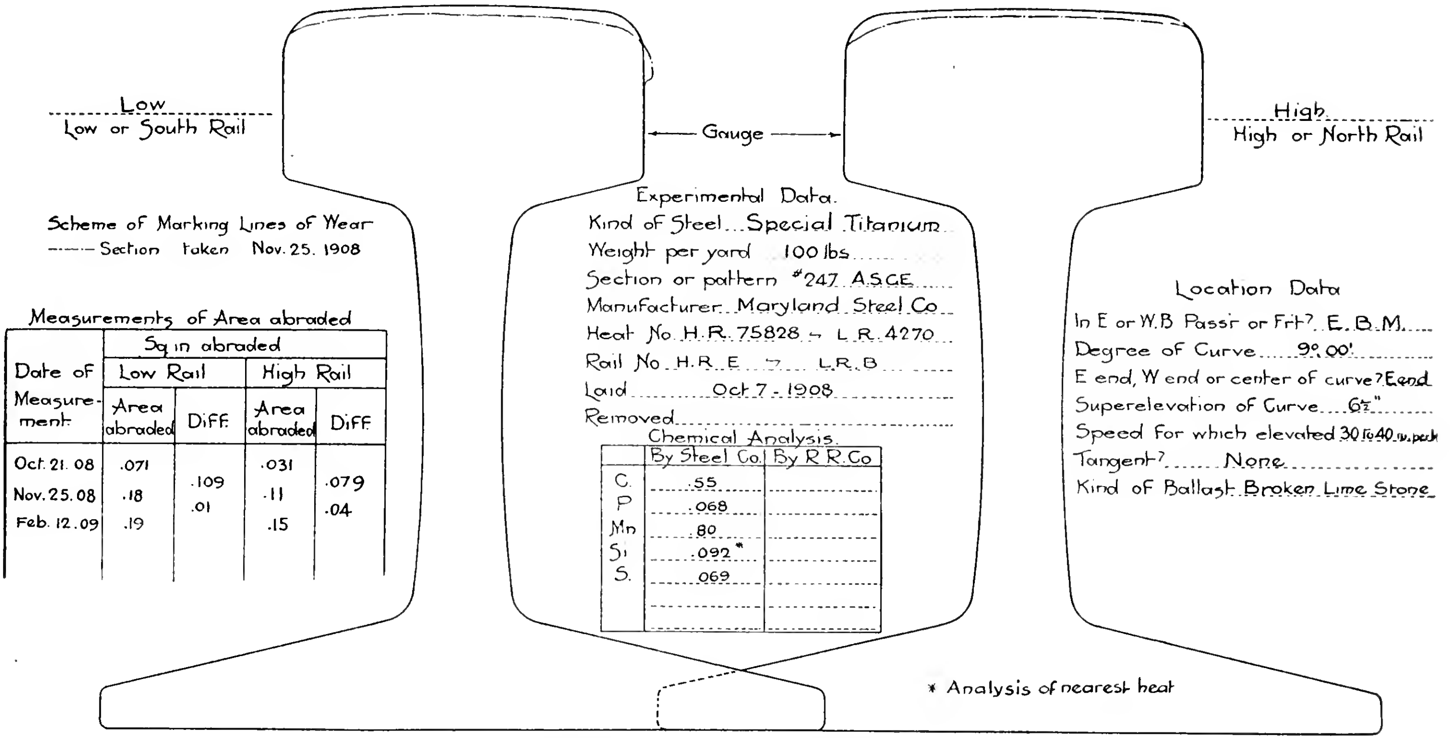
Chemical Analysis.

	By Steel Co.	By R.R. Co
C.		
P		
Mn		
Si		
S.		

Location Data
In E. or W.B. Passr. or Frt.? E.B.M.
Degree of Curve 9° 00'
E end, W end or center of curve? E. end
Superelevation of Curve 6½"
Speed for which elevated 30 to 40 miles
Tangent? None
Kind of Ballast Broken Lime Stone

Measurements taken at Rail Center

LOCATION IN TRACK, (8).



Scheme of Marking Lines of Wear
—·—·— Section taken Nov. 25. 1908

Measurements of Area abraded

Date of Measurement	Sq in abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Oct. 21. 08	.071	.109	.031	.079
Nov. 25. 08	.18	.01	.11	.04
Feb. 12. 09	.19		.15	

Experimental Data.
Kind of Steel. Special Titanium
Weight per yard 100 lbs
Section or pattern #247 A.S.C.E.
Manufacturer Maryland Steel Co
Heat No. H.R. 75828 – L.R. 4270
Rail No. H.R. E 7 L.R. B
Laid Oct 7 - 1908
Removed

Chemical Analysis.

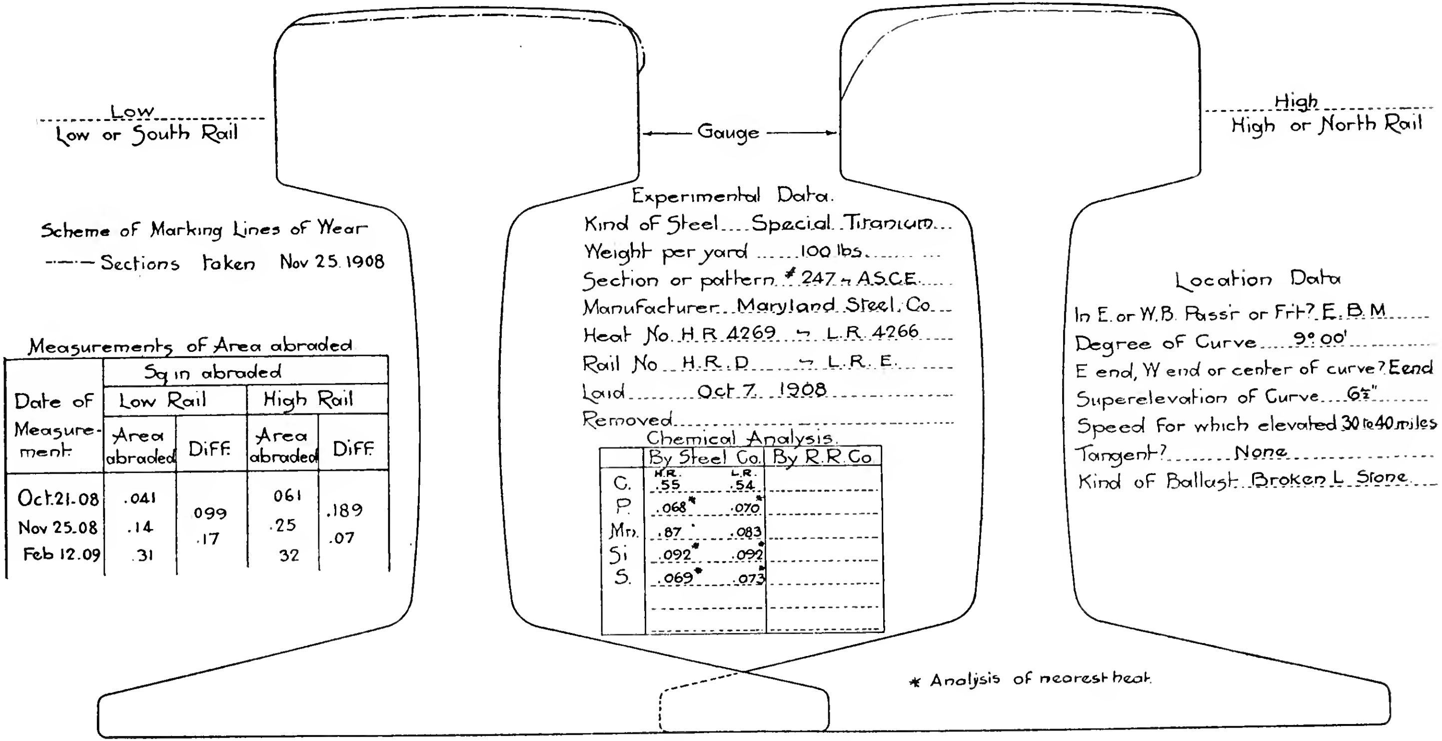
	By Steel Co.	By R.R.Co
C.	.55	
P	.068	
Mn	.80	
Si	.092 *	
S.	.069	

* Analysis of nearest heat

Location Data
In E or W.B. Pass'r or Fr't? E. B. M.
Degree of Curve 9° 00'
E end, W end or center of curve? E end
Superelevation of Curve 6½"
Speed for which elevated 30 to 40 m. per h
Tangent? None
Kind of Ballast Broken Lime Stone

Measurements taken at Rail Center–

LOCATION IN TRACK, (9).



Scheme of Marking Lines of Wear

-·-·- Sections taken Nov 25. 1908

Measurements of Area abraded

Date of Measurement	Sq in abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Oct.21.08	.041		061	
Nov 25.08	.14	099	.25	.189
Feb 12.09	.31	.17	32	.07

Experimental Data.

Kind of Steel.... Special Titanium...

Weight per yard ......100 lbs.........

Section or pattern # 247 – A.S.C.E.....

Manufacturer.. Maryland Steel. Co...

Heat No. H.R. 4269 – L.R. 4266....

Rail No .. H.R.D. – L.R.E. .....

Laid........ Oct 7. 1908.............

Removed..................................

Chemical Analysis.

	By Steel Co.		By R.R. Co
	H.R.	L.R.	
C.	.55	.54	
P.	.068*	.070*	
Mn.	.87	.083	
Si	.092*	.092*	
S.	.069*	.073*	

Location Data

In E. or W.B. Pass'r or Frt? E. B. M.....

Degree of Curve.... 9° 00'.........

E end, W end or center of curve? E end

Superelevation of Curve.... $6\frac{1}{2}''$......

Speed for which elevated 30 to 40 miles

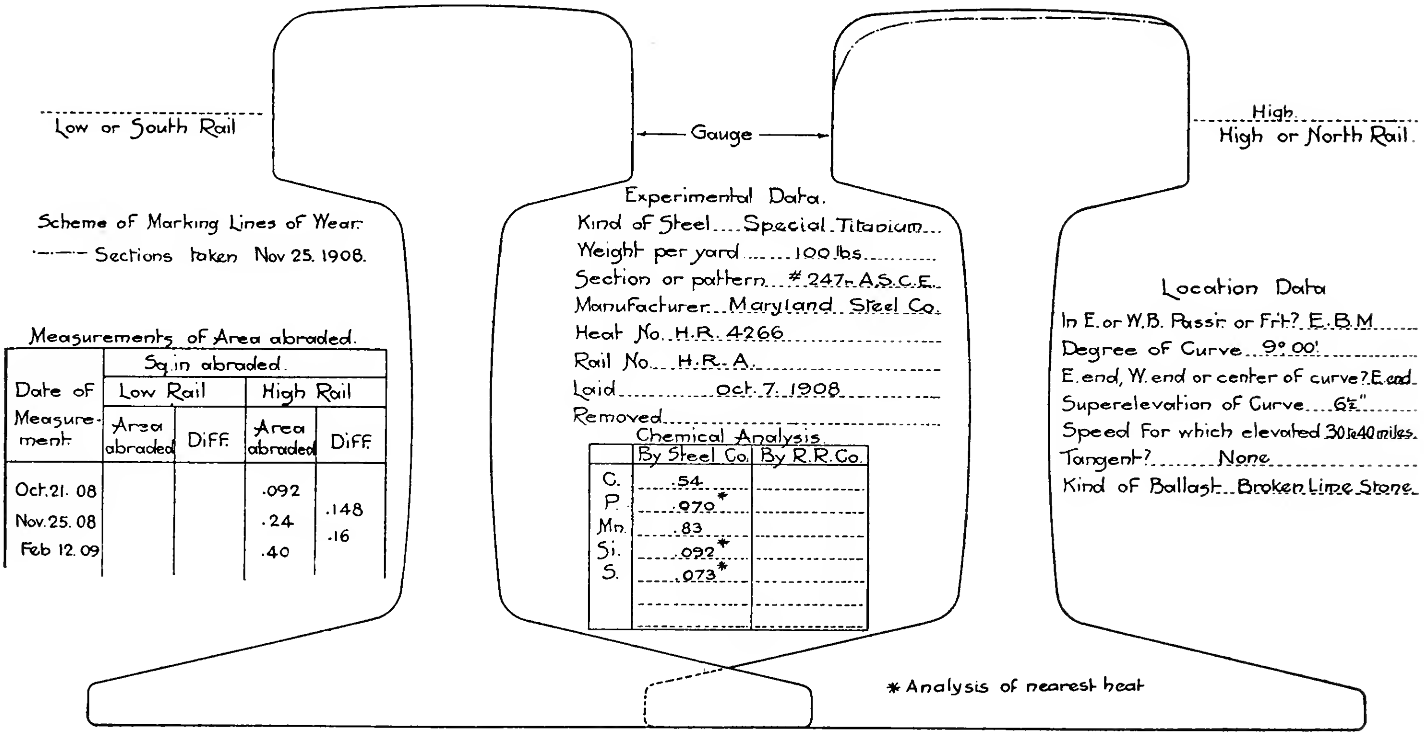
Tangent?....... None..............

Kind of Ballast.. Broken L. Stone...

* Analysis of nearest heat.

Measurements taken at Rail Center

LOCATION IN TRACK, (10).



Scheme of Marking Lines of Wear.
-·-·- Sections taken Nov 25. 1908.

Measurements of Area abraded.

Date of Measurement	Sq. in abraded.			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Oct. 21. 08			.092	
Nov. 25. 08			.24	.148
Feb 12. 09			.40	.16

Experimental Data.
Kind of Steel .... Special Titanium ...
Weight per yard ...... 100 lbs. ....
Section or pattern ... #247 - A.S.C.E. .
Manufacturer .. Maryland Steel Co.
Heat No. H.R. 4266 ....
Rail No. ... H.R. A. ....
Laid .... oct. 7. 1908 ....
Removed ....

Chemical Analysis.

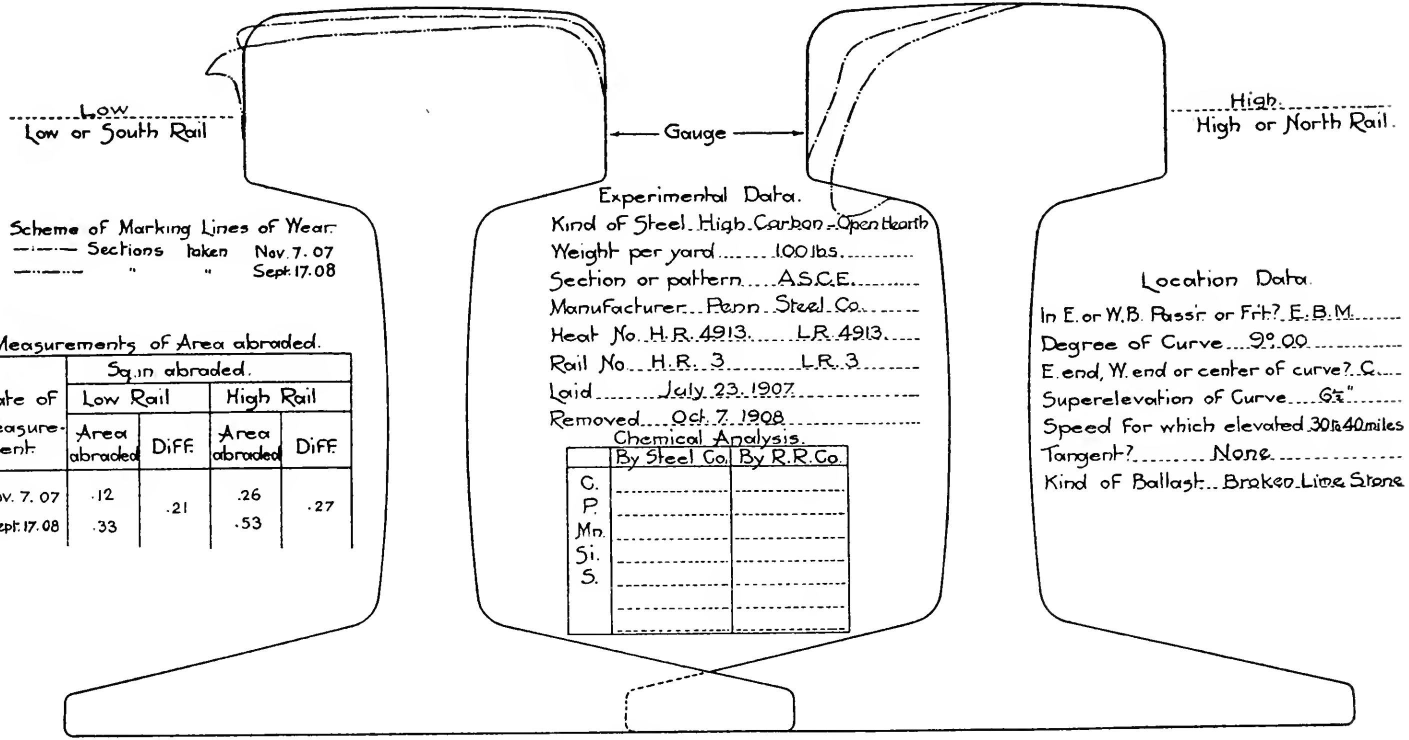
	By Steel Co.	By R.R. Co.
C.	.54	
P.	.070*	
Mn.	.83	
Si.	.092*	
S.	.073*	

Location Data
In E. or W.B. Pass'r or Frt? E.B.M ......
Degree of Curve .. 9° 00' ....
E. end, W. end or center of curve? E. end.
Superelevation of Curve ... 6½" ....
Speed for which elevated 30 to 40 miles.
Tangent? .... None ....
Kind of Ballast .. Broken Lime Stone.

* Analysis of nearest heat

Measurements taken at Rail Center

LOCATION IN TRACK, (II).



Scheme of Marking Lines of Wear.
—·—·— Sections taken Nov. 7. 07
—··—··— " " Sept. 17. 08

Measurements of Area abraded.

Date of Measurement	Sq. in abraded.			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Nov. 7. 07	.12	.21	.26	.27
Sept. 17. 08	.33		.53	

Experimental Data.

Kind of Steel. High Carbon - Open Hearth
Weight per yard ...... 100 lbs. ....
Section or pattern .... A.S.C.E. ....
Manufacturer .. Penn. Steel Co. ......
Heat No. H.R. 4913. ...... L.R. 4913. ....
Rail No. .. H.R. 3 .... L.R. 3 ......
Laid .... July 23. 1907 ....
Removed ... Oct. 7. 1908 ....

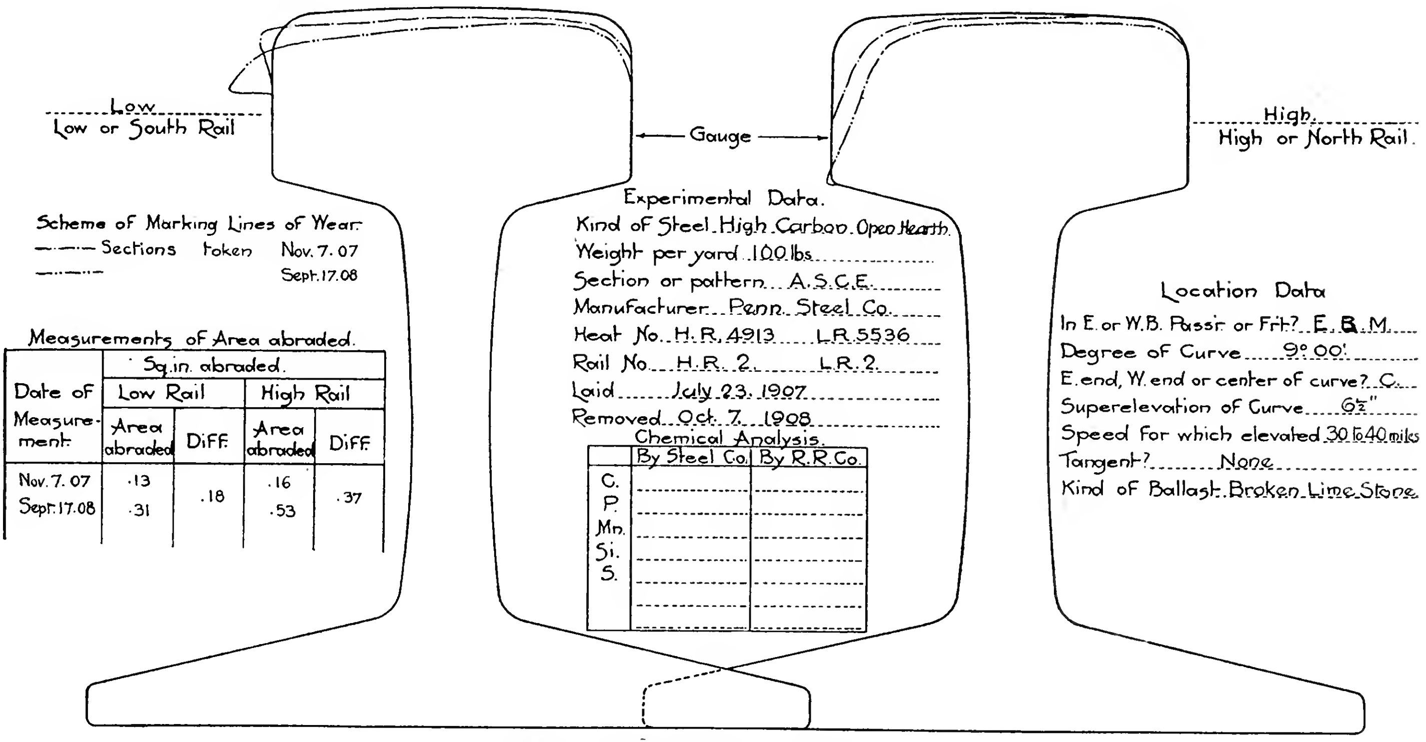
Chemical Analysis.

	By Steel Co.	By R.R. Co.
C.		
P.		
Mn.		
Si.		
S.		

Location Data.

In E. or W.B. Pass'r or Frt? E. B. M. ......
Degree of Curve ... 9° 00 ....
E. end, W. end or center of curve? C. ...
Superelevation of Curve .... 6½" ....
Speed for which elevated 30 to 40 miles
Tangent? .... None ....
Kind of Ballast .. Broken Lime Stone

Measurements taken at Rail Center.



Scheme of Marking Lines of Wear.
—·—·— Sections taken Nov. 7. 07
—··—··— Sept. 17. 08

Measurements of Area abraded.

Date of Measurement	Sq. in. abraded.			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Nov. 7. 07	.13	.18	.16	.37
Sept. 17. 08	.31		.53	

Experimental Data.

Kind of Steel High Carbon Open Hearth.
Weight per yard 100 lbs.
Section or pattern A.S.C.E.
Manufacturer Penn. Steel Co.
Heat No. H.R. 4913 L.R. 5536
Rail No. H.R. 2. L.R. 2.
Laid July 23. 1907
Removed Oct. 7. 1908

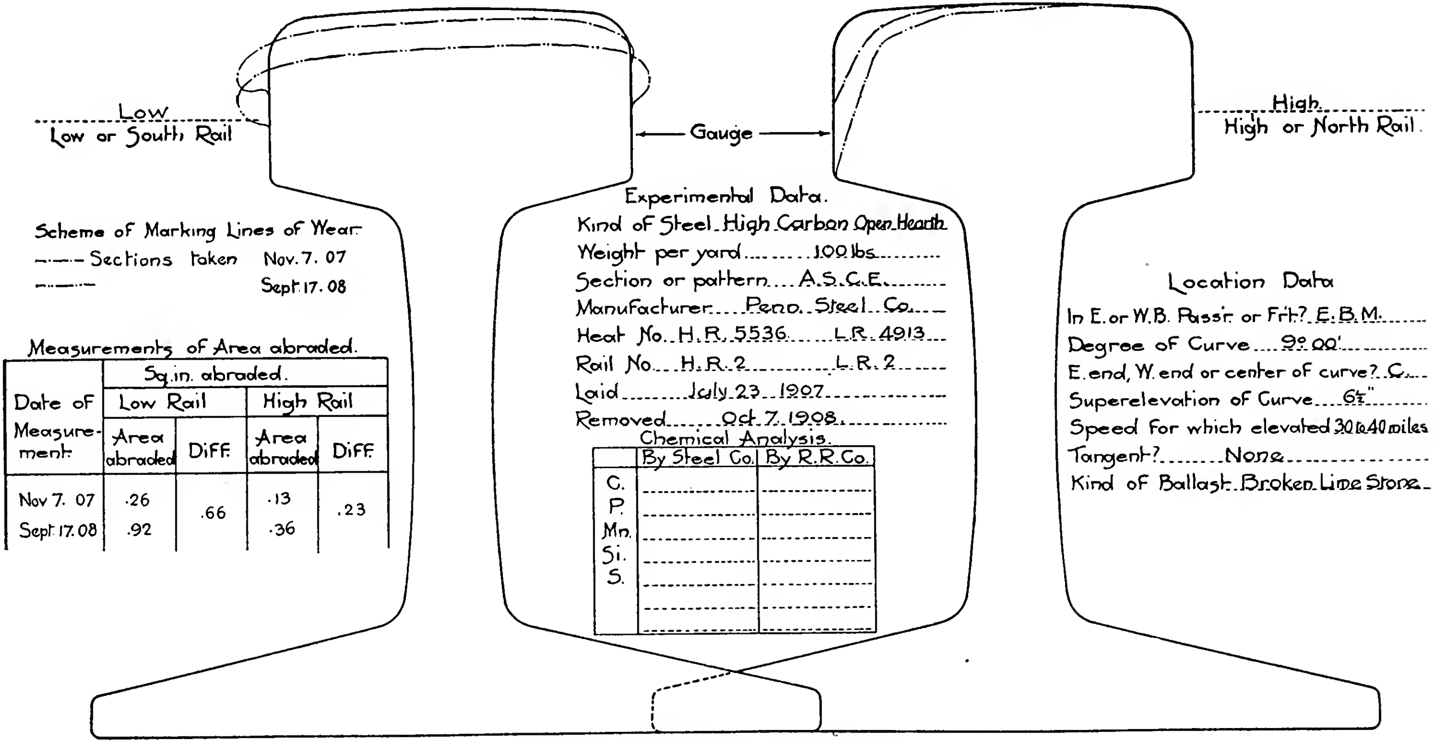
Chemical Analysis.

	By Steel Co.	By R.R. Co.
C.		
P.		
Mn.		
Si.		
S.		

Location Data

In E. or W.B. Pass'r or Frt.? E. B. M.
Degree of Curve 9° 00'
E. end, W. end or center of curve? C.
Superelevation of Curve $6\frac{1}{2}$"
Speed for which elevated 30 to 40 miles
Tangent? None
Kind of Ballast Broken Lime Stone

Measurements taken at Rail Center.



Scheme of Marking Lines of Wear

—·—·— Sections taken Nov. 7. 07

—··—··— Sept. 17. 08

Measurements of Area abraded.

Date of Measurement	Sq. in. abraded.			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Nov 7. 07	·26	.66	·13	.23
Sept 17. 08	·92		·36	

Experimental Data.

Kind of Steel High Carbon Open Hearth

Weight per yard .... 100 lbs ....

Section or pattern ... A.S.C.E. ....

Manufacturer ... Penn. Steel Co. ...

Heat No. H. R. 5536 .... L. R. 4913 ...

Rail No. ... H. R. 2 .... L. R. 2 ....

Laid .... July 23 1907 ....

Removed .... Oct 7. 1908. ....

Chemical Analysis.

	By Steel Co.	By R. R. Co.
C.		
P.		
Mn.		
Si.		
S.		

Location Data

In E. or W. B. Pass'r or Frt? E. B. M. ....

Degree of Curve .... 9° 00' ....

E. end, W. end or center of curve? C. ...

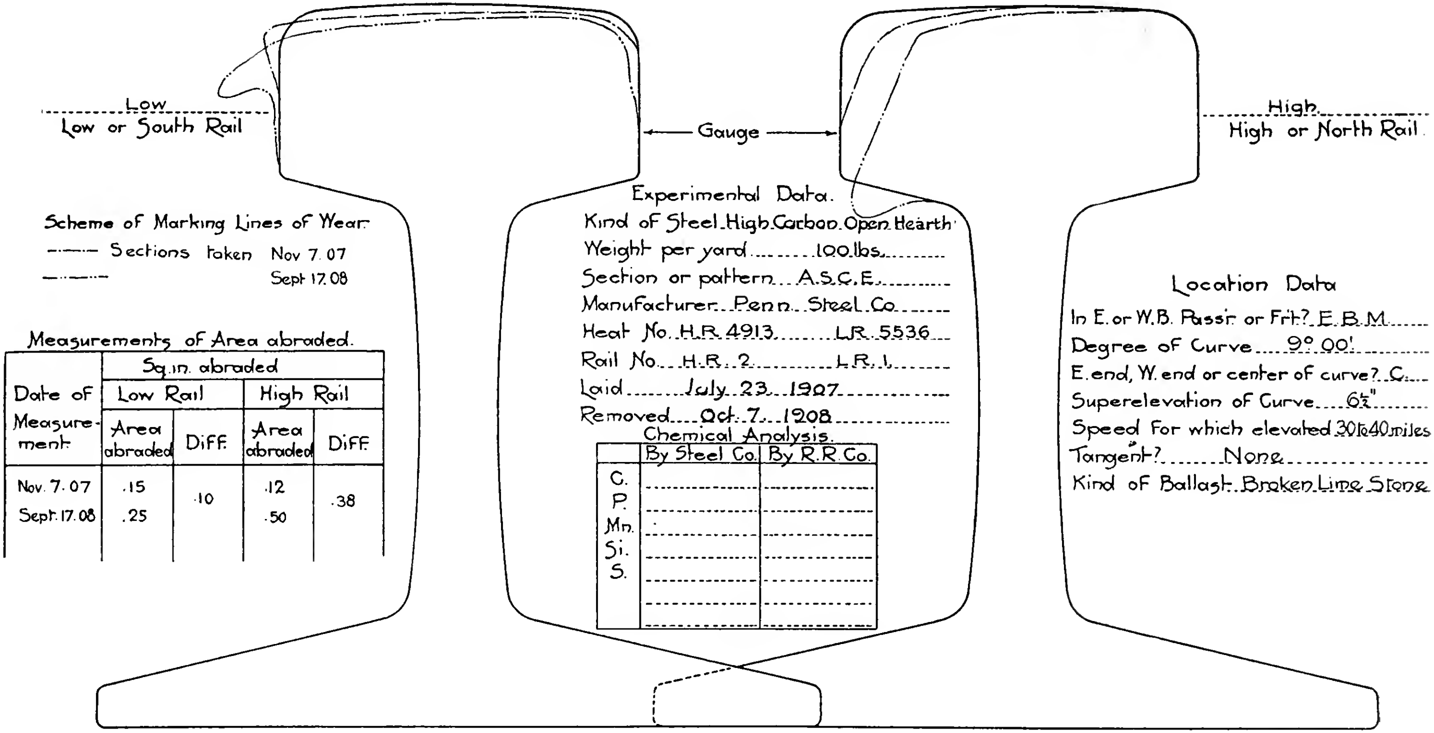
Superelevation of Curve .... 6½" ....

Speed for which elevated 30 to 40 miles

Tangent? .... None ....

Kind of Ballast Broken Lime Stone

Measurements taken at Rail Center.



Scheme of Marking Lines of Wear.
—·—·— Sections taken Nov 7. 07
—··—··— Sept 17. 08

Measurements of Area abraded.

Date of Measurement	Sq. in. abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Nov. 7. 07	.15	.10	.12	.38
Sept. 17. 08	.25		.50	

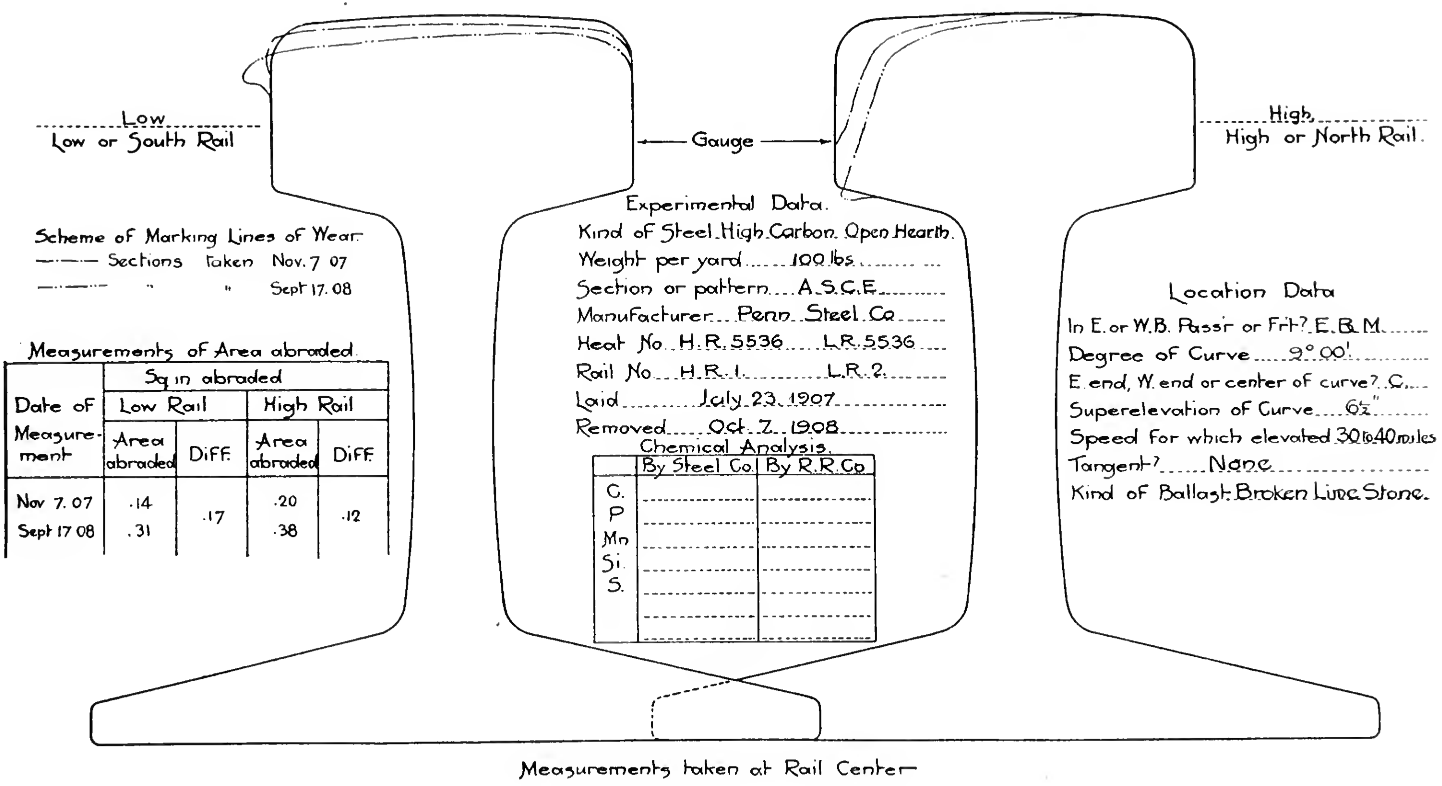
Experimental Data.
Kind of Steel High Carbon Open Hearth
Weight per yard 100 lbs.
Section or pattern A.S.C.E.
Manufacturer Penn. Steel Co.
Heat No. H.R. 4913. L.R. 5536
Rail No. H.R. 2 L.R. 1
Laid July 23. 1907
Removed Oct. 7. 1908

Chemical Analysis.

	By Steel Co.	By R.R. Co.
C.		
P.		
Mn.		
Si.		
S.		

Location Data
In E. or W.B. Pass'r or Frt? E.B.M.
Degree of Curve 9° 00'
E. end, W. end or center of curve? C.
Superelevation of Curve $6\frac{1}{2}$"
Speed for which elevated 30 to 40 miles
Tangent? None
Kind of Ballast Broken Lime Stone

Measurements taken at Rail Center.



Scheme of Marking Lines of Wear.
—·—·— Sections taken Nov. 7 07
—··—··— " " Sept 17. 08

Measurements of Area abraded.

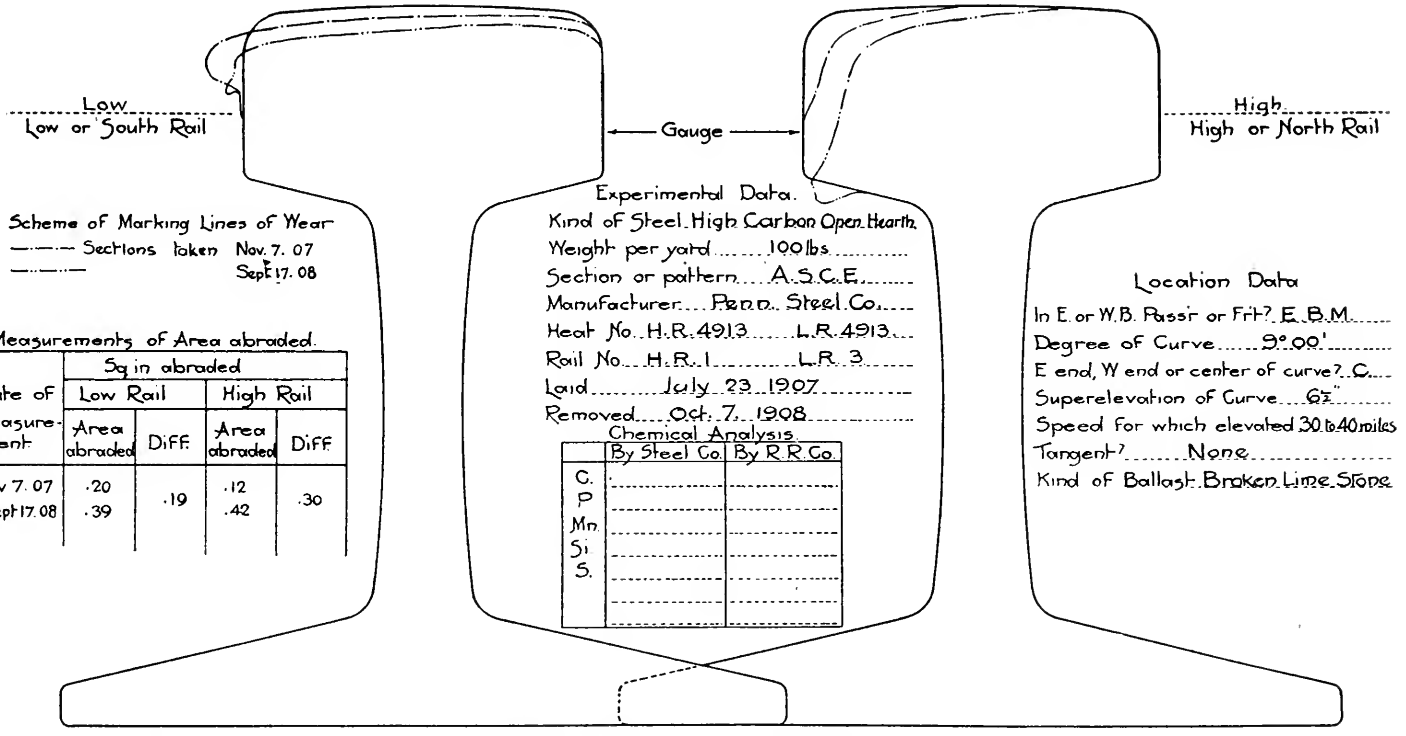
Date of Measurement	Sq in abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Nov 7. 07	.14	.17	.20	.12
Sept 17 08	.31		.38	

Experimental Data.
Kind of Steel High Carbon. Open Hearth.
Weight per yard 100 lbs.
Section or pattern A.S.C.E.
Manufacturer Penn. Steel Co
Heat No H.R. 5536 L.R. 5536
Rail No H.R. 1. L.R. 2.
Laid July 23. 1907
Removed Oct. 7. 1908

Chemical Analysis.

	By Steel Co.	By R.R. Co
C.		
P		
Mn		
Si.		
S.		

Location Data
In E. or W.B. Pass'r or Frt? E. B. M.
Degree of Curve 9° 00'.
E. end, W. end or center of curve? C.
Superelevation of Curve 6½"
Speed for which elevated 30 to 40 miles
Tangent? None
Kind of Ballast Broken Lime Stone.



Scheme of Marking Lines of Wear
—·—·— Sections taken Nov. 7. 07
—··—··— Sept 17. 08

Measurements of Area abraded.

Date of Measurement	Sq in abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Nov 7. 07 Sept 17. 08	.20 .39	.19	.12 .42	.30

Experimental Data.

Kind of Steel. High Carbon Open Hearth.

Weight per yard...... 100 lbs.........

Section or pattern.... A.S.C.E.......

Manufacturer.... Penn. Steel Co.....

Heat No. H.R. 4913...... L.R. 4913...

Rail No... H.R. 1........... L.R. 3.....

Laid........ July 23 1907..........

Removed.... Oct. 7. 1908............

Chemical Analysis.

	By Steel Co.	By R.R. Co.
C.		
P		
Mn.		
Si		
S.		

Location Data

In E. or W.B. Pass'r or Frt? E. B. M.......

Degree of Curve...... 9° 00'.........

E end, W end or center of curve? C....

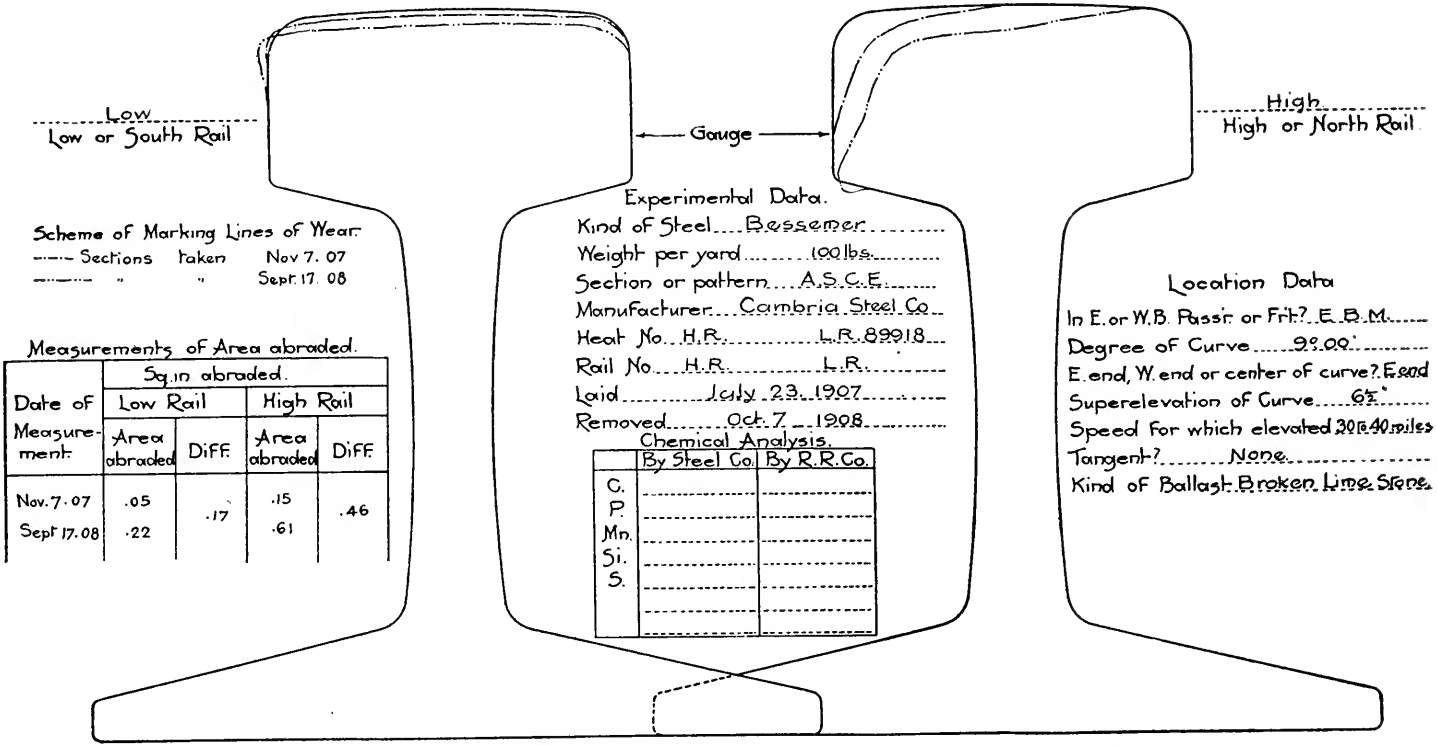
Superelevation of Curve.... 6½".........

Speed for which elevated 30 to 40 miles

Tangent?....... None..................

Kind of Ballast. Broken Lime Stone

Measurements taken at Rail Center



Scheme of Marking Lines of Wear.
-·-·- Sections taken Nov 7. 07
-··-··- " " Sept. 17. 08

Measurements of Area abraded.

Date of Measure-ment	Sq. in abraded.			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Nov. 7. 07	.05	.17	.15	.46
Sept 17. 08	.22		.61	

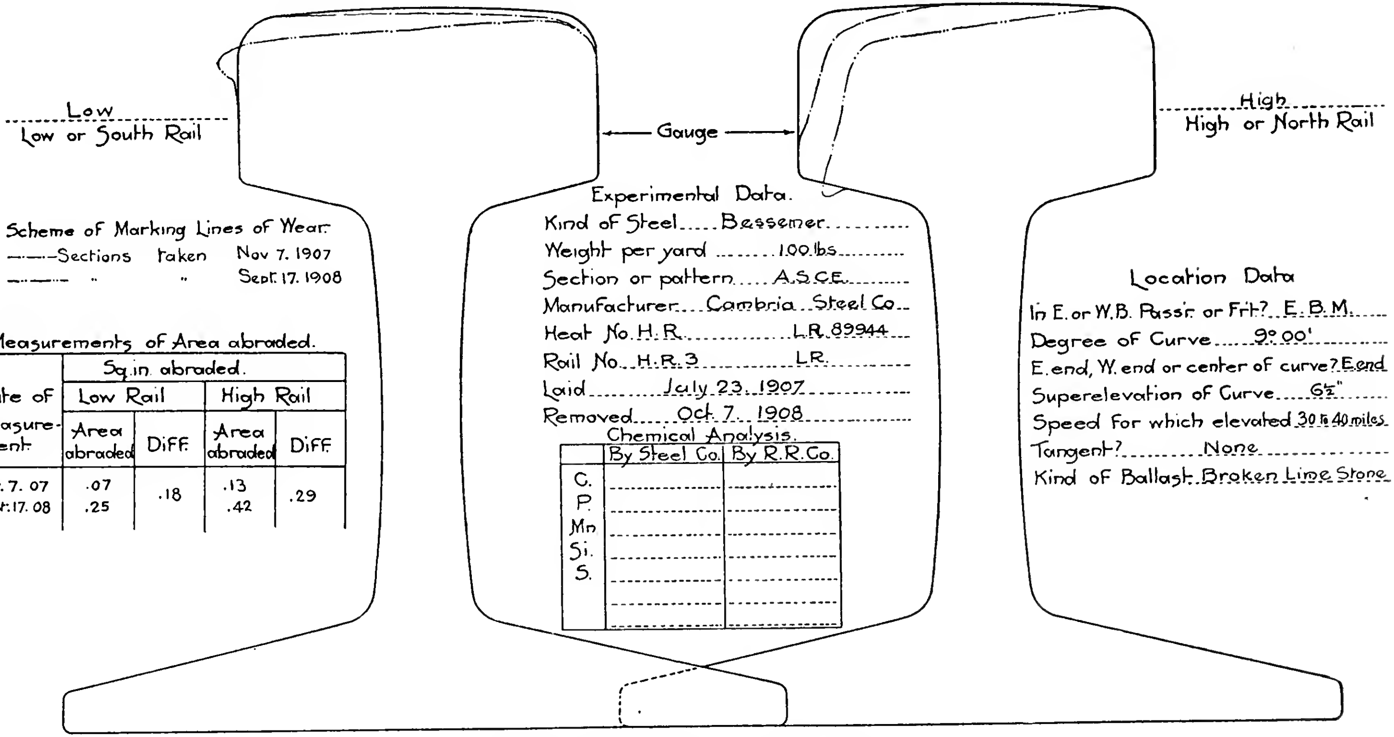
Experimental Data.
Kind of Steel... Bessemer........
Weight per yard........100 lbs.........
Section or pattern... A.S.C.E.......
Manufacturer... Cambria Steel Co.
Heat No. H.R. .... L.R. 89918...
Rail No. H.R. .... L.R. ....
Laid .... July 23. 1907 ....
Removed ...... Oct. 7 .. 1908 ....

Chemical Analysis.

	By Steel Co.	By R.R. Co.
C.		
P.		
Mn.		
Si.		
S.		

Location Data
In E. or W.B. Passr. or Frt.? E. B. M.....
Degree of Curve...... 9°.00'..........
E. end, W. end or center of curve? E. end
Superelevation of Curve ...... 6½"......
Speed for which elevated 30 to 40 miles
Tangent? .... None.............
Kind of Ballast Broken Lime Stone.

Measurements taken at Rail Center.



Scheme of Marking Lines of Wear.

—·—·—Sections taken Nov 7. 1907

—··—·· " " Sept. 17. 1908

Measurements of Area abraded.

Date of Measurement	Sq. in. abraded.			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Nov. 7. 07 Sept. 17. 08	.07 .25	.18	.13 .42	.29

Experimental Data.

Kind of Steel..... Bessemer..........

Weight per yard ....100 lbs.........

Section or pattern.... A.S.C.E.........

Manufacturer... Cambria Steel Co..

Heat No. H. R. .... L.R. 89944...

Rail No. H. R. 3 .... L.R. ....

Laid .... July 23. 1907 ....

Removed..... Oct. 7. 1908 ....

Chemical Analysis.

	By Steel Co.	By R. R. Co.
C.		
P.		
Mn		
Si.		
S.		

Location Data

In E. or W.B. Pass'r. or Frt? E. B. M. ......

Degree of Curve .... 9° 00' ....

E. end, W. end or center of curve? E. end

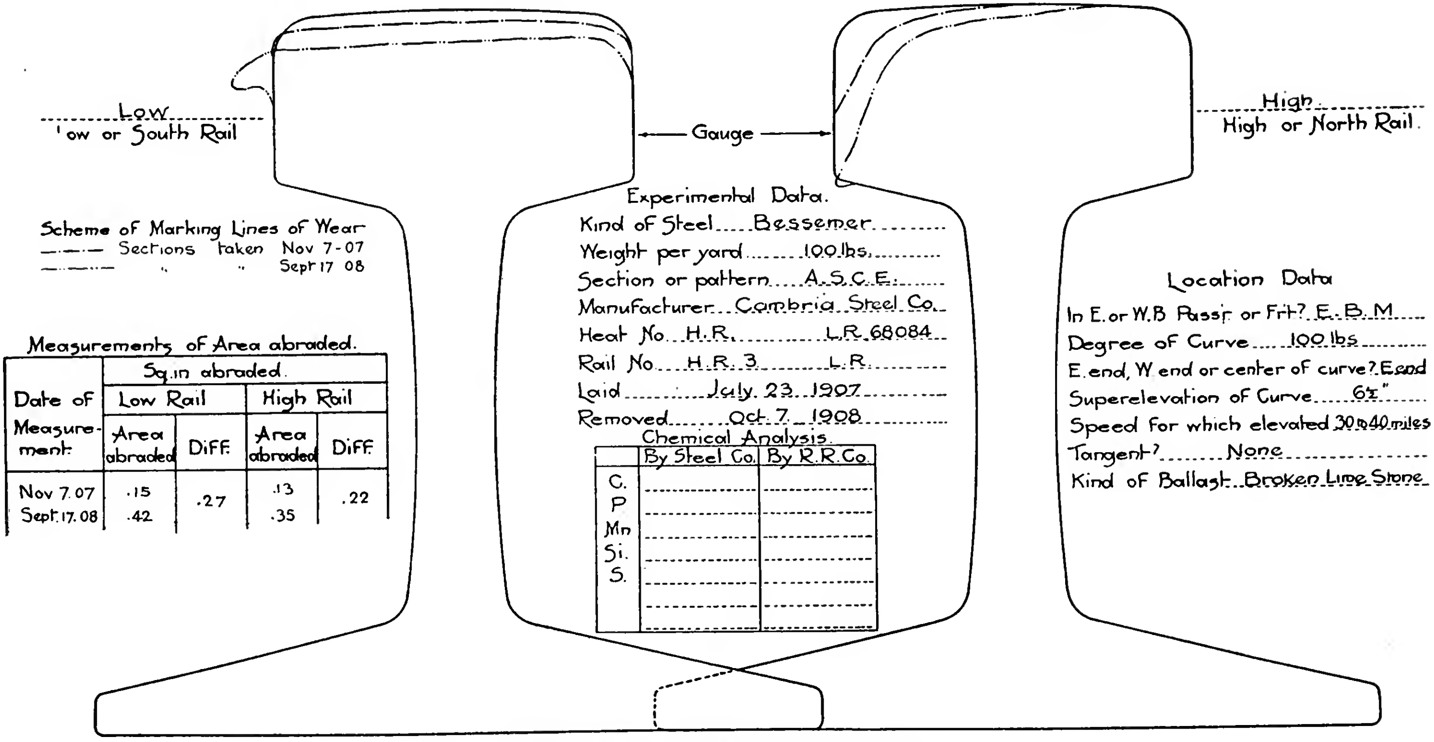
Superelevation of Curve..... $6\frac{1}{2}''$ ......

Speed for which elevated 30 to 40 miles.

Tangent? .... None ....

Kind of Ballast Broken Lime Stone

Measurements taken at Rail Center



Scheme of Marking Lines of Wear
—·—·— Sections taken Nov 7-07
—··—··— " " Sept 17 08

Measurements of Area abraded.

Date of Measurement	Sq. in abraded.			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Nov 7.07 Sept. 17.08	.15 .42	.27	.13 .35	.22

Experimental Data.

Kind of Steel.... Bessemer........

Weight per yard....... 100 lbs...........

Section or pattern..... A.S.C.E.........

Manufacturer.. Cambria Steel Co.

Heat No. H.R. .... L.R. 68084

Rail No... H.R. 3........... L.R. ....

Laid .... July. 23. 1907..........

Removed....... Oct. 7. 1908..........

Chemical Analysis.

	By Steel Co.	By R.R. Co.
C.		
P		
Mn		
Si.		
S.		

Location Data

In E. or W.B. Pass'r or Frt? E. B. M.......

Degree of Curve...... 100 lbs..........

E. end, W. end or center of curve? E. end

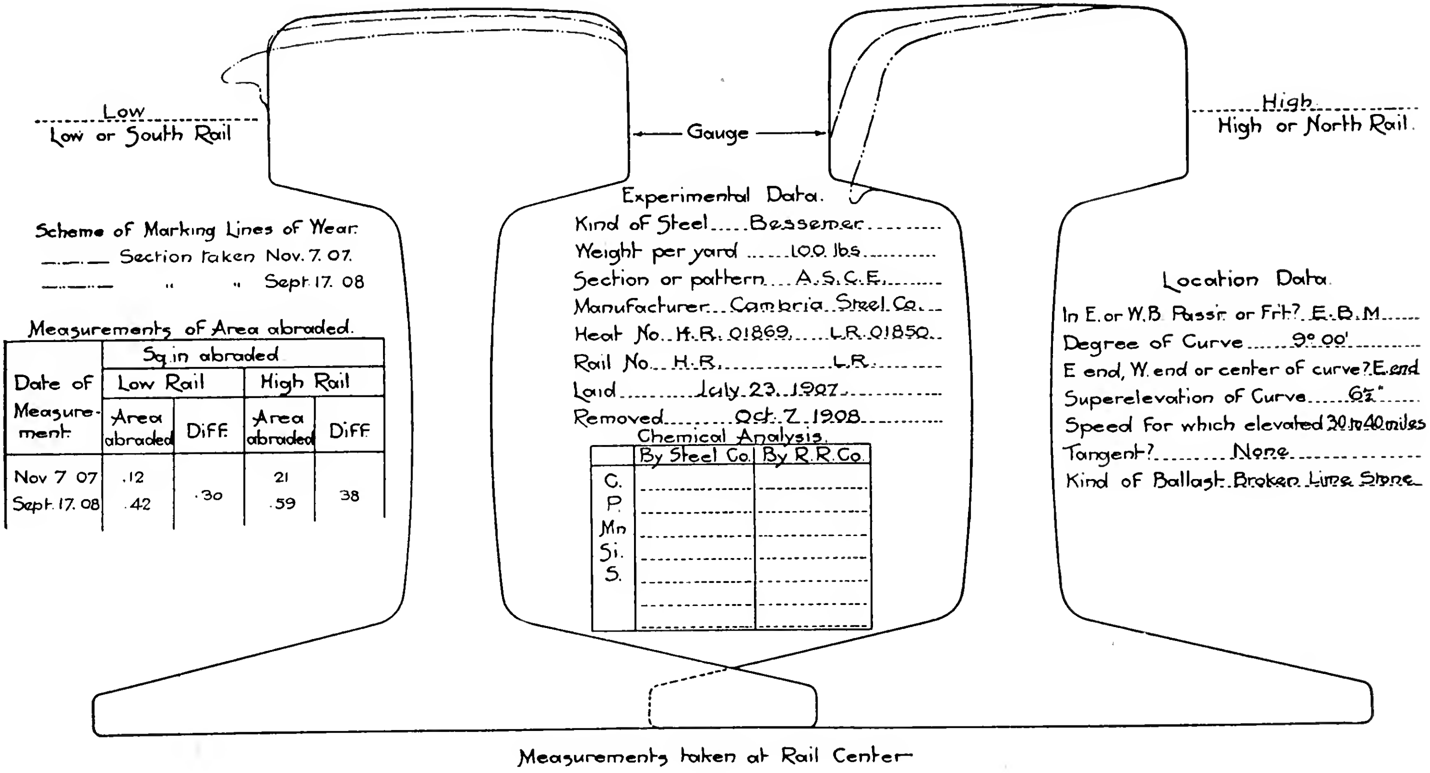
Superelevation of Curve...... 6½"......

Speed for which elevated 30 to 40 miles

Tangent?......... None...................

Kind of Ballast. Broken Lime Stone

Measurements taken at Rail Center



Scheme of Marking Lines of Wear.
—.—.— Section taken Nov. 7. 07.
——.—— " " Sept. 17. 08

Measurements of Area abraded.

Date of Measurement	Sq. in abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Nov 7 07	.12	.30	21	38
Sept. 17. 08	.42		.59	

Experimental Data.

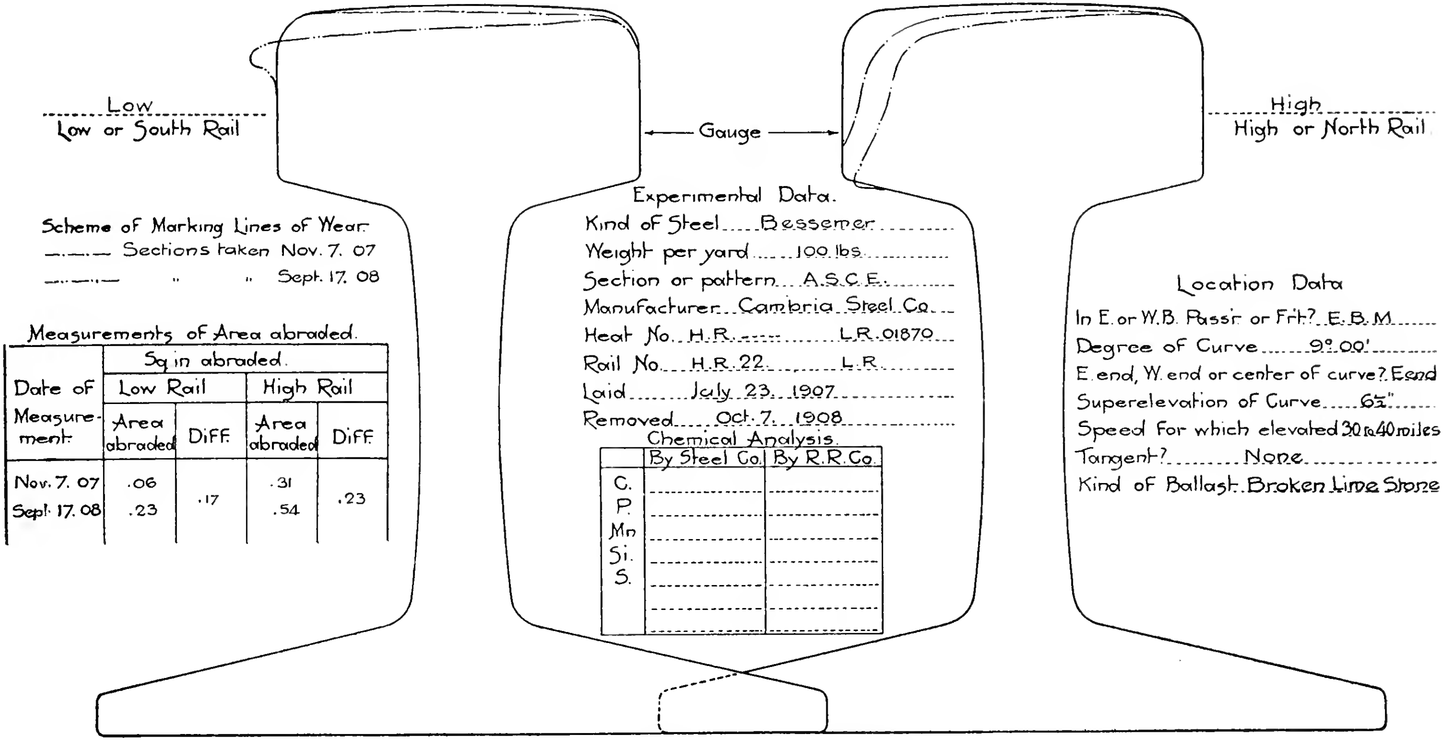
Kind of Steel.....Bessemer.........
Weight per yard......100 lbs...........
Section or pattern....A.S.C.E..........
Manufacturer...Cambria Steel Co...
Heat No..H.R. 01869......L.R. 01850..
Rail No...H.R..................L.R..........
Laid...........July 23. 1907................
Removed.........Oct. 7. 1908.................

Chemical Analysis.

	By Steel Co.	By R.R. Co.
C.		
P.		
Mn		
Si.		
S.		

Location Data.

In E. or W.B. Pass. or Frt.? E.B.M......
Degree of Curve.......9° 00'...........
E end, W. end or center of curve? E. end
Superelevation of Curve......6½".......
Speed for which elevated 30 to 40 miles
Tangent?..........None....................
Kind of Ballast..Broken Lime Stone



Scheme of Marking Lines of Wear.
—.—.— Sections taken Nov. 7. 07
—..—..— " " Sept. 17. 08

Measurements of Area abraded.

Date of Measurement	Sq in abraded.			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Nov. 7. 07 Sept. 17. 08	.06 .23	.17	.31 .54	.23

Experimental Data.

Kind of Steel.... Bessemer........

Weight per yard...... 100 lbs..........

Section or pattern... A.S.C.E..........

Manufacturer.. Cambria Steel Co...

Heat No.. H.R. ----............ L.R. 01870....

Rail No... H.R. 22........... L.R.............

Laid.......... July 23. 1907...............

Removed...... Oct. 7. 1908...............

Chemical Analysis.

	By Steel Co.	By R.R. Co.
C.		
P.		
Mn		
Si.		
S.		

Location Data

In E. or W.B. Passr. or Frt.? E.B.M........

Degree of Curve........ 9° 00'..........

E. end, W. end or center of curve? E. end

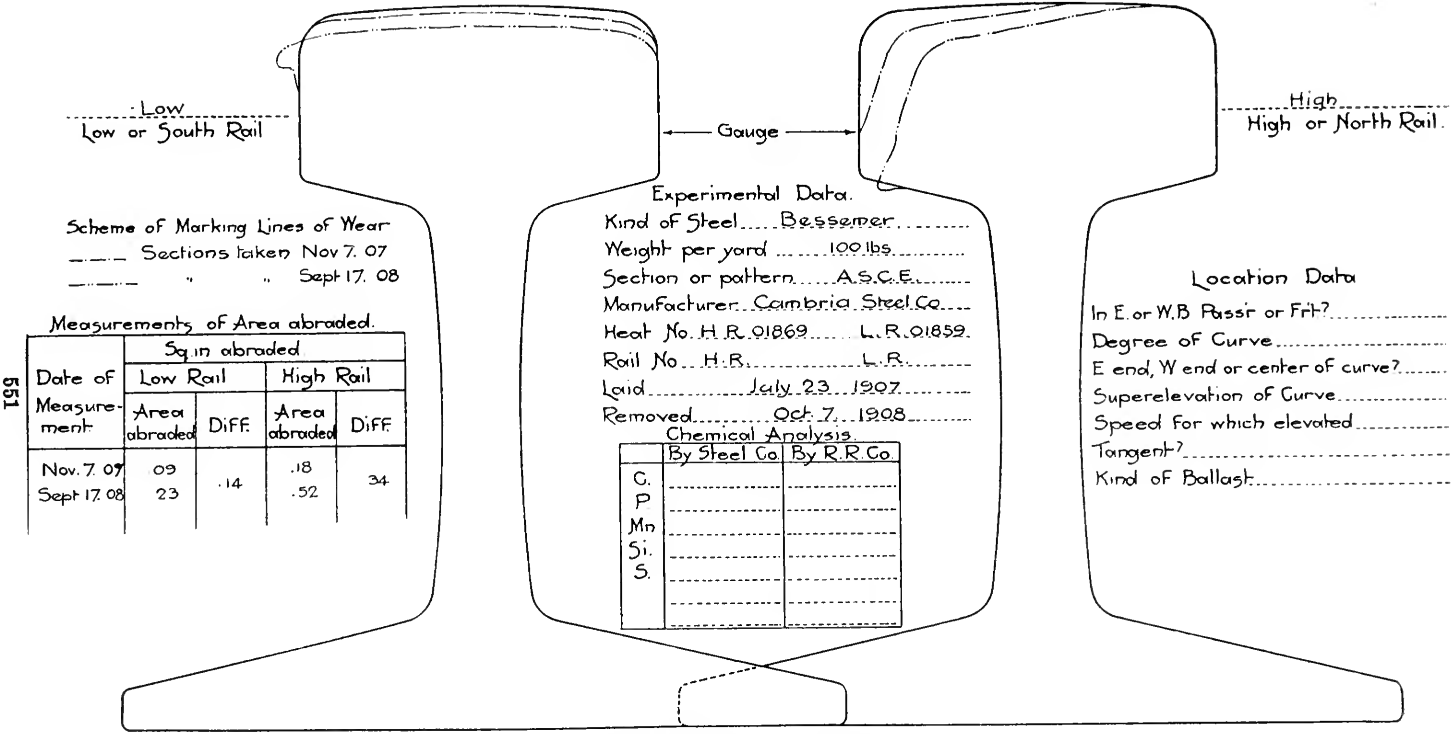
Superelevation of Curve...... 6½"........

Speed for which elevated 30 to 40 miles

Tangent?.......... None...........

Kind of Ballast. Broken Lime Stone

Measurements taken at Rail Center.



Scheme of Marking Lines of Wear
— - — Sections taken Nov 7. 07
— - - — " " Sept 17. 08

Measurements of Area abraded.

Date of Measurement	Sq. in abraded			
	Low Rail		High Rail	
	Area abraded	Diff.	Area abraded	Diff.
Nov. 7. 07	09	.14	.18	34
Sept 17. 08	23		.52	

Experimental Data.
Kind of Steel Bessemer
Weight per yard 100 lbs
Section or pattern A.S.C.E.
Manufacturer Cambria Steel Co.
Heat No. H.R. 01869 L.R. 01859.
Rail No. H.R. L.R.
Laid July 23 1907
Removed Oct. 7. 1908

Chemical Analysis.

	By Steel Co.	By R.R. Co.
C.		
P		
Mn		
Si.		
S.		

Location Data
In E. or W.B. Passr or Frt?
Degree of Curve
E end, W end or center of curve?
Superelevation of Curve
Speed for which elevated
Tangent?
Kind of Ballast

Measurements taken at Rail Center

Appendix I.

(Bulletin 111.)

RAIL FAILURES DUE TO BURNS AND CRYSTALLIZATION CAUSED BY SLIPPING OF ENGINE DRIVERS, BALTIMORE & OHIO RAILROAD.

By A. W. Thompson, Chief Engineer Maintenance of Way.

One of the less frequent causes of rail failures, and one concerning which there is very little published information, is that weakness in a rail due to the burning and crystallization of the metal by slipping of engine drivers. Undoubtedly this is deserving of more attention than it has been given in the past, as there are numerous instances on record of wrecks and derailments caused by broken rails of this class. The breaks are distinguished from other kinds and show very characteristic structure of the fracture. They occur in localities where there is unquestionably much slipping of the drivers, such as at points where an engine starts a train in pulling out from a station, and also in freight service at points where there may be a regular stop and back-up movement, as at a junction.

Such rails also might be found in yards where heavy cuts of cars are handled by a single switching engine. A probable cause for the scarcity of the latter class is the lighter weight of the switching engines in comparison with the weight of the usual road engine. The recent rapid advance in the loads on driving wheels of switching engines, particularly in the larger and better equipped yards, may result in more failed rails from this cause, especially in that part of the yard in which the push and pull method of operation may be used.

In the text of papers written upon other subjects allied to the rail question, casual mention has been quite often made of specific instances of rail which has failed from crystallization of the metal, but these discussions and records have never been isolated or carried to any definite conclusion concerning this particular subject. There must be records of this kind in the files of every railroad, and interest should be taken toward making these available to the American Railway Engineering and Maintenance of Way Association, and compiling them into comparative and intelligible form.

To furnish a beginning upon which to build, the following instances, taken from the experience of the Baltimore & Ohio Railroad, are compiled in concise form, these being selected because test of the physical and chemical properties was made of the broken rail in question. The first instance which has come to the writer's notice occurred at Salisbury Junction; a westbound passenger train, running at a speed of 40 miles per hour, being derailed while passing around a 6° 30′ curve.

This curve is to the right, with a grade descending at the rate of 1.25 feet per 100, both in the direction of traffic. At the time of the accident the temperature was 10 degrees above zero.

The rail causing the accident was 33 ft. long, A. S. C. E. section, 85 lbs. per yard, rolled by the Cambria Steel Company in 1905, and laid during August of the same year; thus showing a service of about two and one-half years.

The rail was in the low side of the curve, being jointed with a four-hole splice, and it broke into twelve pieces. The lengths of the pieces varied from 3 in. to 24 ft., most of which were over 1½ ft. long. The attached photographs show a view of these pieces with the exception of the end pieces, which remained in the splice. At two points the breaks were square, as if sawed, but in the other cases the breaks were slanting, each in different directions. This was the only rail damaged in the accident. Gage at point of accident was found to be 4 ft. 8⅞ in.; elevation of curve, 6¼ in.; both line and surface were good.

Microscopical tests of the rail later developed the fact that slight cracks existed in the base of the rail before the accident occurred, but these cracks were entirely too small to have been detected by even close examination with the eye before the rail became separated. The rail was inspected by track walker only a short time before the derailment took place.

The rail showed very little wear and the only marks which could be detected were those made by the slipping of the drivers of the engine. The frequency with which these marks occurred on this one rail was due to the fact that westbound freight engines stop nearly always in about this spot to back up and set off empties on the Salisbury Branch, and in considering the failure of this rail this point should be carefully borne in mind.

The pieces were not carried any distance, with the exception of the longer ones, and this condition would naturally lead to the conclusion that the breaks were caused by the downward pressure of the engine passing over the rail ends.

A chemical analysis of the rail showed the following:

	Chemical Analysis.	Specifications Called for.
Carbon	.48	.43 to .53
Sulphur	.77	....
Phosphorus	.108	Not to exceed .10
Manganese	1.10	.80

This analysis shows the composition to be rather high in phosphorus, with manganese closely approaching the upper allowable limit. While either one in themselves would not be a serious matter, the combination would tend to make a somewhat brittle rail, even though the phosphorus is no higher than is found in many good rails.

In making physical tests of this rail a weight of tup of 1,640 lbs. was used, this being the only drop available in the Test Bureau. Supports were placed 3 ft. apart, and when the test piece was placed in the machine with the head up the tup was allowed to fall 10 ft., and when the test piece was placed in the machine with the head down, the tup was allowed to fall 8 ft. It was the intention to so select the height of the drop that the number of blows would show a comparison of the different rails; that is, it was so arranged that the drop would not break a rail which had been in service and was not defective, while it might break a rail which was burnt. Under these conditions the following results were secured. These conditions do not conform to those usually specified, but other rails were tested under same conditions in direct comparison:

Rail Causing Derailment at Salisbury Junction.

	—Deflection in Inches—	
	Head Up in Supports 10-ft. Drop.	Head Down in Supports 8-ft. Drop.
1st Blow	.65	broke
2d Blow	1.20	......
3d Blow	1.80	......
4th Blow	2.25	......
5th Blow	2.75	......
6th Blow	broke	......

The rail placed with head up broke with fine crystalline fracture, near supports. Rail with head down broke near center, on first blow, with a fine crystalline fracture.

Rail of Maryland Steel Company Tested for Comparison With Above.

	—Deflection in Inches—	
	Head Up in Supports 10-ft. Drop.	Head Down in Supports 8-ft. Drop.
1st Blow	.61	.62
2d Blow	1.30	1.06
3d Blow	1.80	1.44
4th Blow	2.22	broke
5th Blow	2.72	......
6th Blow	3.25	......
7th Blow	broke	......

This rail was perfect so far as known, but had seen service in track. With head up the test piece broke near support with a fine crystalline fracture. With head down it broke near the center with similar surface appearance.

A further comparative test of rail of the Cambria Steel Company's manufacture showed the following:

	Head Down in Supports 8-ft. Drop.
1st Blow	.73
2d Blow	1.28
3d Blow	1.74
4th Blow	2.22
5th Blow	2.58
6th Blow	broke

This rail also broke near center with fine crystalline fracture. A common and noticeable feature of all these breaks is that with head up they break near supports, while with head down they break near the center, but the burnt rail broke under a much less number of blows whichever way it was placed, and with a very much less final deflection.

The second instance in which any extended test was made of the chemical and physical properties of the failed rail occurred at Shenandoah Junction, as a westbound passenger train was pulling out from the station. This rail broke into five pieces and had been, evidently, badly burnt by slipping of the drivers as the engine started the train up a quite heavy grade from the station. The brittleness of this rail was further indicated by its breaking at one point while it was being cut at another by the section foreman.

This rail was rolled by the Carnegie Steel Company in 1896, of A. S. C. E. section, 85 lbs. per yard. There was no surface indication of defect in the rail, and roadbed conditions were good and not contributary causes to this failure. Track was fully ballasted with stone and had good drainage, and the ties were in good condition and properly spaced. No undue strains were brought to bear on the rail by longer supports between ties or by any unusually flexible ballast.

The curve at this point was 4° 30′ and had an elevation of 3½ in., with gage ¾-in. wide at the point of failure, caused by wear of rail over the standard gage of 4 ft. 8½ in. on this degree of curvature. The grade was 0.75 per cent. ascending, westbound. The chemical analysis of this rail showed the following:

Rail Causing Derailment at Shenandoah Junction.

	Chemical Analysis.	Specifications Called for.
Carbon	.48	.43 to .53
Sulphur	.027	....
Phosphorus	.095	Not to exceed .10
Manganese	.76	.80

The chemical composition of this rail is apparently good, but microscopical examination showed small cracks in the head, which may have been produced by slipping of the drivers, since these surfaces of the metal at the crack showed the characteristic blue color due to heating.

The drop test of this rail, made under the same conditions as those above, showed the following:

	—Deflection in Inches—	
	Head Up in Supports 10-ft. Drop.	Head Down in Supports 8-ft. Drop.
1st Blow	.25	broke
2d Blow	1.90	......
3d Blow	2.50	......
4th Blow	3.35	......
5th Blow	4.10	......
6th Blow	broke	......

Again in this test do we find the break near the supports when the head was placed up, and at the center when the head was placed down, each with a fine crystalline fracture.

In making the above test with the head up, a piece one foot long was snapped off of the end of the test piece where it projected over the supports, the fracture of which showed about 60 per cent. of an old defect in the head and 40 per cent. in the web. The attached photograph of this section shows plainly the burnt and crystallized condition of the metal and the different color of the injured portion. It also discloses a small pipe near the base of the rail.

After the piece with head down had been tested, a further test was made of a piece of this same rail 10 in. in length, which was broken off with a sledge-hammer, and clearly showed a burnt spot in the head ¾-in. long by 5/16-in. deep.

A summary of these tests in tabular form follows:

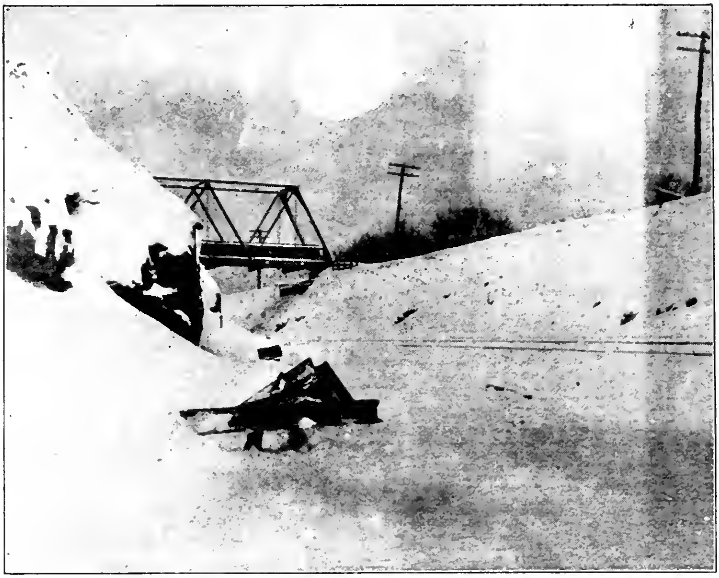
	Standard Rail after Service.				Rail Causing Shenandoah Jct. Wreck.		Rail Causing Salisbury Wreck.	
Manufacturer.......	Maryland Steel Company		Cambria Steel Company		Carnegie Steel Company.		Cambria Steel Company.	
Date rolled	July, 1905.		April, 1907.		July, 1896.		March, 1905.	
	No. of Blows	Fracture.	No. of Blows	Fracture.	No. of Blows	Fracture.	No. of Blows	Fracture.
Drop 10 ft. Head up.	7	Fine Crystalline near Support.			6	See Photograph.	6	Fine Crystalline near Support.
Drop 8 ft. Head down	4	Fine Crystalline at Center	6	Fine Crystalline near Center.	1	Near Center burnt spot.	1	Fine Crystalline near Center.

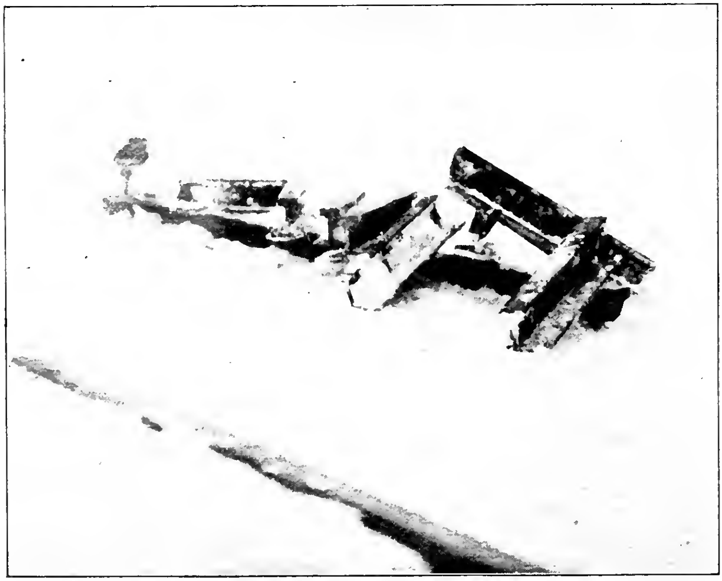
An examination of this table, keeping in mind the chemical analysis, indicates clearly the weakening effect due to the burn.

All these failures correspond in location and when the test pieces were turned with head down one blow broke such rails as were burned, whereas rails which had seen service in track, but were not defective, required four to six blows to cause a break. The burnt rail of the Carnegie Steel Company being of fair chemical composition, shows conclusively that failure was due to burns. There is a possibility that in the case of the Cambria Steel Company's rail the chemical composition had something to do with the failure, as the rail only showed a service in track of 2½ years. While both of these rails were marked with burns due to slipping, and in all probability failed from that cause, yet the term of service was so different, as well as other conditions, that no definite conclusions should be drawn from these two instances alone.

Such a failure as that at Salisbury Junction might have been the sooner induced because of the greater vibration and impact from the momentum of the passenger engines, with their higher speed, together with the blow from the reciprocating parts and the wheel balance, and in those tests made with the heads down, this very metal which has been burnt and weakened by crystallization is subjected to the greatest tensile stress. With the head up the same metal is on the compression side of the neutral axis, and under such conditions naturally would not fail as quickly, this being borne out by the records of the tests.

These rails were called upon to withstand heavy traffic, both freight and passenger, on curves and grades somewhat above the average, but these records are not complete or conclusive, and are interesting only as being specialized on failures due to a change in strength of metal from burning. Further records are needed, not alone to determine the effect upon the rail itself, but to tabulate the loss and damage in wreck from this particular cause, that the importance of this subject may be brought clearly to the attention of the officers of all roads, to the end that steps may be taken to prevent such practice in so far as it is possible.





VIEWS SHOWING PIECES OF RAIL WHICH BROKE AT SALISBURY JUNCTION.

Failed Rail (Carnegie) Rolled 7-96. From Wreck at Shenandoah Junction.

DISCUSSION.

(Vice-President L. C. Fritch in the chair.)

Vice-President Fritch:—The first order of business is the report of the Committee on Rail, which will be found in Bulletins 118 and 121 and the supplement to Bulletin 121, now being distributed. The Chairman of the Rail Committee will present the report.

Mr. Chas. S. Churchill, Chairman (Norfolk & Western):—The work of this Committee is outlined in Bulletin 118; we have endeavored to follow those instructions and make as much advance as possible, considering all the circumstances, as explained in this Bulletin. The only item of the work that we regard as completed is item 4, "Present report showing diagrams or photographs of typical characteristic rail failures." The first item is, "Consider Revision of Manual." We have, at the beginning of our conclusions, three changes in the Manual that I will refer to a little later. Instruction 2, "Continue the investigation of the breakage and failure of rails and present summary of conclusions drawn from reports received;" our progress report upon this is embodied in three Bulletins, Nos. 111, 116 and 121, to date. These are a collection of reports received from the different railroads in the United States compiled by Sub-committee C, Mr. W. C. Cushing, chairman; and a little later we will ask Mr. Cushing to explain some of those tabulated statements. In carrying out the work outlined we have not only had this Sub-committee C, but also the Sub-committee designated as Sub-committee A, with Mr. J. A. Atwood as chairman, which has had dealings with the Manufacturers' Committee and has had many interviews with them, and have dealt with them in making tests, and further has charge of the tests that have been conducted at the Watertown Arsenal and at the various mills. Sub-committee B, with Mr. J. B. Berry as chairman, has been looking into standard rail sections, and recommended changes in specifications. That, in brief, is the outline of the work and organization of the Committee.

As to what we have accomplished: I wish to state at the outset that we have endeavored to hold our meetings with the mill people at the various mills, just as stated in this Bulletin, and we have gotten around the country quite thoroughly, have talked with the superintendents and other officers of the mills and have invariably found them ready to co-operate, ready to assist and ready to make suggestions.

We believe that in this way we are arriving at harmonious conclusions, and those that we are presenting now are the result of getting together with the Manufacturers' Committee.

The photographs of failed rails which are published in Bulletin 116, pp. 6 to 66, we would like to have considered as a conclusion of that subject, excepting that some special cases which come up from time to time will be treated as such where they will give information. But as for making another special report on this subject, we think it unnecessary; and on that we wish to have the approval of the Association.

On the subject of specifications, our remarks are given at the bottom of page 11 and top of page 12: "A new specification should not be proposed at this time without careful consideration. So far as we know, no railway company has purchased rails under the specifications approved by the American Railway Association and referred to us; nor do we know of any railway company that has succeeded in buying rails during the past two years according to a specification entirely satisfactory to the railway company. We believe that all of the specifications under which rails have been rolled have been compromises on the part of both parties, with the general result that neither party is entirely satisfied. Our experience during the year has brought to our attention some defects in all of the specifications now before us; and acting under the impression that there is a distinct feeling that we should revise our specifications, we offer the attached specifications for your consideration."

In drawing up these specifications, we have had before us the important point, that we shall determine upon the quality of the rail not so much by prescribing details of manufacture as by establishing some tests that will determine whether the rail output is good or not. So from top of page 13, Bulletin 118, I quote one or two statements here: "We are of the opinion that the physical and chemical tests required should be prescribed, and that we should see that the material submitted for acceptance meets the prescribed tests. We should not dictate to the manufacturers the amount of crop which shall be removed from the top of the ingot, as this should vary with the care and time consumed at the various mills. The railroads should not be asked to take anything but sound material in their rails. The mills can furnish such sound material if the proper care and sufficient time are taken in the making of the ingots." We are, however, positive from our examinations at all these various mills that the tests to be inaugurated by the Committee, combined with the results of the tests at Watertown and the performance of the rail in the track, will give us valuable data to aid us in coming to a final conclusion.

Now as to conclusions: The results so far obtained from the heavy base American Railway Association sections are disappointing, as we have received some rails from the mills of the new section which were as bad as those from the old A. S. C. E. sections, showing that the quality of the rail does not depend upon the section. And you will note the following: "The small demand as indicated by mill sales data and the slight possible variation in section of rail below 75 lbs. weight per yard, makes inadvisable the consideration of new sections for this light weight rail." "No recommendation as to sections of 75 lbs. and over is made at this time, because of the lack of undisputed data upon which to base such design, the service value of the rail unquestionably being dependent upon chemical composition, furnace practice and mill practice, as well as upon the detailed differences of dimensions, and the exact effect of each of these various factors is largely in doubt."

Now with these brief remarks I wish to ask that the Association will act upon the conclusions in the order given. The Committee presents the conclusions on page 15, Bulletin 118, but before action is taken I want to refer to the photographs of the typical characteristic rail failures. We would like to have the Association approve of the publication of rail failures in Bulletin 116, and let us consider that our Committee has completed its work under that head.

Vice-President Fritch:—Unfortunately Bulletin 116 is out of print, and we are not able to distribute copies of it to the members at this meeting. The members have had copies of that Bulletin mailed to them. If there is no objection, we will adopt the Committee's recommendation and publish the data given in Bulletin 116 on typical rail failures.

Mr. Churchill:—Now, as to the conclusions, the Committee presents the following conclusions for your approval. Items 1 and 2 are simply verbal changes of what has been printed in the Manual, verbal changes descriptive of the drop test machine which has been heretofore adopted by this Association.

Paragraph 2 is to be amended as follows: Eliminate the last sentence and substitute the following: "Anvil to be guided in its vertical movement by removable finished wearing strips, these wearing strips to be suitably attached to the finished edges of the column base." That slight change is made in order to describe the machine more accurately.

Paragraph 5 is to be amended as follows: Insert the following after the word "castings" in the first sentence: "And the surface of the anvil between these pedestals shall be formed to receive a wooden block to absorb shock under broken test pieces." That is the practice of the mills to-day, and has been ever since the machine was put into use.

Paragraph 6 is to be amended as follows: In the first sentence substitute the words "column base" for "base plate." That is simply a correction in description.

Vice-President Fritch:—If there is no objection the Committee's recommendation with reference to item 1, making a change, in the specifications and plan for drop testing machine, will be adopted.

Mr. Churchill:—Item 2 is as follows: "That the specifications and plan for drop testing machine, as revised above, be printed in the Manual of Recommended Practice."

Vice-President Fritch:—If there is no objection, item 2, as just presented, will be adopted.

Mr. Churchill:—The third change in the Manual which we recommend is as follows: "That the present Specifications for Steel Rails be withdrawn from the Manual of Recommended Practice of the Association as no longer representing the current state of the art." No one is using these specifications now, and hence we think they should no longer be published in the Manual as recommended practice.

Vice-President Fritch:—If there is no objection, item 3, as just read by the chairman of the Committee, will be adopted. There is no objection, and the item is adopted.

Mr. Churchill:—Item 4 refers to the specifications for Bessemer and Open-Hearth Rails. The original specifications are printed on pp. 18 to 21 of Bulletin 118, and without reading No. 4, just at present, I presume we had better go to the specifications, but before we take up these specifications I wish to say that before this Bulletin was published in December we prepared them by holding several meetings, and the specifications printed in this Bulletin 118, we think, is a first step in a change from the specifications that have just now been withdrawn from the Manual; and our first step toward specifications makes the testing of the rails, after they are made a determining factor, as to whether they shall or shall not be accepted by the buyer. Those specifications as printed in this Bulletin were sent to the Manufacturers' Committee; and then as soon as possible thereafter we held a joint meeting with the Manufacturers' Committee and went through every item in these specifications. The meeting was a harmonious one and of good to both parties; both sides were very much pleased with the outcome of it. We obtained ideas from the Manufacturers' Committee and they stated they were very glad of the free discussion we gave, and the telling of our troubles; and as was stated at the beginning, they seemed ready to meet our views and do everything they could to bring about an improvement in the rails from their different mills. As the result of that meeting we had a later Committee meeting and made slight modifications of this specification contained in the Bulletin, and this little pamphlet form is the result; and it is this form of the specification that we would like to have taken up paragraph by paragraph, and discussed and acted upon under item 4 of our conclusions.

Vice-President Fritch:—We will take up the specifications by paragraphs. The Secretary will read them. If there is any discussion on any of these points, please speak promptly. This is a very interesting and valuable subject. Any member who has any suggestions to make is invited to present them.

(The Secretary read paragraphs 1 and 2 of the Specifications for Steel Rails.)

Mr. G. J. Ray (Delaware, Lackawanna & Western):—Mr. Chairman, in regard to item 2, the chairman of the Committee stated a moment ago that an effort should be made to secure a material which shall be in accordance with the chemical requirements of the prescribed test, and I think that should be done, if possible. It is now stated that chemical composition of steel from which the rails are rolled shall be within the following limits, etc.

It is a well-known fact that the rail which we get is vastly different in composition from the analysis of the test ingot. In taking this up with the manufacturer, I have found this difficulty. We have been endeavoring to get an open-hearth rail that would come within certain limits. It is the rail itself we run over, and not the test ingot. If our specifications are so worded that we are tied down to the chemical analysis of the test ingot, we cannot throw out the rails regardless of what the chemical composition of the rail is. The manufacturers tell you that they cannot guarantee anything in the rail, and that all they can do is to guarantee that the test ingot will be within certain chemical limits. I have found in actual practice one or two cases that under stringent inspection we were able to get open-hearth rails within certain limits; that is, the analysis taken on the rail itself. The point I make is that we should have something in the specifications to definitely limit the chemical composition of the rail itself. Of what good is it to have the specifications call for chemical analysis of an open-hearth rail with carbon between 67 and 80, and have the rail run up to 88, or below the lower limit? The specification plainly says it must be within the limit by analysis of the test ingot. I realize that you cannot test the rail before it is rolled. This test must be upon the ingot. You must test the ingot in order to tell how the rail is coming out; but I think we ought to have something in the specification which will guarantee to us within certain limits the composition of the rail itself.

In connection with this, the last paragraph of article 3 comes in. It has not been read, but states the percentage of carbon. "The percentage of carbon in an entire order of rails shall average as high as the mean percentage between the upper and lower limits." This part of the specifications (if you undertake to get a rail according to this specification) I presume would refer to the analysis of the ingot. If so, it should plainly state that, because you cannot tie yourself down to the analysis of the ingot in one place and state the analysis of the rail in another.

Mr. Jos. O. Osgood (Central Railroad of New Jersey) :—I wish to add a word to what Mr. Ray has said on the subject. We have found a great difference between the specification of the steel and what we actually got in the rail, and I would also ask why it is the limit of carbon of the rail has been placed as low as 76 as a maximum for a 100-lb. rail.

Mr. Churchill:—As to the first point, we do not find as much variation as the gentleman has mentioned. These reports that we have been receiving show rails that do come within these limits. On the other hand, if there is segregation of material or other defects in the rail, then we will find the chemical analysis will vary out of reason, and it is those defects we wish to detect by tests. We cannot stop the rolling mills to take analysis of individual rails, and I think the gentleman will concede that. We have a right to take those tests if we choose and the mill people have in the past, before these specifications were talked of even, taken rails back when complaints were made by the different railroad companies, after defects were found and the material did not come within the specification.

As to the second point, the amount of carbon in open-hearth rail, we have attempted to provide for that to some extent in article 3, that if the phosphorus runs low, then the carbon can be increased. Above the special amount (0.76) for open-hearth rail, for example, we think, from all our meetings with the manufacturers, this is about as high as we should go with safety for an open-hearth rail with 0.04 phosphorus. I want to call attention right here to the fact that we have divided these specifications into only two classes of chemistry. You all know that that has never been done before. We now have rails over 70 lbs. per yard and under 85, with one series of specifications for chemical analysis, and rails over 85 are given another. We think that entirely too much weight has been placed upon little variations in chemistry, and what we want more particularly is to find out what we are getting in the rails by testing the rails, just the same as we examine bridge material; we do not prescribe minutely the chemical contents of all the steel that goes into our bridges; there being only a few limiting features. We think that we can get rails the same way, if we can make proper tests on the finished product.

Mr. Ray:—I think we should include in our specifications a clause to the effect that the chemical analysis of the rail itself shall be within certain limits. If the manufacturer cannot guarantee our rail within a limit of thirteen points, which is given in this specification for carbon, he ought to guarantee it within fifteen points. There is certainly some limit which should be set in this matter. The point I make is this, that in your rail itself the carbon may vary from fifteen to eighteen or twenty points. I am not saying it cannot be rolled so that it does not vary to this extent, for I believe it can be rolled within that limit; but the fact remains that it is not. It is in certain rails, but careful analysis we have made on rails from one heat to another shows conclusively that the rail does not run within the limit which the test ingot was reported to run. As a matter of fact, in these tests we have found that the test ingot and the rail itself run reasonably close, so that if care is taken in the manufacture of the rail, the rail can be rolled within certain limits. I believe we should specifically set the limits in the rail itself. I realize you must have something to be governed by, and that can only be done by analysis of the test ingot. It is the rails that break in the track, and not the test ingots, and it is this wide variation which makes the trouble, and we have no protection whatever against the manufacturer. He may say that his test of the ingot is within the specification; and we may have the rail on the road and into track before tests are checked—I guarantee that the rails purchased by the majority of the companies are in the track before the analyses given them by the manufacturer are checked; that is the case with nearly every road in this country. The rails are used before the test analyses are checked up by their own chemists. My point is we should have something specifically stating the limit in the rail itself.

Vice-President Fritch:—Do you not think the Committee has endeavored to do that?

Mr. Ray:—No, they do not. They say that the chemical composition of the steel from which the rails are rolled shall be within the following limits. There is nothing in this specification from one end to the other which specifies the chemical analysis of the rolled rail. I guarantee if you take the specification to any manufacturer in the country, he will not guarantee to roll the rail and have it (the finished rail) in accord with the specifications covering the chemical composition of the steel.

Vice-President Fritch:—You refer to the entire contents, including carbon?

Mr. Ray:—The carbon, of course—some of the important features here are included; but it is the case with all the composition, and we should have something definite in the specification in regard to the rail itself and not altogether in regard to the test ingot.

Vice-President Fritch:—Covering not only the carbon, but the other chemical contents as well.

Mr. Ray:—I refer to the carbon distinctly, because by checking other things, getting your phosphorus down to where it belongs, you want the carbon at a certain point for the open-hearth rail. The lower you get the phosphorus the higher you can get the carbon.

Mr. Thomas H. Johnson (Pennsylvania Lines):—I do not think the last speaker has ever studied any of the well-known analyses of different compositions in the ingot. Whatever the chemistry of the different elements of the ingot may be, no two rails rolled from the same ingot will show the same analysis, neither will test pieces taken from different portions of a section of any one rail show the same analysis. To make a special provision covering the chemistry in the finished rail is simply an impossibility, and you could not carry it out.

Mr. Ray:—I know very well that no two rails of any one ingot will show the same analysis. I have had several hundred of them analyzed the last season, all sections and all parts of the rail, and I know that is true. The point I make is that there should be some limit within which the rolled rail should come, and if it cannot be within thirteen points, it should be within something else. I cannot see how you are going to decide on the analysis of the ingot, and let the rail go. You must analyze the rails, and if you do, you may find they are not anywhere near the chemical analysis of the ingot. If so, you have no comeback whatever on the manufacturer. It is care in the manufacturing of rails that will make better rails, and it is only care in the manufacture that will accomplish the objects we have in view. It is going to take more care to make the rails within certain limits, and that is what we ought to have.

Mr. W. C. Cushing (Pennsylvania Lines):—The Pennsylvania Lines West of Pittsburg this year are getting seventy-five thousand tons of rail, and we are having a regular check analysis of the ingot metal made after receiving the analysis of the metal from which the rails are rolled, from the mills, and have found that they check within reasonable limits.

We do not check the ingot analysis with an analysis of the rail steel, as it would be an impossibility for any mill to guarantee how close that is going to come, because we have to deal with segregation, and, in the present state of the art, segregation has not yet been fully controlled by the mill. We all find that occasionally. Except in the case of segregation there seems to be no difficulty in having the rail steel come within reasonable limits of the metal from which it is rolled, just as Mr. Johnson said. We therefore find no reason or necessity for putting any such clause in the specifications.

Mr. Wm. R. Webster (Consulting and Inspecting Engineer):—I would like to move that this clause 2 be accepted, and that the matter of additional requirements upon the finished rail be referred to the Committee to give us their opinion next year. It is a matter we cannot decide to-night, and it is useless to take up further time with it.

Vice-President Fritch:—It is moved and seconded that article 2 be accepted and that the Committee be instructed to give us further suggestions next year, if they consider it necessary.

Mr. Wm. R. Webster:—If they deem it advisable. I do not ask it, but leave it in the hands of the Committee.

Vice-President Fritch:—Are you ready for the question? All in favor of that resolution signify by saying Aye; contrary, No. The motion is carried.

(The Secretary read paragraph 3.)

Vice-President Fritch:—Any discussion on article 3? If not, it will be adopted.

(The Secretary read paragraph 4.)

Vice-President Fritch:—Any discussion on article 4? This is a very important subject, gentlemen; we should have a full and free discussion.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I would like to ask the Committee what the view of the manufacturers is with reference to that.

Mr. Churchill:—The manufacturers have agreed to that clause in this form, as to the wording, "The end of the bloom formed from the top of the ingot shall be sheared until the entire face shows sound metal." We discussed that fully with the manufacturers.

Vice-President Fritch:—Any further discussion on article 4? If not, it will be adopted.

(The Secretary read paragraph 5.)

Vice-President Fritch:—Is there any discussion on article 5? If not, it will be adopted.

(The Secretary read paragraphs 6 and 7, which were adopted as read.)

(The Secretary read paragraph 8.)

Mr. J. C. Nelson (Seaboard Air Line):—I would like to ask the chairman of the Committee why they decided on a 33-ft. length of rail? Why not 36 or 39? On some roads I understand they are using 39 ft., and perhaps longer.

Mr. Churchill:—There is a good deal of matter in these specifications that has not been changed, in this part especially; this clause is one of them. There is also in the American Railway Association records, which were turned over to us as a basis for our action, a similar provision. I might say that it is the longest length of rail we are sure can be loaded in cars. Certainly many cars are longer than that, but we are not always certain of getting long cars at mills. The real reason, however, is that 33 ft. for length of rail is the standard of this Association.

Vice-President Fritch:—Any further comment on section 8? If not, we will proceed.

(The Secretary read paragraph 9.)

Mr. John G. Sullivan (Canadian Pacific):—I would like to ask the Committee if they do not consider a rail with camber within the limits of 3 or 3½ in. in 33 ft. a better rail, less apt to be damaged in the gagging, and if they had any difficulty in the manufacturers agreeing to give them such a rail? We are getting rails under such specifications in Canada.

Mr. Churchill:—I believe that we will be able to get rail that cools straight within 3½ in. from a great many mills. But that is not true in all mills; and many mills say they cannot do it at the present time. It is to the interests of the millmen themselves to get this ordinate as low as they can; and we have made the difference 4 in. for one type of rail and 5 for the other, because the thin base rail will cool less straight than the thick base rail, and we are very certain that all mills will come well within these figures. We hardly think it is to the advantage of the purchaser to put in the hands of the inspector such a small detail as a half-inch or an inch variation from a straight line as a basis for condemning a rail in view of all of these facts.

Vice-President Fritch:—Any further discussion on article 9? If not, we will proceed to 10.

(The Secretary read paragraph 10.)

Vice-President Fritch:—There is no change in this article from the old specification. If there is no objection, we will proceed.

(The Secretary read paragraph 11.)

Vice-President Fritch:—Any remarks on section 11? If not, we will proceed to 12 (a).

(The Secretary read paragraph 12 (a).)

Vice-President Fritch:—Any discussion on drop testing?

Mr. John G. Sullivan:—The Committee has made a distinction in the chemistry of the rail between the Bessemer and the open-hearth, but I note they make no distinction in the drop test. We are getting out some rails at present, and we have a rather rigid drop test. The mills are not complaining about the test on the open-hearth, but they are complaining about the drop test on the Bessemer, although we make a difference of two ft. in the height of drop.

There is one other point I note the Committee has not touched. I presume it is conceded that the drop test is a mechanical method of checking the chemistry, as it were. If the chemistry is correct there would probably be no necessity for the drop test. The point that a gentleman brought out about the chemistry of the rail, I think, might be practically covered so far as the physical test could be made by putting limits in the deflection that you would get in the drop test. We are doing that at present, that is, putting a minimum and maximum limit to which the rail would deflect under drop. If you have such limits, it seems to me you are getting a test on the hardness of your rail.

Mr. Churchill:—The Committee intends doing that. In section B, as you will see, "it is proposed to prescribe under this paragraph the requirements in regard to deflection, fixing maximum and minimum limits, as soon as proper deflection limits have been decided upon.

Mr. John G. Sullivan:—What we are depending upon for our hardness is, for instance, if your rail does not break under the drop test, but deflects 5 or 6 in. in the space of three or four ft., whichever your distance between supports may be, it would be deemed as being a rail too soft. If, however, on the other hand, the deflection was only one inch, that would be an indication that the rail was too hard.

Mr. Churchill:—That is just exactly the object of our Committee. We do not have enough information before us to determine proper figures. We have a very good idea of what those figures should be, but we prefer not to put them in the specifications now, just as you say.

Vice-President Fritch:—The Committee would be glad to have any suggestions from the members on that question. Are there any further remarks on section 12? If not, we will proceed to section 13.

(The Secretary read section 13, including paragraphs (b), (c), (d).)

Vice-President Fritch:—Section 13 is open for discussion. If there is no objection, we will pass to 14.

(The Secretary read section 14.)

Vice-President Fritch:—These have already been adopted by the Association. If there is no objection, we will proceed.

(The Secretary read section 15.)

Mr. W. H. Courtenay (Louisville & Nashville):—I would like to inquire why the word "injurious" is used there.

Mr. Churchill:—We think defects such as small bends while on cars would not be injurious or make rails defective for use on track. On the other hand, if the defects are of a larger character, a bad deep nick, or any defect whatever—we made this very sweeping—or any defect whatever discovered by the inspector, or a flaw of any kind that will render the rail unsafe, it is to be rejected.

Mr. Courtenay:—It might be a flaw, only an eighth of an inch deep, and the question might arise whether that is an injurious flaw or defect. On the other hand, that flaw might be a quarter or three-quarters of an inch deep.

Mr. Churchill:—That we must leave, I think, to our inspectors. One class of specifications describes how deep a nick or flaw shall be to be rejected. This Committee thought best not to go into such detail. We think we have inspectors that are around mills constantly who are able to decide those questions at the mill, and rather than prescribe that a flaw an eighth of an inch deep is not sufficient to reject a rail, whereas a flaw a quarter of an inch deep is sufficient to reject a rail, we leave that to the inspector. The same flaw an eighth of an inch deep would be injurious in certain places. On the other hand, a quarter of an inch flaw in certain places might not be injurious.

Mr. Courtenay:—The point is, when a slight defect is in the rail, due to pipe or air bubble, whether such a rail is to be accepted or not.

Vice-President Fritch:—It is to be rejected.

Mr. Courtenay:—It strikes me in this specification, on account of slight flaws due to air bubbles in the ingot, and apparently running in one-eighth of an inch (that description of flaw varies from nothing at all to a very grave defect), it would materially strengthen the specification if that word "injurious" were eliminated.

Vice-President Fritch:—Would you eliminate it entirely?

Mr. Courtenay:—I would that word "injurious."

Mr. Thos. H. Johnson:—I think the gentleman wholly misapprehends the meaning of that particular sentence. That relates to superficial defects—defects due to an air bubble or "pipe" are interior and never show on the surface. Now, as to the surface defects, they are defects which occur as the rail goes through the roll. They may be due to a fold which makes a fault in the surface, similar to a nick. It does not matter whether it is one-eighth-inch or one-half-inch deep, it is equally dangerous. It may be due to a piece of cinder adhering to the roll, which merely makes a deficiency in the contour of the rail, which is harmless. It is that type of defect which that paragraph covers.

Mr. Courtenay:—Twenty-six years ago I inspected many rails at the mills. That species of flaw which begins at the outer corner of the rail head and runs in will vary from nothing—from a condition in which it is hardly discernible—until it becomes a very great defect. At that time it was a question with me, as an inspector, when these flaws were extremely slight, whether I should reject the rails, or whether they should only be rejected when the flaws became somewhat greater, and there was a difference of opinion between myself and the mill authorities at that time; we still get rails occasionally, which are accepted by our inspectors as first quality rails, that have these very slight flaws, and it is a question whether the inspector overlooked the slight flaws or knowingly passed them. I am of the opinion that a rail with a very slight flaw of that character is much more liable to break than a rail with no visible flaw whatever, and it would seem to me that a flaw of that type should be sufficient to reject the rail even though it may be very small. For that reason I make the inquiry about the word "injurious," whether it is the opinion of the Committee that these extremely slight flaws, when of the same general character that sometimes run one-quarter inch, one-half inch or three-quarter inch from the gage edge of the rail, should be sufficient cause for condemning the rail—whether a very slight flaw of that character is sufficient cause for throwing a rail into the second quality class.

Vice-President Fritch:—It says "injurious defects."

Mr. Courtenay:—Who is to decide whether a defect is injurious or not?

Vice-President Fritch:—That must be left to the inspector. In your inspection of the rail you speak of, if you found a flaw which was injurious to the rail, would you have accepted the rail?

Mr. Courtenay:—Yes; the custom at that time was to pass a flaw of greater depth in the base of the rail than in the head, and the point was the subject of argument at that time between the mill superintendent and the inspector.

Vice-President Fritch:—If you eliminate the word "injurious,' then a rail must not have any defect or flaw of any kind on the surface.

Mr. Courtenay:—I would not call a mechanical dent in the head of the rail a defect at all. Neither would I call a scratch on the head of the rail a defect, due to the fact that while the rail was hot, it got a little askew with the guide of the rolls and got scraped.

Vice-President Fritch:—That is what the Committee intends to cover. It does not refer to any interior imperfections, but imperfections on the surface only.

Mr. Courtenay:—The point seems of some importance, because it strikes me that with this specification you might have a flaw, and although its outward appearance on the rail may seem to be very unimportant, it is of the same general character and induced by the same causes as interior flaws.

Vice-President Fritch:—Can you prepare a clause to specify the different defects?

Mr. Courtenay:—It seems to me entirely practicable to eliminate the word "injurious."

Vice-President Fritch:—Then, no matter if the defect were of no consequence, it would reject that rail as No. 1.

Mr. Courtenay:—I would not include mechanical indentations; that is not a flaw.

Vice-President Fritch:—Have you something to suggest in lieu of article 15 as it reads?

Mr. Courtenay:—My suggestion was simply to make it read: "No. 1 rails shall be free from defects and flaws of all kinds."

Mr. J. P. Snow (Boston & Maine):—It seems to me the way in which this clause is written covers the gentleman's case exactly. If he discovers these very slight flaws he speaks of and considers them injurious, as he says he does, and he thinks the rail would be liable to break at that point, it certainly then becomes an injurious flaw in his judgment, and he has a right to reject it. If we leave that out and make it free from all defects, then he has to throw out the rail if there is the slightest indentation, which he says does not hurt it any. I think it is better to leave it as it is.

Prof. C. Frank Allen (Massachusetts Institute of Technology):—It says that rails shall be free from injurious defects and flaws of all kinds. In case the inspector thinks the defects are injurious and the representative of the rolling mill thinks they are not injurious, should there not be some statement in this clause as to whose decision shall govern it?

Vice-President Fritch:—The inspector should be the umpire in that case.

Prof. Allen:—Should not the clause so state?

Mr. Wm. R. Webster:—In regard to the point raised by Professor Allen, the inspectors as a general thing take care of that matter individually. I think that is a point that the Committee might take under consideration and express their views upon at the next meeting. I do not think it is right to ask the Committee to change any part of their specification unless they want to do so willingly, and therefore I move that the clause as it now reads be accepted, and that they give us their views as to the different classes of flaws, if they have any remarks to make, next year.

Vice-President Fritch:—Is there a second to Mr. Courtenay's motion?

Mr. Courtenay:—I beg to say I did not make a motion—I was merely making a suggestion. I did not intend that as a motion at all.

Vice-President Fritch:—Will the Committee accept Mr. Webster's suggestion to accept the clause and give a further report on it next year?

Mr. Churchill:—We will consider that next year.

Mr. Wm. R. Webster:—That thing has been threshed out over and over again. The Committee have given a good clause here, and if they have anything further to add to it, let them do it next year, but accept the clause as it now stands.

Vice-President Fritch:—The Committee accepts the suggestion.

(The Secretary read paragraph 16.)

Mr. L. A. Downs (Illinois Central):—Nothing is said about loading, except that they shall be loaded in the presence of an inspector. I have known of mills damaging rails while loading them in coal cars, and the rails have been kinked after they have been loaded in the car. I think it would be well to have something in the specification on that point, and it should be specified who is responsible for the loading.

Mr. Churchill:—It seems the fact that they are loaded in the presence of an inspector makes him responsible for their correct loading. That is the object of the reading.

Mr. L. A. Downs:—I do not know whether that would cover it. It does not define what he shall do if they are not loaded properly.

Vice-President Fritch:—Is not that under the control of the inspector if done in his presence, and should not he be responsible for the proper loading?

Mr. L. A. Downs:—No; under these specifications it simply says: "All rails shall be loaded in the presence of the inspector."

Vice-President Fritch:—It is assumed it would be under his control.

Mr. Churchill:—That is our understanding of the reading. We think when we put an inspector on the ground and tell him he must see these rails properly loaded and shipped correctly, he is responsible.

Mr. Downs:—I think it would be wise to make it broader—to make it read "carefully loaded," and not thrown on the cars. I have seen rails loaded at the mill which were injured and kinked after they have been loaded on the cars, because of their not being loaded properly. I think the clause can be made broader and do a great deal of good.

Mr. Churchill:—We have endeavored to make the wording precise and brief right through, and we believe that clause will do the work and get the results.

Mr. C. H. Stein (Central Railroad of New Jersey):—I notice that it specifies that No. 2 rails should have two prick marks on the side of the web, near the heat number near the end of the rail, so placed as not to be covered by the splice bars. It seems to me that the use of the words "near the end of the rail" are unnecessary, because the heat number is not always near the end of the rail. I have seen cases where it was right in the center of the rail. In fact, some mills put the heat numbers at both ends of the rail, and some put them in the center, and I think these words, "near the end of the rail," should be left out.

Mr. Wm. R. Webster:—I think it is very essential to leave those points in. It is very important sometimes to look for them; very often.

Mr. Stein:—That does not just cover the point I made. I agree that the prick punches should not be covered up, but the heat number, instead of being at two places on the rail, at the end, is sometimes at the center of the rail.

Mr. Wm. R. Webster:—Sometimes in two places?

Mr. Stein:—Sometimes in two places, sometimes only in one. I looked over 2,000 tons of rail last week, and in every case the heat number was in the center of the rail. This specification would not fill that requirement, because you would not find the prick punches near the end of the rail. I think to simply state, near the heat number, would be sufficient, and these prick punches would not be near the end of the rail.

Vice-President Fritch:—You would allow the last words of that clause to remain?

Mr. Stein:—Yes, undoubtedly. Leave out, "near the end of the rail," because they would be near the center of the rail. I know in hunting for the rail letter, a great many manufacturers put it near the end of the rail, so that it is not covered up by the splice bars. Others will put it behind the heat number, others will put it in front of the heat numbers. I think this covers the thing succinctly. I hunted for the heat number and rail letter near the end in several thousands of tons of rail and could not find it there, so I do not think we ought to state it is near the end of the rail.

Mr. Thos. H. Johnson:—I would like to ask the last speaker what mills those rails were from. The Committee, in all the mills we have visited, have not seen heat numbers applied in such way as would produce that result. They either have a rotating wheel which repeats the mark at every circumference of the wheel, or they have the mark controlled by a man in attendance, who drops it on the rail at the first end and again at the last end. We have not seen any mill that followed the practice of marking the heat number in the middle of the rail.

Prof. Allen:—In relation to one of the objections made, that all rails shall be loaded in the presence of the inspector, would there be any objection to adding to that, "and to his satisfaction," so as to read "all rails shall be loaded in the presence of the inspector and to his satisfaction." Then it definitely and succinctly states what I think the Committee is trying to reach.

Vice-President Fritch:—Mr. Stein, do you wish to make a motion?

Mr. Stein:—I will simply answer the question of one of the preceding speakers. It is stated that the Committee visited four different mills. Now, in examining quite a number of tons of rail from one of those mills, I never saw the heat number missed in a single instance. There was not a single instance in which that heat number was not at the two ends of the rails. In the case of two of the other mills specified here, I found heat numbers in the center of the rail; in the case

I particularly referred to, I found it invariably at the center of the rail, and in a great many of the rails I examined—2,000 tons—I did not find it in a single case anywhere but at the center of the rail, and one of the mills was visited by the Committee.

Mr. Thos. H. Johnson:—Which mill?

Mr. Stein:—I will tell you privately; I would not like to state it publicly.

Mr. Churchill:—I will state, in answer to the gentleman, under the head of "branding," we expect to get better results in marking the rails than ever before. Sub-committee A have that up with the manufacturers now, this matter of getting all the mills to be more systematic in branding, and we think that article 11, taken in connection with this one, will secure the result; the marks for heat numbers to be placed at the branding point nearest to the end of the rail, and, therefore, easiest to find. Prof. Allen, we will take that up, as passed by the Association. The question as to the satisfaction of the inspector we can take up next year; that is the intent of the wording really, in the presence of the inspector, and, therefore, must be to the satisfaction of all.

Prof. Allen:—It occurs to me to be desirable in specifications and in all documents, if you do so without serious difficulty, to say distinctly what you mean, and I would like, in addition to that, to suggest a similar reading, if it is allowable for me to suggest it at this time; so that No. 15 shall read that "it shall be free from injurious defects and flaws of all kinds, to the satisfaction of the inspector." That makes it absolutely definite, and there is no question as to who shall determine the injurious quality of the defect. It makes it absolutely definite, and to that extent better.

Vice-President Fritch:—The Committee feels that adding a word of that kind is superfluous; that these specifications are supposed to be to the satisfaction of the user, or they would not be drawn. The Committee feels that it is unnecessary to add such words.

Mr. Courtenay:—Merely as a matter of information, I beg to say that the Louisville & Nashville road have had a great deal of trouble getting its rails loaded properly. They dump them over the side of the car and let them fall any way they may. We have complained bitterly about that, and the mills have given a variety of excuses why they could not load properly. Instead of having one rail laid head up and the next head down, we have frequently had them thrown in promiscuously. We have complained to the inspector and the mill both.

Mr. Cushing:—I think I can offer some explanation of trouble of that kind. The same thing happened in our case, and in making investigation at the mill we found that the improper loading always occurred in the case of cars that were too short. They were cars that the rail almost entirely filled up. There was scarcely any margin of length between the end of the rail and the car, and the mills showed to us conclusively that they could not load the rail in cars of that kind in the way that the railroad companies wanted, but when the cars furnished were of sufficient length, with a foot or two margin between the ends of rail and car, the men were able to get in and load them properly; and I think you will find all mills are willing to do the same thing without having anything said about it in the specifications.

Mr. Robert Trimble (Pennsylvania Lines):—In connection with loading of rails, a recent investigation of ours showed that nearly all the mills are putting in improved loading devices, so that even with short cars they will be able to load the rails properly.

Mr. Wm. R. Webster:—I would like to ask some of the speakers who have expressed themselves about extra care that should be taken in loading the rails, if they will say what care shall be taken in unloading the rails, so as to avoid injury. If you will add that, I will move that those sections be adopted.

Vice-President Fritch:—I think Mr. Webster has touched a sore spot.

(The Secretary read section 17-a; also paragraph b.)

Vice-President Fritch:—Section 17 is open for discussion.

Mr. John G. Sullivan:—I do not want to be too persistent, but if I am not out of order I would refer again to the limits of the drop test, and as the Committee has expressed a willingness to take that up I would like to have them say they will take up the question of defining the limits in the drop test.

Mr. Churchill:—The Committee have made a footnote that we are going to do that.

Mr. John G. Sullivan:—There are no free schools where I am from, and I did not notice that.

Mr. L. A. Downs:—Mr. Chairman, I would like to bring up one more matter in reference to section 15, about the loading of rails.

Vice-President Fritch:—We will hear you.

Mr. L. A. Downs:—I want to make a motion to the effect that the last paragraph in section 15, the last sentence, be changed to read, "All rails shall be loaded in the presence of the inspector, and in such a way that they shall not be bent."

Vice-President Fritch:—The motion is not seconded. The question is on the adoption of article 4, not the adoption of the specifications.

(Upon vote, article 4 was then adopted. The Secretary then read conclusion No. 5.)

Vice-President Fritch:—Mr. Cushing will make some remarks about this conclusion.

Mr. Cushing:—Your Association authorized the preparation of rail failure statistics in 1908, and the first statistics under that authority were collected as of October 31, 1908, for the six months ending at that period. An effort was made to tabulate the results and have them included in sufficient time for the action of the Association at the tenth annual convention of 1909, but it has been found that it takes a longer time than was anticipated for receiving and tabulating and digesting these statistics, and the result was that they were not printed in time for action at the last convention and appeared in Bulletin 111 after the convention. They had hardly been disposed of when it came time to collect the six months' statistics for April 30, 1909. The circulars were sent out and the information came in in about the same way, taking a much longer time than was originally figured on as being required for their preparation. Those statistics were finally published in Bulletin 116. They had hardly been disposed of when it came time to prepare for the statistics of October 31, 1909, and the Committee determined that they would make an effort to have those results tabulated and furnished for the convention this year. That has been done in Bulletin 121, but it was the last Bulletin that was issued for this convention, and it was found that we were obliged to begin this tabulation on January 1st. The result was that a large number of reports from the railroad companies were not received between October 31st and January 1st, but continued coming in till the last day of February, so that quite a number of important reports were left out and not included in this tabulation.

The preparation of these statistics is very laborious, and it seems really unnecessary to have more than one report a year, and for that reason the Committee makes this recommendation. I will have some additional remarks to make after the Association acts on that recommendation. The request is made because the work is too great; it takes longer than was anticipated to do it; it takes at least five months instead of three as originally anticipated; and therefore it is unnecessary to attempt to do it every six months.

Vice-President Fritch:—Is there any discussion on conclusion 5? If not, all those in favor of the adoption of conclusion 5 as submitted by the Committee, will signify it by saying aye; contrary, no. The conclusion is adopted.

Mr. Cushing:—The plan of the Committee is that hereafter the date will remain the same, October 31st, but that some time will be taken for receiving and collecting and digesting the reports, and that no attempt will be made to have those statistics printed in a Bulletin before the convention; they will follow shortly after the convention, and be ready for the Proceedings; and if the Association desires to act formally on the statistics it will be done by letter-ballot instead of on the floor of the convention as at present, as there is usually little to discuss in them on the floor; they are rather for the purpose of study and written discussion more at one's leisure. We would like to have that plan approved by the Association, instead of our attempting to rush them through and omitting a lot of valuable reports in order to get them out in time.

The first two sets of reports to which I referred, that were published, did not contain very many remarks in regard to them, but as the statistics have become a little more perfect, we have given some thoughts obtained from a study of the last collection on page 10. It is not the intention to act on these thoughts, but just to call your attention to them and give you an idea of what we think these statistics accomplish.

Unless they bring out something else hereafter, that seems to be the most we can get out of them. They have been not only tabulated, but diagrams have been made with the object of making the comparisons which I have mentioned. But in looking through those diagrams you won't be able to tell whether heavy base rails are better than light base rails or whether high section rails are better than low section rails. It is due largely to the conditions I have mentioned (given on p. 10 of Bulletin 121), and from the fact that the periods of the rails in the track are different. It is well shown by these diagrams that most of the rail failures occur in the first four years of the life of the rail, but the periods of failure being different, the comparisons are not on the same basis. Rail which has been in a long time, and consequently produces a diminished number of failures, is compared with new rail, which may be giving many failures.

Now, then, the Association is requested to approve of a change in a few of the forms which have been used for collecting rail failure statistics, because in making these up we have found changes desirable, and as this is the time for printing the Manual, we would like to have them as complete as possible before they go in. This information is given on page 11, Bulletin 121. The main change is in Form 2004-A: "Summary of Steel Rail Failures." It is desired to change the unit for comparison from percentage as heretofore in the blanks to number of failures from 10,000 tons of new rail laid. The same unit will then be used for the diagrams and for the tabulated statement. At the present time, two units are used, one for the diagram and one for the general statement. Our experience leads us to believe that the diagram unit is the preferable, and that is the object in requesting the change in these forms.

The changes in Forms 2004-B and 2004-C naturally follow from those in 2004-A; I think if one is approved, the others should be also.

The change in the laboratory report is simply a correction in the headings, introducing the words "per square inch" omitted in the former report. That is 2003-A. The only remaining change is in 2004-D, "Position in ingot of steel rail." All of these are shown in the Bulletin referred to, and the latter simply omits the printing of the mill name, and has a space added for the "Kind of Steel."

Vice-President Fritch:—It has been moved and seconded that the conclusions on the bottom of page 11, Bulletin 121, recommending changes in these forms be approved. All in favor of that motion will signify it by saying aye; contrary, no. The motion is carried.

Mr. C. E. Lindsay (New York Central & Hudson River):—I would like to ask why the Committee rejected the suggestion to print in Form 2002-A the gage line, reference to the gage line, so that you could show on the sketch the relation of the break to the gage line.

Mr. Cushing:—I do not know that I ever heard of that.

Mr. Lindsay:—It was offered at the last meeting, and the Committee said they would consider it.

Mr. Cushing:—I do not know that I ever heard of it, Mr. Lindsay. It is one on us if it was, because nobody seems to have a note of it.

Mr. Lindsay:—I think you will find it in the 1909 Proceedings.

Mr. Cushing:—Are you referring to the Track Foreman's report?

Mr. Lindsay:—I am referring to Track Foreman's report, but I have not a copy.

Mr. Cushing:—The Committee does not remember of having had that given to it and they have had no note about it, and have not even considered it.

Mr. Lindsay:—I would like to renew the suggestion.

Mr. Cushing:—Will you send us a letter stating your idea precisely?

Mr. Lindsay:—Yes.

Mr. Churchill:—Now the only other matter the Committee want to present is a little explanation of what we are doing and propose to continue toward reaching conclusions, both as to specifications in the future and the rail section, and Mr. Atwood, Chairman of the Committee, will explain what we have in hand.

Mr. J. A. Atwood (Pittsburg & Lake Erie):—Mr. Churchill refers to the tests which Sub-committee A have been asked to inaugurate. Arrangements have been made with the manufacturers for the manufacturing of a certain number of rails by the Cambria Steel Company, Lackawanna Steel Company, Maryland Steel Company, United States Steel Company, Pennsylvania Steel Company, Bethlehem, and other plants of the United States Steel Company—some open-hearth rail, some Bessemer rail. These rails are to be tested chemically, physically, and possibly on the revolving machine of the Pennsylvania Steel Company, and on a machine which the Maryland Steel Company have built for testing the crushing ability—the ability of a rail to resist crushing. These rails will also be tested in the track test, and a certain number of them will also be tested in service. This series of tests will take a long time, and we will hardly be able to get results which can be of service—we possibly may have some results to present at the meeting next year. We have engaged Mr. M. H. Wickhorst, of the Chicago, Burlington & Quincy, to assist us in this respect in looking after these tests. He will give his personal attention to the making of these tests and to the guiding and directing of the Committee and assisting the Committee in every way he can.

We have made, as you all know by reading the Bulletin, several tests of rail joints at the Watertown Arsenal. The result of those tests have been tabulated and will be presented in a Bulletin to be published shortly. Drop tests which have been made at the Maryland Steel Company mill have already been printed in Bulletins. That covers I believe in a general way the actual tests which Sub-committee A has had under way. We of course expect to develop information as we go along and be guided by the information which we shall get, and we trust that the Association will have patience in the hope that we shall be able to produce some results which will be of lasting benefit.

Mr. Churchill:—In conclusion, all I have to add is that I do not want to have the Association think that we have agreed in every little detail with the Manufacturers' Committee, but we have gotten together as closely as we can, and we have obtained substantial agreements on the greater part of these specifications. One point, for example, is the drop test difference, and in order that you may understand that, the manufacturers have published their specifications with a drop test of 16 ft., the same as ours, for a 70-lb. rail, 17 ft., however, for 80 to 90-lb. rail, whereas ours is 19; 18 for 100-lb. rail, where ours is 20. And we do not wish to make this change to theirs until we make a further study as to the effect by measuring elongations during the drop tests, and we hope to have some results for the next convention.

Mr. Lincoln Bush (Consulting Engineer):—This Committee on Rail has done a very large amount of hard work, thorough investigation and careful study of the subject, with very satisfactory results, and I therefore move that a vote of thanks of this Association be tendered them for their very good and satisfactory work.

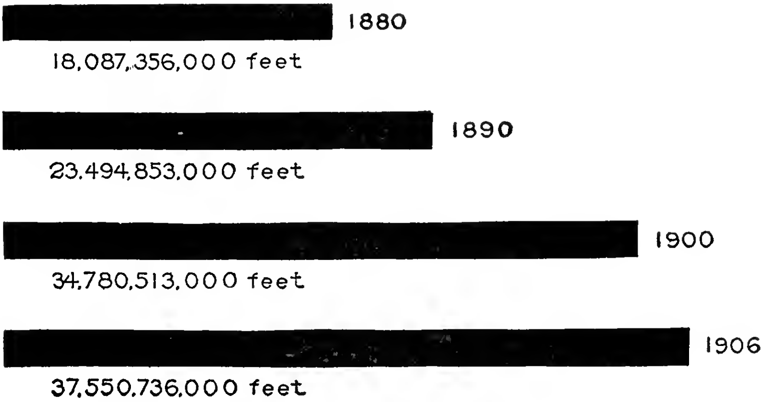
Vice-President Fritch:—It has been moved and seconded that a vote of thanks of this Association be tendered to the Committee on Rail for its most intelligent and valuable report and the earnest work, thought and attention they have put upon this work. All in favor of that resolution signify it by saying aye; contrary, no. The resolution is unanimously adopted and the Committee is relieved with the thanks of the Association.

CONSERVATION OF CROSS-TIES BY MEANS OF PROTECTION FROM MECHANICAL WEAR.

(Bulletin 121.)

By J. W. KENDRICK, Vice-President, Atchison, Topeka & Santa Fe Railway System.

. A very serious problem that the railroads of the United States have to meet is that of tie supply. Experts estimate that the timber supply of this country if used at the current rate of consumption will be exhausted before the end of the century.



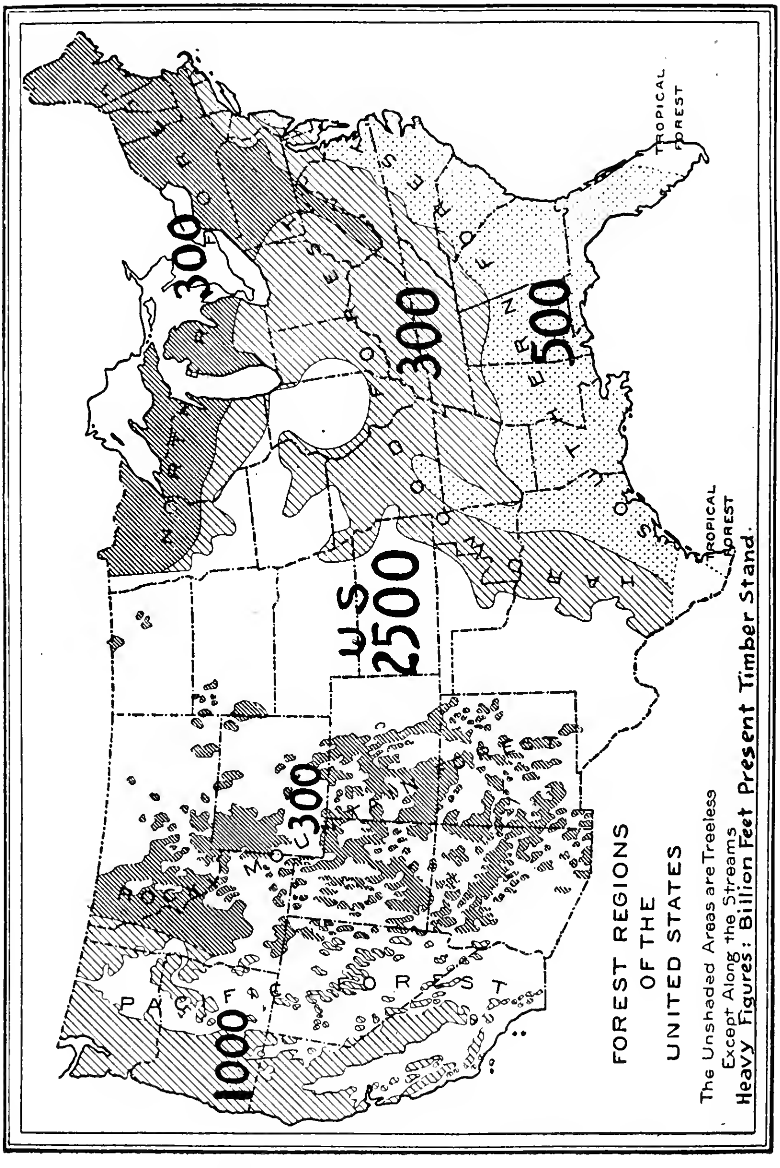
Increasing Lumber Production in United States.
(Chart Prepared by Forest Service.)

In *The Outlook* for October 12, 1907, Gifford Pinchot estimates that the supply, taking into account the annual forest growth, will last but thirty-three years, or until 1940.

However, it is highly improbable that *all the wood* will be completely used up by that time. Our forests will probably continue to supply us with wood for the next thousand years—but at an ever-increasing price. As the supply becomes less, as the demand becomes greater, because of an ever-increasing population, and per capita on account of our intensive industrial growth (for which our transportation arteries furnish the very life-blood), the price of wood will mount higher and higher, finally putting it out of consideration for all except the finest uses.

In 1905 a large number of railroads stated that the cost of cross ties, or sleepers, had increased during the year ending June 30, 1903, as compared with a period of five years previous to that time, from 40 to 100 percent. From 1897 to 1907 the average price of oak and locust ties has increased over 50 percent. Except in certain limited sections, it is now practically impossible to secure ties made of the more durable woods. The supply of oak ties in many sections of the country has long since been exhausted.

In 1905 the shortest haul for ties in large quantities averaged from ten to fifteen miles. The average for ties hauled by rail was about 500 miles and the longest haul from 1,200 to 1,700 miles.

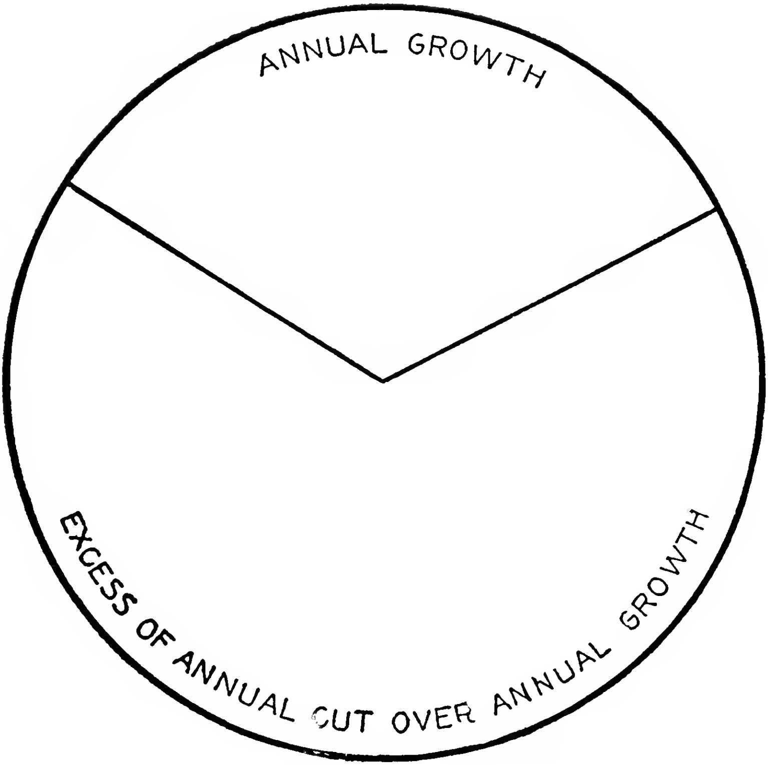


FOREST REGIONS OF THE UNITED STATES

The Unshaded Areas are Treeless Except Along the Streams

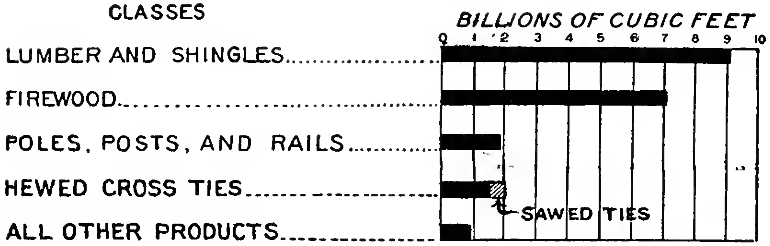
Heavy Figures: Billion Feet Present Timber Stand.

Map from Report of National Conservation Commission.

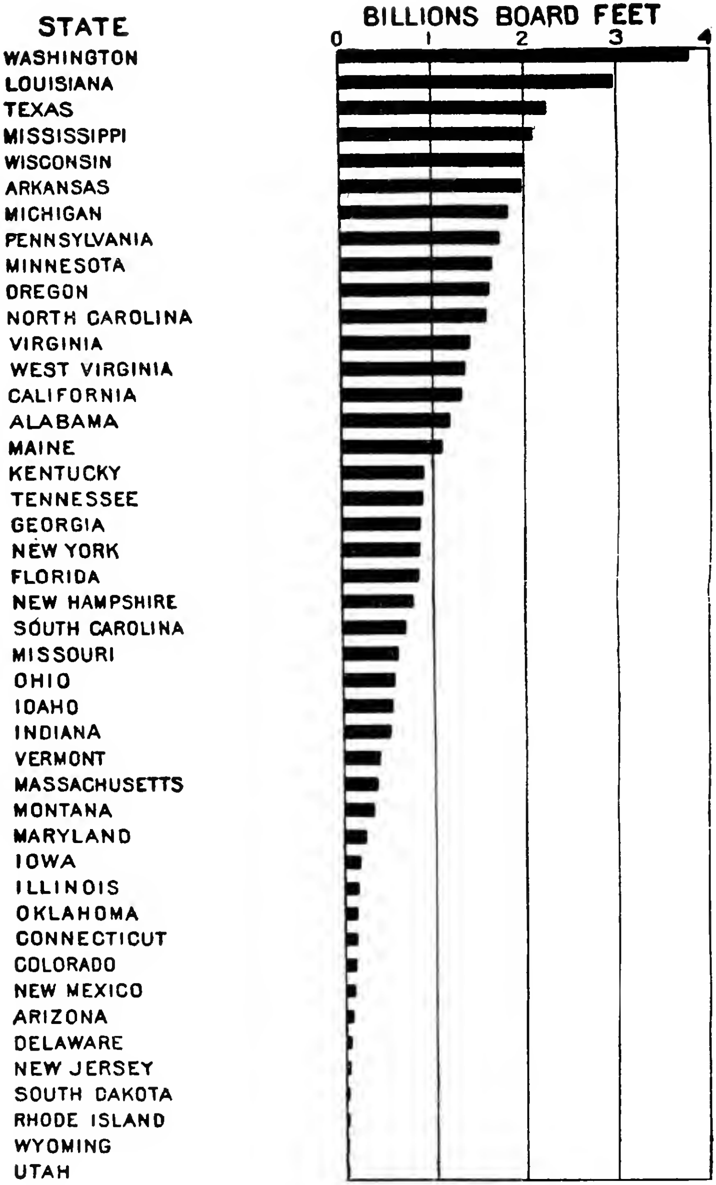


Excess of annual cut over annual forest growth.

(Chart Prepared by Forest Service.)

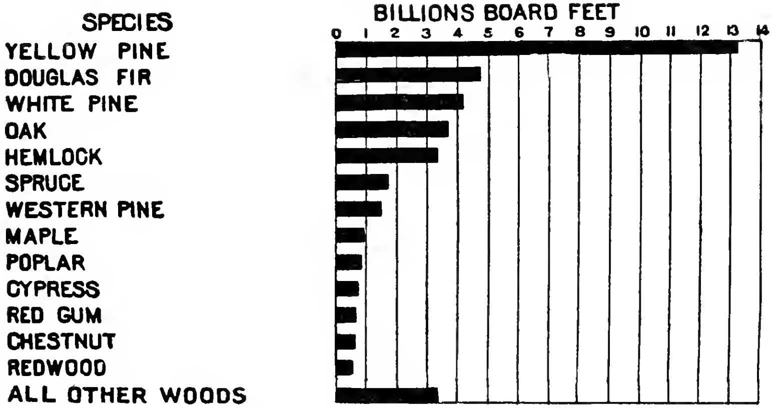


Forest Material Required, 1907.
(Chart Prepared by Forest Service.)

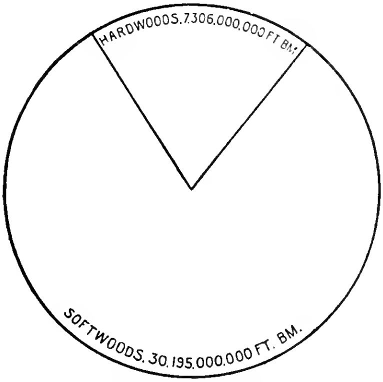


Lumber Cut by States, 1907.
(Chart Prepared by Forest Service.)

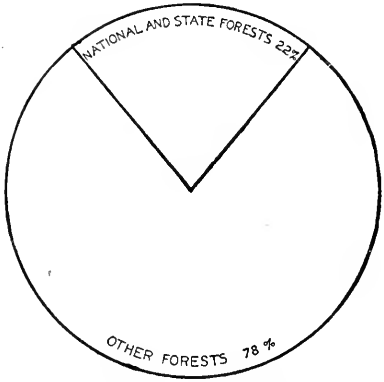
The original forests of the United States covered practically the entire country east of the Mississippi, except central and northern Illinois, and also included Missouri, Arkansas, Indian Territory, Louisiana and the eastern half of Texas. They also covered the Pacific states north of San Francisco and west of the Sierras, and large patches all through the Rocky Mountains from Montana to Mexico. They contained a stand of some 5,000 billion feet of timber, but half of which is now standing, the area north of Mason and Dixon's line and east of the Mississippi having been largely cut away.



Lumber Cut by Species, 1907.
(Chart Prepared by Forest Service.)



Hardwood and softwood lumber production, 1906.



Ratio of State and National forests to private and unreserved forests.

(Charts Prepared by Forest Service.)

The Southern and Pacific Coast forests are now being actively exploited, and the Rocky Mountain forests are mostly nationalized.

The estimated timber supply of the United States expressed in feet, board measure, is 2,500 billion. Of the present stand of timber, *less than 20 percent* is hardwood, or less than 500 billion feet. The annual consumption of timber for all purposes in the United States is 40 billion feet and for ties alone 2 billion feet. The mileage of the railroads of the United States on January 1, 1910, was over 235,000, referring now to miles of line. Including the mileage of second and additional tracks, and of all yards and sidings, the total mileage was over 350,000.

The railroads of the country use from 2,500 to 3,500 ties per mile in main lines and from 2,000 to 3,000 ties per mile in sidings and yards.

Assuming an average number of 3,000 per mile, and assuming only fifty feet of timber used to make each tie, the total timber put into steam railway ties in the United States today is over 50 billion feet, or equal to 2 percent of the present total stand of timber.

Assuming, furthermore, an average life of seven years per tie, the yearly requirements *for present track and present traffic conditions* will be over 7 billion feet, representing 150 million ties. The actual figures as reported by the Census Bureau and Forest Service for calendar year 1907, a normal year, showed over 144 million, at a time when the total mileage was but 330,000, thus closely checking the estimate given above.

Of the ties purchased in 1907, 40 percent were hardwood, 14 percent were for new track, 77 percent were hewed and 13 percent were treated. The 1907 figures are given in preference to 1908, which was not a representative year because of the depression in business. In 1908, however, 22 per cent of the ties were treated.

To recapitulate: The existing timber is 2,500 billion feet, of which hardwood is 500 billion feet; present lumber consumption, 40 billion feet; present annual tie consumption, about 150 million ties, of which oak contributes 60 million; treated ties constitute over 30 million; new track consumes over 20 million.

Forest growth does not replace one-third the present timber consumption. The provision being made by railroads for reforesting is practically negligible.

Considering the very rapid growth in population, the ever-increasing development of the country, the construction of homes and the attendant enormous increase in the requirements upon our timber reserves, a comparison of the figures of present consumption with the total, representing the established timber reserves of the country, cannot fail to be striking, and it must be remembered that in order to fully develop the resources of the country many thousands of miles of additional railroads must be built, with appurtenant terminals, and existing roads must increase their tracks and their equipment in order to satisfactorily handle the ever-increasing business resulting from the development of the territory that they traverse.

Two strong tendencies must be constantly borne in mind in considering this entire tie question:

(1) The per capita use of timber and of transportation is continually increasing.

(2) Traffic density, hence the weight and volume of traffic passing over each mile of track is also increasing at a rapid rate, tending to wear out track and ties more rapidly, and requiring larger, firmer ties and more per mile.

The preservative treatment of cross ties in the United States is of comparatively recent origin. In 1908 the railroads purchased 10,565,925 treated ties and treated in their own plants, in addition, 12,590,643, the total treated ties being 23,156,568, or 21.8 percent of the total number of ties purchased. Four years ago the majority of the roads that were treating ties used zinc chloride. Since that time there has been a general abandonment of this character of treatment by itself, particularly in regions with much precipitation and the use of creosote has been more widely adopted, but the question of proper preservation of ties so far as decay is concerned is still comparatively new, as is shown by the latest obtainable statistics just quoted.

The supply of timber in the United States has been so abundant and the cost of cross ties so comparatively small that the question of preservation against decay has only been seriously considered very recently. There is no reason to suppose that this country can escape the experience of the older nations of the globe, especially those of Europe, where half a century ago the system of wood preservation was adopted, and where it became necessary because of the great cost of timber to exercise every possible means for increasing its durability.

During the discussion of the source of supply and the use of cross ties at the session of the International Railway Congress held in Washington in 1905 the foreign representatives at the Congress expressed the greatest surprise at what they considered the unwarranted waste and destruction of timber and cross ties in this country. The mileage of the railroads of the United States in 1890 was 166,700; in 1900 it was 194,262. Assuming that in 1910 it will be 240,000, and that the increase for the next decade will be equal to that of the period between 1900 and 1910, the total mileage in 1920 will be about 300,000. Assuming again that the same ratio of the consumption to mileage will exist in 1920 as in 1907 (although it will probably be at an ever increasing rate), the number of ties required for maintenance and construction purposes will be approximately 200 million, equivalent in feet, board measure, to 6½ billion.

Selecting four typical United States railroads of large mileage, radiating from Chicago to the Atlantic seaboard, to the Gulf, to California, and to Puget Sound, we find that, roughly speaking, the average cost of ties treated and untreated in track is about 70 cents. The cost of placing ties in track will vary, of course, according to wages, character of roadbed or ballast, and general climatic conditions, but will probably range from 12 to 15 cents per tie.

The term, "Cost of Ties in Track," is used because the cost of removal and insertion of ties constitutes a very important element in track work. If the ties were more durable from any cause and the necessity for renewals were less frequent, it is obvious that a very great saving could be effected. Assuming an average cost of only 65 cents per cross tie, the sum required to provide 144 million ties during the year 1907, for the railroads of the United States, was nearly $100,000,000. If the average cost of placing ties in track is 15 cents each, the cost of the tie delivered at the points where renewals are required would be 50 cents. This will be above the actual cost in some favored localities; below it in others. Upon the whole, considering the location of the roads selected, it is believed to fairly represent existing conditions.

What will the cost be in 1920? In the light of the experience of the past decade, is it not fair to assume that it will increase at least 50 percent? This is in fact ultra conservative, but, without taking a larger and more probable figure, and assuming the annual consumption of ties in 1920 to be, as above stated, some 200 millions and applying a price of $1.05 per tie in track, a price that is now being paid by some railroads in this country, and exceeded by most of those in Europe, the amount required for annual tie renewals at that time will be over $210,000,000. Subtract from this, if you please, whatsoever your judgment may dictate, taking into consideration the ever-increasing requirements for timber for railroad and other users, and the result will remain impressive, an amount so great as to command earnest thought regarding future tie supply on the part of those who are, or who will then be, interested in the maintainance of our national highways.

The developments of the past five years have proven that the railroad officials of the country are alive to the fact that this very important problem requires immediate and earnest consideration. In fact, it affords one of the few great opportunities for enormous reduction in the expense of maintaining our railways. The average life of railroad cross ties in the United States is about seven years, referring now to those that are not treated with some preservative against decay. Europe has practically demonstrated beyond a doubt that so far as decay is concerned it can be prevented for a period of tweny-five years or more.

An inspection made by Mr. E. O. Faulkner, in 1907, of a portion of the track of the Paris, Lyons & Mediterranean Railway, over which 70 trains are run daily, resulted in the discovery of a large number of ties that show conclusively what can be achieved by proper methods. Most of these ties were of Baltic Pine, and had been in use for twenty-six years, and the one which is illustrated on page 166, which was selected as a fair sample, is not decayed, and is still fit for many years of service.

Cross ties remain in the tracks of European railways until they are removed for causes other than decay (i. e., because of mechanical wear), and afterwards serve for years for fence posts and other inferior purposes. True, European wheel and axle loads are much less than ours, but this fact has little to do with resistance of the ties against decay.

We in America have considered this problem because the facts of the past few years have forced its consideration upon us. We are passing through the experience of European railway men, who encountered the same problem in years now long passed and who have solved it successfully according to the requirements by which they were confronted. Our problem is measurably more difficult. We have to deal with conditions as to climate, precipitation, and so forth, which are limited by greater extremes than those ordinarily existing in European countries.

Again, we have to deal with quite different conditions as regards character and weight of locomotives and cars, conditions not conducive to durability of ties. Naturally, the wide experience of the managers of European railways and the methods that have been adopted and successfully pursued by them seem to indicate the course that we should follow. We should adapt their practice to our needs as far as possible until such time as something better can be found. There is no reason to suppose that ties properly treated will not resist decay in this country for an average of twenty-five years.

Decay may begin within the tie or attack it from without. Wood is subject to deterioration because of the attack of enemies of both the animal and the vegetable kingdom. The chief cause of deterioration of ties, aside from mechanical wear, is due to the penetration of the wood by vegetable spores which feed upon and cause the destruction of the wood cells. Many inquiries have been made as to the cause of cross tie failure. The answers have been: because of decay about 75 per cent, because of rail cutting 25 per cent. The writer believes that these figures are misleading; that more than 25 per cent of ties are removed on account of what we generally term mechanical wear, and, in fact, mechanical wear so generally precedes decay that the cause of tie failure cannot be accurately ascertained.

Mechanical wear, in rail cutting, and in killing or the disruption of the fibres by spikes, opens up the interior of the wood to the action of the fungi causing decay, hastening the process. Decay of course breaks down the structure of the wood and weakens it beyond the power to withstand mechanical wear. The two processes of tie destruction facilitate each other. Mechanical wear thus undoubtedly hastens decay, and reduces the life by several years.

Some eighteen or twenty years ago the subject of the protection of ties against rail cutting was actively introduced, and as the weight of locomotives and cars was increased, and the necessity for tie protection became apparent, tie plates were gradually adopted. Then, as now, and as it will be in the future, the element of first cost in connection with a new and untried device of unknown merit was a matter of prime consideration.

It is well known to everyone that the tie plates of eighteen or twenty years ago were entirely inadequate. They shriveled under the weight imposed upon them as the green leaf does under the influence of frost. Like the leaf, they disintegrated. The finely spun theories about the plate becoming part of the tie because its ribs, or flanges, were forced into the grain of the wood, were dissipated by the inexorable demonstrations of practical experience. The wood composing the tie inva-

Rail-Cut Ties.

Damage to Ties from Tie-Plates of Insufficient Area.

Rail-Cutting on Track Not Provided with Tie-Plates.

riably developed a cross check coincident with the penetration of the ribs or flanges, and the rail rested upon a bent, buckled, or broken, sheet of pressed or cast metal, which in turn rested unstably upon a disintegrated mass of wood fiber, and into the cavity thus formed water entered, decay spores followed and the days of the cross tie so armored were practically numbered. The lessons of experience are only learned at great cost.

Even supposing the tie plate to be effective, the question of primary expense was still to be considered. The cost of timber was still relatively cheap, very cheap, in fact. The time for facing the problem in its entirety had not yet arrived; and so by various stages the railways of the United States year after year, or at intervals of a few years, changed the type of the metallic tie protection, or tie plate, and grudgingly increased its strength and area.

In view of the fact that this country had passed through many years of experience with timber bridges, that the properties of timber had been investigated by engineers and scientists, that its ability to resist compression, and so forth, had been demonstrated, had been accepted, had been taught in our engineering schools, it seems strange that anyone should have thought that a piece of metal of such inadequate area could transmit pressures, approximately determined, without crushing the wood fiber, or that, knowing as we did, and have known for more than twenty years, the properties of steel and iron, their capability for transmitting stresses or pressures without destruction, we should have provided for conditions more unfavorable than those which ever existed in any properly constructed bridge, such ridiculously inadequate metallic bearing and transmitting agencies as those that we adopted, and upon which the railroads of this country have spent millions of dollars. Yet, that is what we did.

The English engineer uses a heavy cast iron chair of ample size. The Continental engineer favors a rolled plate, but they are adequate for the purpose for which they are intended, and the tie removed from the track of the Paris, Lyons & Mediterranean Railway after twenty-six years of service still sound, and apparently in as good condition so far as decay is concerned as it ever was, shows only the imprint of the tie plate upon the timber, and this tie was not selected because it was in exceptional condition, but was one of many that looked alike, and is only a fair sample of other ties that were inserted at the same time. The tie plate, as used in the United States, has in many cases been a destructive rather than a preservative agent.

But the tie plate that has been, and too often is even now, is not the worst feature of our track. There are many elements that are bad; some are worse than others. Let us consider some of these elements. The statistics of the Forestry Service and the Department of Commerce and Labor for the last year show that about 18 per cent of the ties used were sawed; the remainder were hewed. Hewed ties, like everything else, may be well or badly made. If they are badly made, the upper and lower faces are not plane surfaces. The mark of the axe is frequently in evidence.

They are often crooked, especially in this latter day, when everything of which a tie can possibly be made is used.

If one walks the tracks of many of the railroads of the country cross ties will be found which not many years ago would not have been accepted even as culls. Woods that were formerly excluded by terms and designations in specifications have become preferential. Many of the cross ties now inserted on certain roads where timber is scarce are not large enough to make first class fence posts. Other ties are made of timber naturally crooked and without proper surface.

In order to secure good track a tie should have a supporting medium composed of proper ballast, should afford an upper plane surface for the support of rails, and, on important lines, should be protected from rail cutting by the introduction of tie plates of proper dimensions. If the surface of the tie is imperfect, the utility of the tie plate is diminished little or much, according to the bearing that it has upon the tie.

Granted that tie and tie plates are all that can be asked for theoretically and practically, we then proceed to spike the rail to the ties with 5½ x 9-16 inch (or whatever the size may be) spikes. These are driven well or badly, according to the varying skill of the trackmen, or to the care that they take.

Tie plates with ribs are used. It is impracticable to bed them in the wood with any rapidity and the trackmen are content with securing a bearing on the tie, leaving a space dependent upon the length of the flanges of the tie plate between its lower surface and the top surface of the tie. Thus such penetration as has been secured, is the result of some preliminary pounding with a spike maul and driving the spike home. On curves two spikes are frequently driven on the outside, and on track that is intended for high rates of speed, for passenger trains, and also for freight traffice, it is frequently the case that the rails are double spiked on both sides. The passage of loads over the rails and the transmission of pressure upon the tie plates is relied upon to bed them in the wood. Then, of course, the spikes are slack and it is necessary to complete the driving after the tie plates are in place.

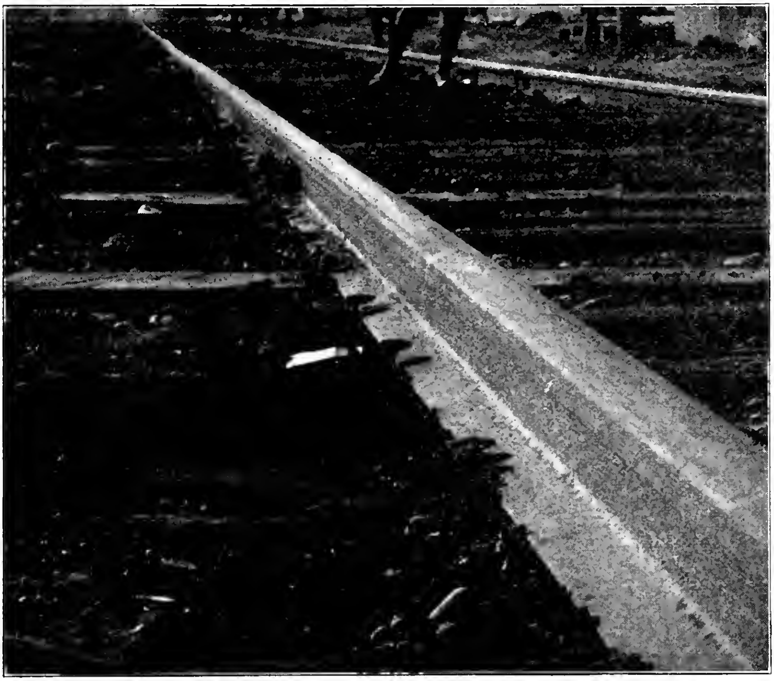
The roadbed of a railroad is more or less elastic. All ties do not have the same bearing, this being dependent upon the area of the bottom surface of the tie, character of ballast and the extent to which it is tamped under the tie, so that even in the most perfect track only approximately stable conditions exist. It is a well known fact that each pair of wheels on the engine and on the cars that it hauls causes what is known as a "wave," an actual depression of the rail occurring at the point of application of the load imposed by each pair of wheels and a corresponding elevation taking place before and behind that pair of wheels, due to the flexure of the rail.

When the wheels are immediately over any particular tie the tendency is, of course, to cause the rail and the tie plate to sink into the tie and compress its fibers, whereas, in adjacent ties the tendency is to rise and exert an upward pressure on the head of the spike. As a consequence anyone who may walk the track of any railroad in the United States will

Spike Heads Not in Contact with Rail Base.

find comparatively few spikes that are in contact with the rails. Some of them lack a quarter of an inch to an inch or more from coming to a bearing on the base of the rails. Of course, it is the duty of the trackmen to drive those spikes home again, but it is a well known fact that anything in the nature of a nail or spike that is once loosened after being driven will never fit as snugly as it did in the first place.

If ties are made of oak, or some other hardwood in which the elasticity and resistance to compression is considerable, the holding power of the spike is, of course, considerably more than in soft grain woods, but in the end the result is the same. It eventually becomes necessary to draw the spike and drive it in a new place. The hole which it formerly occupied may not be plugged. If it is plugged, the spike may be re-driven in the place originally occupied, but the hole has been enlarged, moisture creeps in and the spores of the infectious fungi follow. Ties fail quite as much, if not more, from spike cutting as from rail cutting, and this is especially true where curvature is excessive and it is necessary to re-line and re-gauge the track at frequent intervals.



Spike Heads Not in Contact with Rail Base.

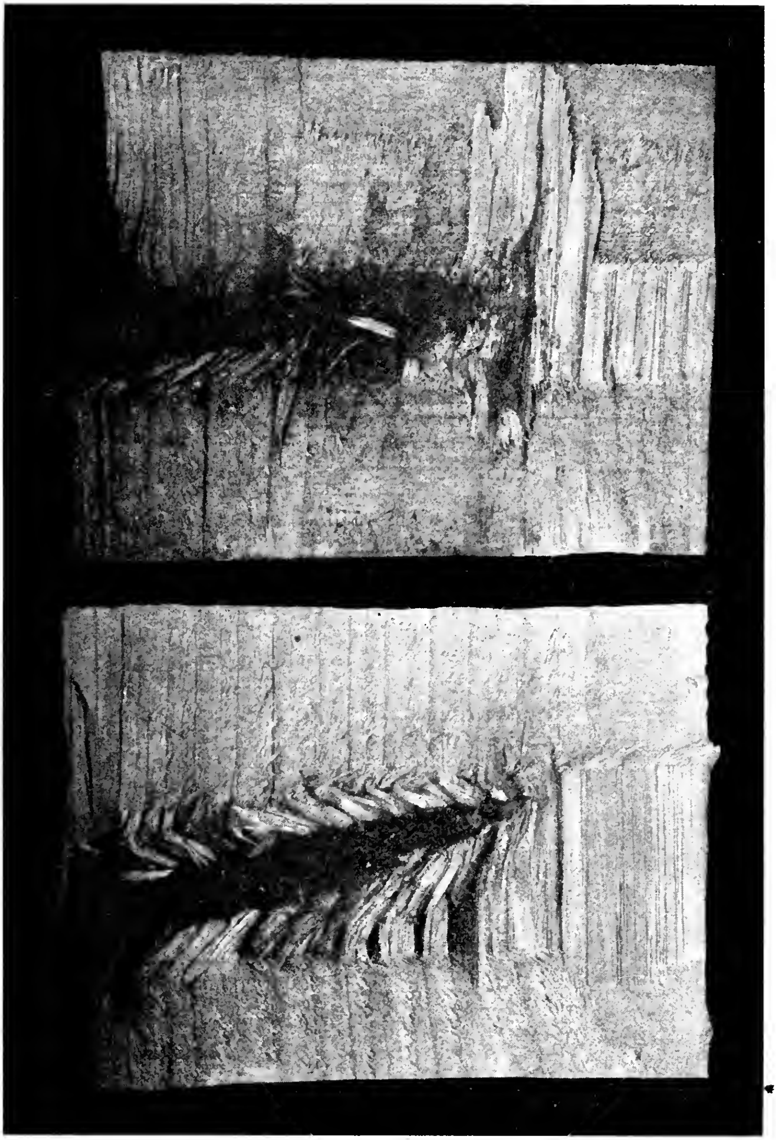
All foreign engineers and managers express surprise that the railway officials of the United States have not long ago adopted the screw spike, which has been in general use in Europe for many years.

The economical use of ties (a practical application of "conservation") depends, first, upon their preservation; second, upon their proper manufacture or shaping for the service that they are to perform; third, upon the introduction in the case of heavy traffic lines of adequate metallic bearing agencies, or tie plates, to transmit the load from the comparatively narrow rail base to the wood; and fourth, upon a form of fastening, i. e., a screw spike, which will hold the rail closely to the bearing surface upon which it is to rest. If all of these conditions are not observed, the wave motion of the rail, together with the intermittent depression and lifting of the ties, and the sliding back and forth or sawing motion of the rails will speedily result in their destruction.

Again, when it becomes necessary at periods ranging from a few months up to seven or eight years to renew rails (we are speaking of main line service now) what happens? Usually the rail is of heavier section than that it replaces. The ties were already cut by rails of lighter section having a narrower base, or, even if the rail is the same in section, the ties are nevertheless cut, and before the new rail can be placed (without going into detail, which is unnecessary for our purpose, in regard to the entire process of relaying), it is indispensible that the tie should be adzed. The labor is usually unskilled, and it is regretable that it is becoming more so each year. The adzes speedily become dull. Some ties are practically uncut; others are cut by varying degrees up to perhaps an inch or two inches, and with dull tools an attempt is made to bring them to a proper surface to receive the new rails. The result is that they are mutilated, some of them are cut one-third through, depressions are formed which gather and hold moisture, the old spike holes, plugged or unplugged, are covered, or partially covered, by the base of the rail, spikes are driven in new places, and the ties are left in such a condition that they are peculiarly receptive to moisture and germs that cause decay.

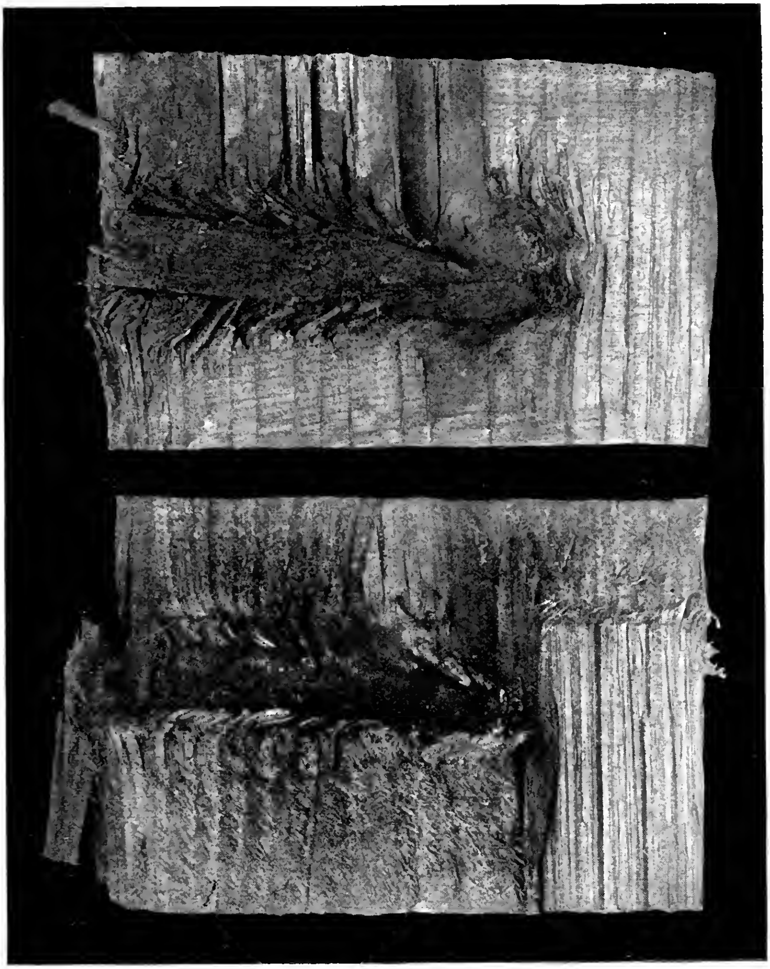
You will find this condition of affairs on every railroad in the United States. The question of the power of timber to resist compressive strain, which, as previously stated, was determined many years ago, having been entirely neglected, reliance is placed on increased width of rail base to prevent cutting. Various theories are entertained in regard to the nonnecessity for using tie plates on tangents, if at all. Hundreds of thousands, yes millions, of treated ties (soft wood) have been placed in track without protection from rail cutting, and only after they have been seriously damaged has the necessity for some protection against mechanical wear been acknowledged.

Why should we not consider the matter from a common sense standpoint? Why should we not first of all treat our ties so that we may reasonably expect them to last twenty-five years; then provide a sufficient metallic bearing surface under the rail to prevent mechanical wear, and size or surface the tie, if hewn, so as to make a perfect contact between it and the bearing surface of the tie plate which transmits the pressure incident to the load. Then if the tie plate is sufficiently strong to transmit the pressure, and if the rails are properly fastened to the ties by the best known means, a means the practicability of which has

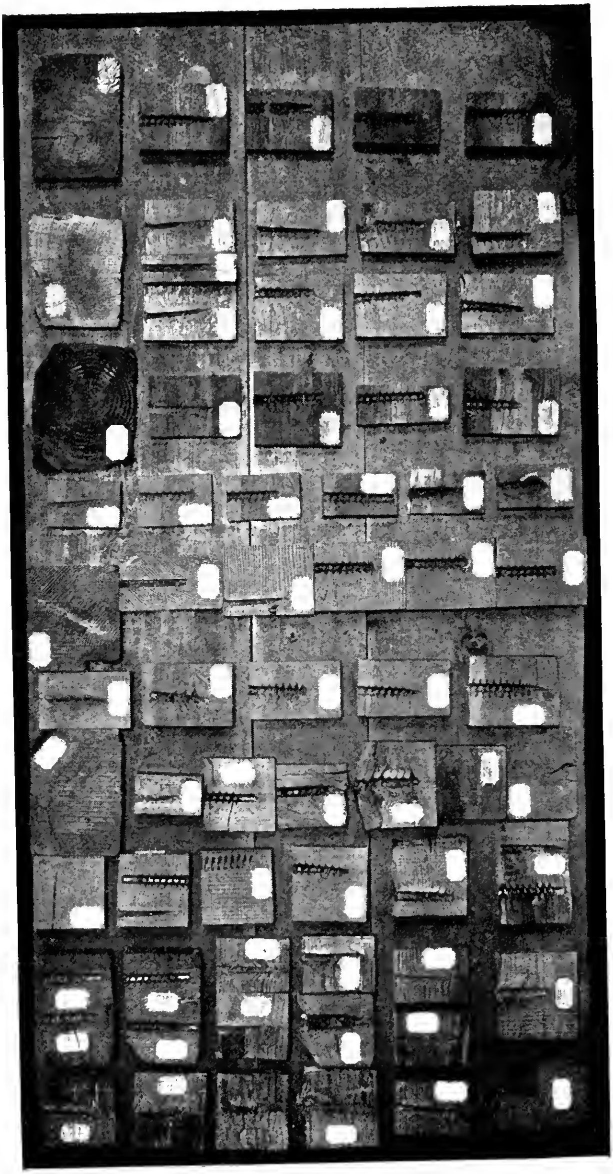


Section of Ties in Service One Year and Three Years.

Section of Ties in Service Four Years and Five Years.



Section of Ties in Service Six Years and Seven Years.



Schedule of Spike Tests Made.

been proven for many years in European practice, why should we not get such service from our ties to make them last three times as long as under present conditions, and, if the problem is properly solved, even four times as long?

In considering this subject we have felt it desirable to traverse for ourselves ground that had already been covered, although that precaution might seem superfluous in view of the experience of foreign roads.

There have been many experiments tried for the purpose of demonstrating the effect of the use of certain varieties of spikes upon the fiber or grain of the woods into which they were driven, and experiments to determine their holding value, but as far as we know these experiments have been tried for the purpose of demonstrating the superiority of one cut spike as compared with another. Various people have advocated the adoption of a spike having a long taper point which would not so badly distort the wood fiber in passing through it. Others thought a triangular spike or bayonet section would be preferable to those now commonly used. Still others thought that a round spike with square shank and chiseled point would better meet the requirements, and this field has been very thoroughly exploited.

We do not know whether the same line of experiments that we tried had previously been conducted by anyone, but, at any rate, our experiments seem to justify the position that we take, that the use of the destructive cut spike now universal on all American railroads, should be discontinued. In support of this assertion we beg to submit the following photographs illustrative of tests which we conducted with the utmost care in the laboratory of R. W. Hunt & Company at Chicago. As each picture bears its legend, comment in every individual case is unnecessary.

The destructive effect of the spikes upon the timber is so clearly shown by these cuts that any remarks seem superfluous, except to state that where the age of the timber is not given in connection with the illustration it will be understood that it is new.

In contrast to these examples, your attention is invited to the results obtained in other tests made with ties in which screw spikes were inserted in wooden plugs, in accordance with European methods. Screw spikes may be inserted directly in the tie, or the tie may be bored and plugged for each spike that is to be applied.

The following cut shows a screw spike in a tie. The disturbed appearance of the wood on either side of the hole is due to the fact that it was sawed to close proximity to the spike and then split. You will notes that the fibre of the wood was practically undisturbed for the reasons stated.

As before mentioned, it is a common practice in Europe to provide a wooden screw plug or dowel to receive the spike. The ties are bored with holes about about 5½ inches long and 1½ inch in diameter. These holes are then threaded to about one inch pitch. The ties are then treated, usually with creosote, and the wood around the hole intended for the plugs is thoroughly impregnated. The plugs or dowels are also impregnated with creosote and are screwed home in the holes prepared for them, the tie is then sized and the tops of the plugs are smoothly cut off in the same operation. The number of spikes varies from two to four at each rail bearing.

The question may be asked, of what use are the plugs? In the first place, the boring of the tie previous to treatment makes it practicable to thoroughly impregnate it with a preservative against decay at the points where it is most vulnerable, namely, where the spikes are inserted, and where the wearing action of the tie plates and the rails occur.

But there is another very good reason which will be shown by the table which follows. Tests were made for the purpose of determining the resisting power of various kinds of spikes against withdrawal under various circumstances.

	Mean.	Maximum.
Square spike in unbored tie	4,558 lbs.	6,826 lbs.
Round spike in unbored tie	2,478 lbs.	6,066 lbs.
Square spike in bored tie	4,082 lbs.	5,810 lbs.
Round spike in bored tie	4,108 lbs.	6,940 lbs.
Screw spike in bored tie	6,916 lbs.	10,842 lbs.
Screw spike in oak plug	8,170 lbs.	9,724 lbs.

Of course, the resistance of the driven spike as compared with the screw spike is very much greater, according to this table, than it would be after it had been used for a little while. After they are once loosened their power of resistance against an upward force would be much less. It will be observed that the resistance of the screw spike against withdrawal is much greater than of the others.

A series of tests were made to determine the comparative crushing strength of ties with, and without, a certain number of plugs.

Test "A" represents tie plate on tie without plugs.

Test "B" represents tie plate on tie with two plugs.

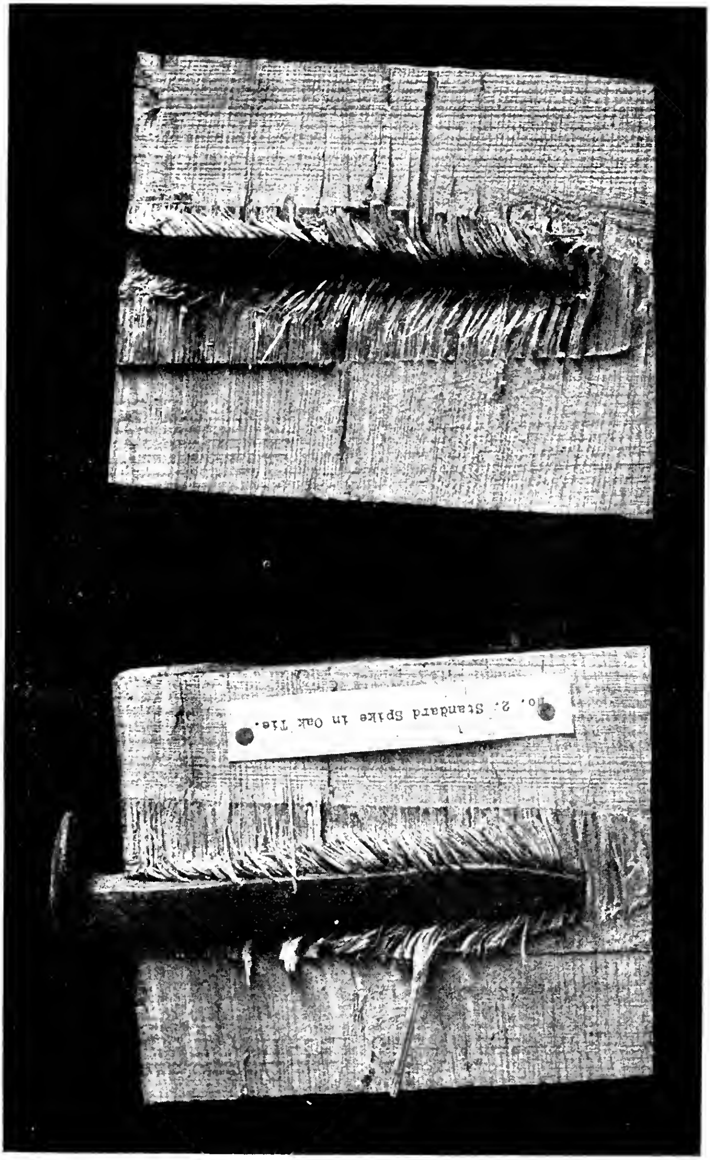
Test "C" represents tie plate on tie with four plugs.

The compression in inches under pressure of 80,000 pounds was as follows:

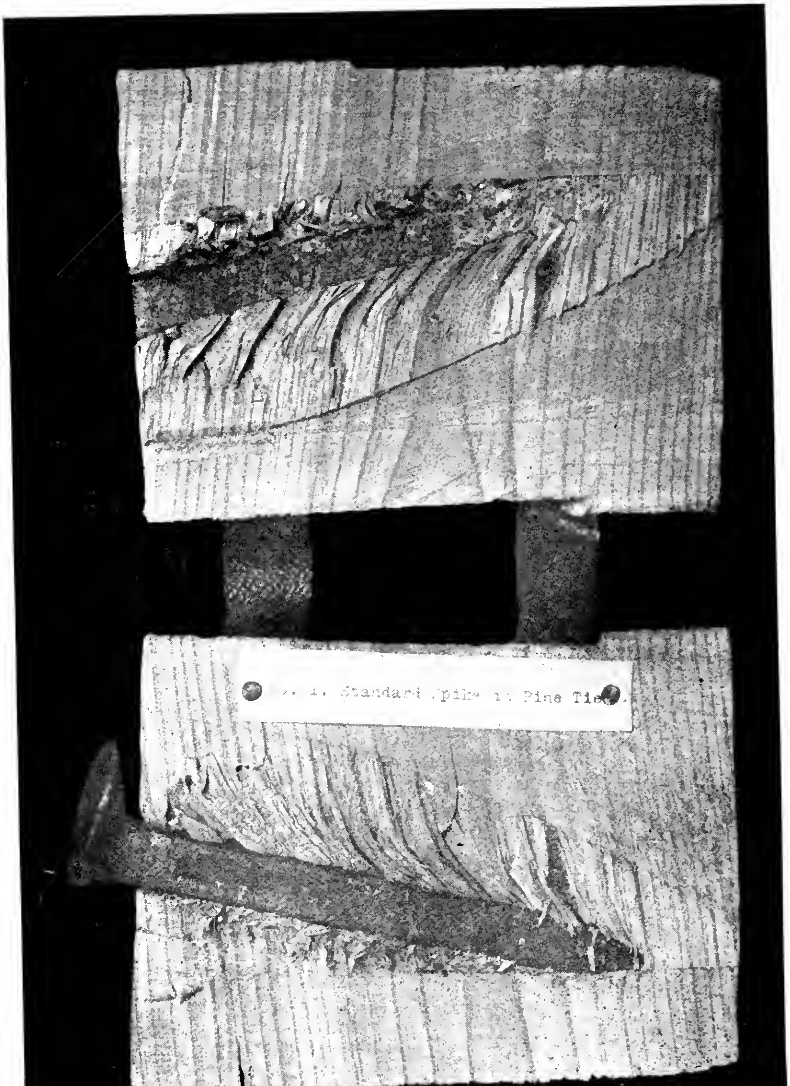
Test:	1st Series.	2nd Series.
"A"	2.69 inches.	3.25 inches.
"B"	1.03 inches.	1.34 inches.
"C"	.97 inches.	.87 inches.

The only conclusion that can be reached as a result of these experiments is that the plug acts as a column, transmitting by means of its threads the pressure to which it is subjected through each layer of wood fibres, so that the pressure is distributed from top to bottom instead of being concentrated upon the top layer.

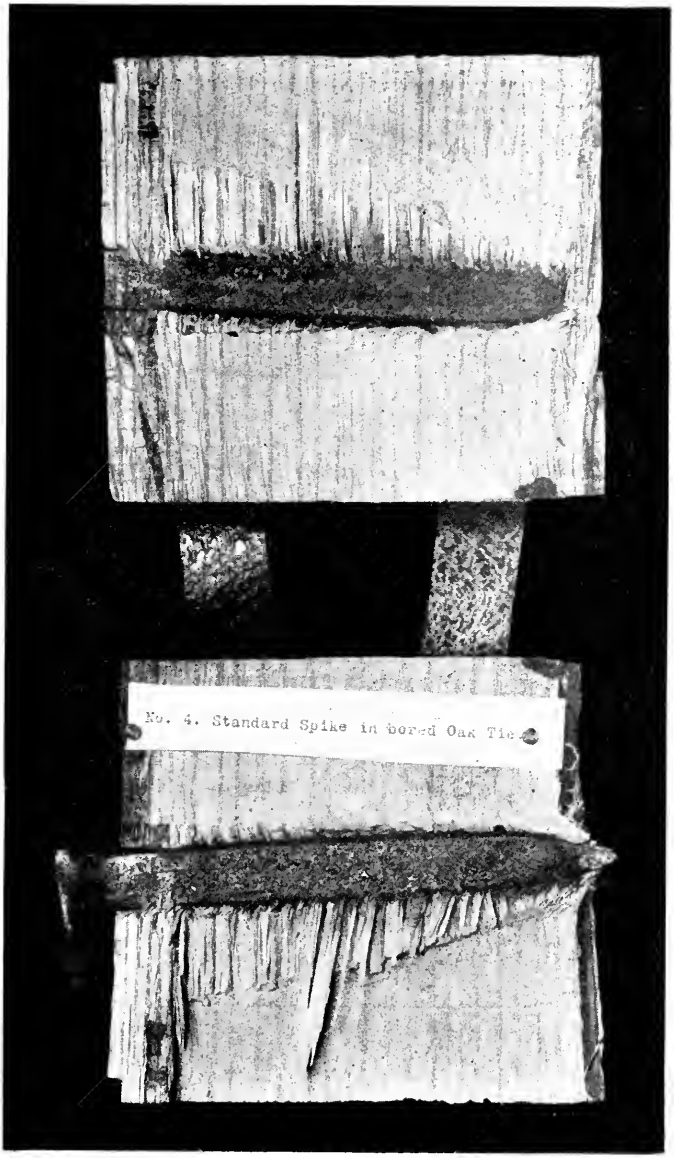
It seems proper at this point to illustrate three cuts of the Baltic pine tie taken from French track, to which reference has been made. The story upon the tag attached to the tie states the facts. It will be observed that after the first ten years of service before the wooden tie plugs, or dowels, were inserted the tie became rail cut, hence the scarfing which is shown by the cut. The effect of the remaining sixteen years' service, during which time the tie plate was used, is also indicated by the cut, and it will be noted that the compression of the wood under the tie plate is



Cut Spike Driven in Oak Showing Fibre Distortion.

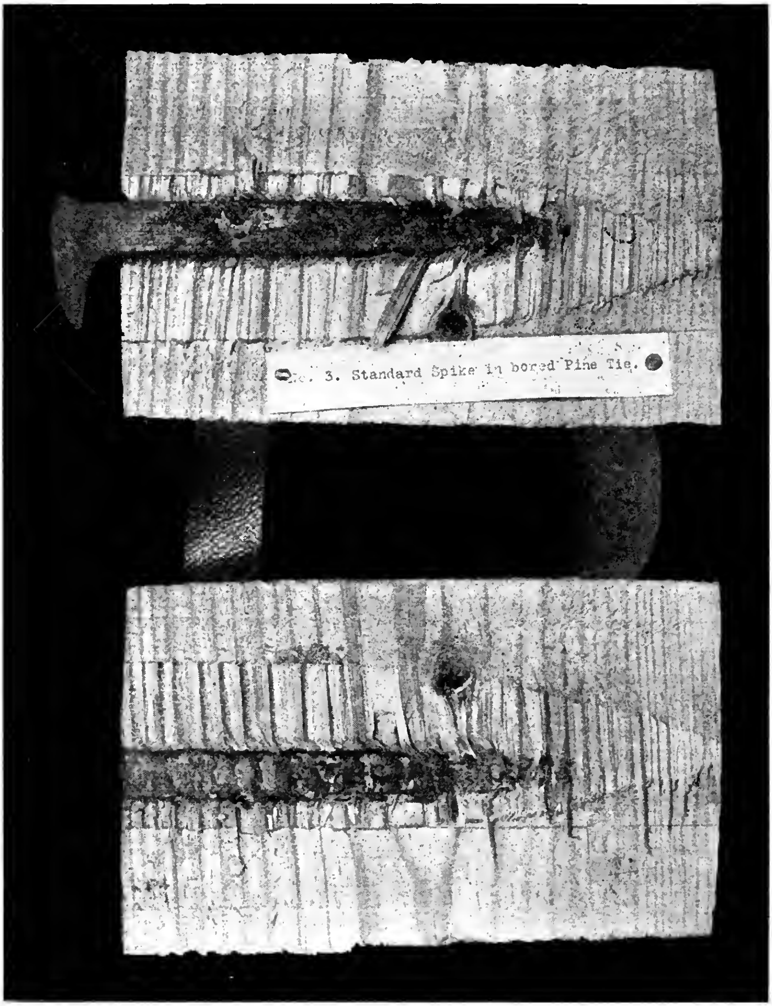


Cut Spike Driven in Pine Tie.

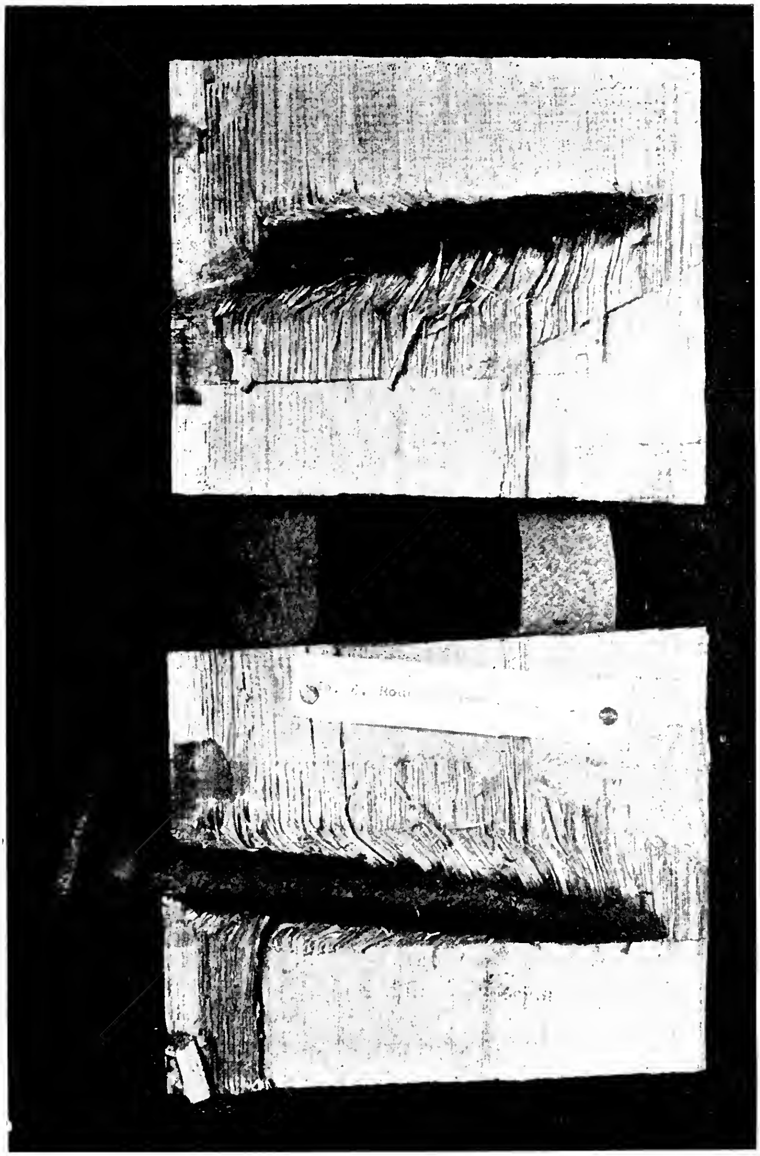


Cut Spike Driven in Bored Oak Tie.

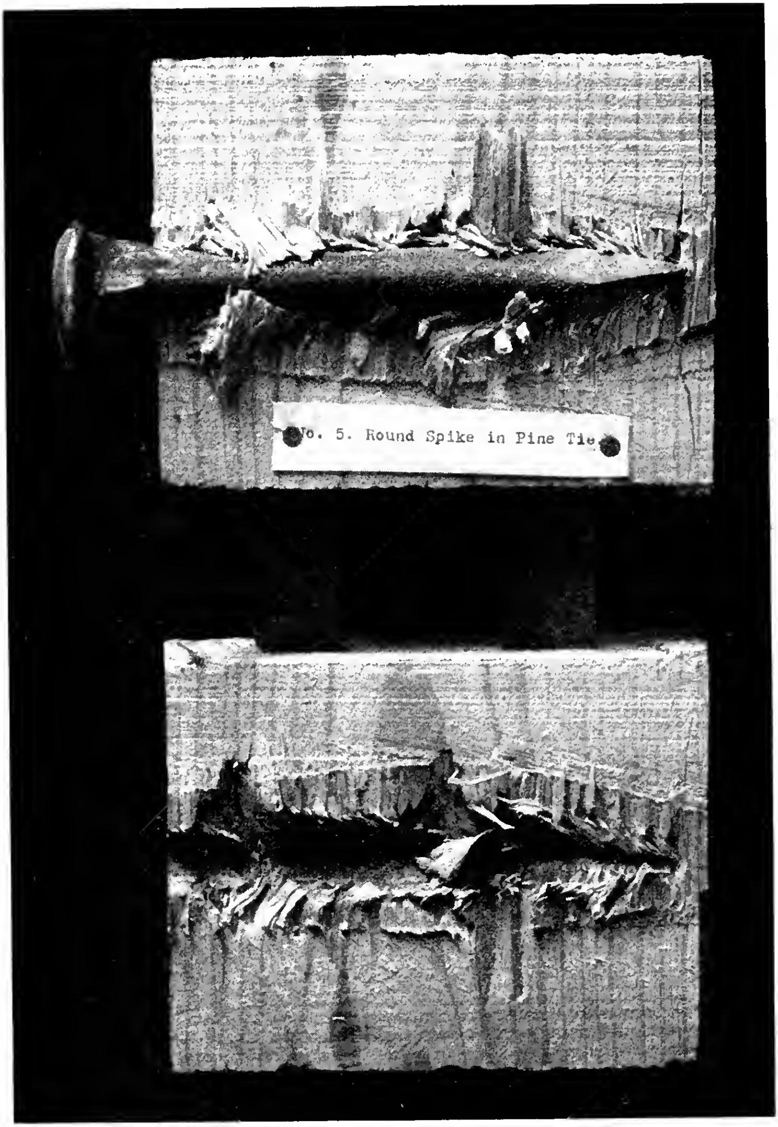
(All Ties Should Be Bored, Whatever Kind of Spike Is Used.)



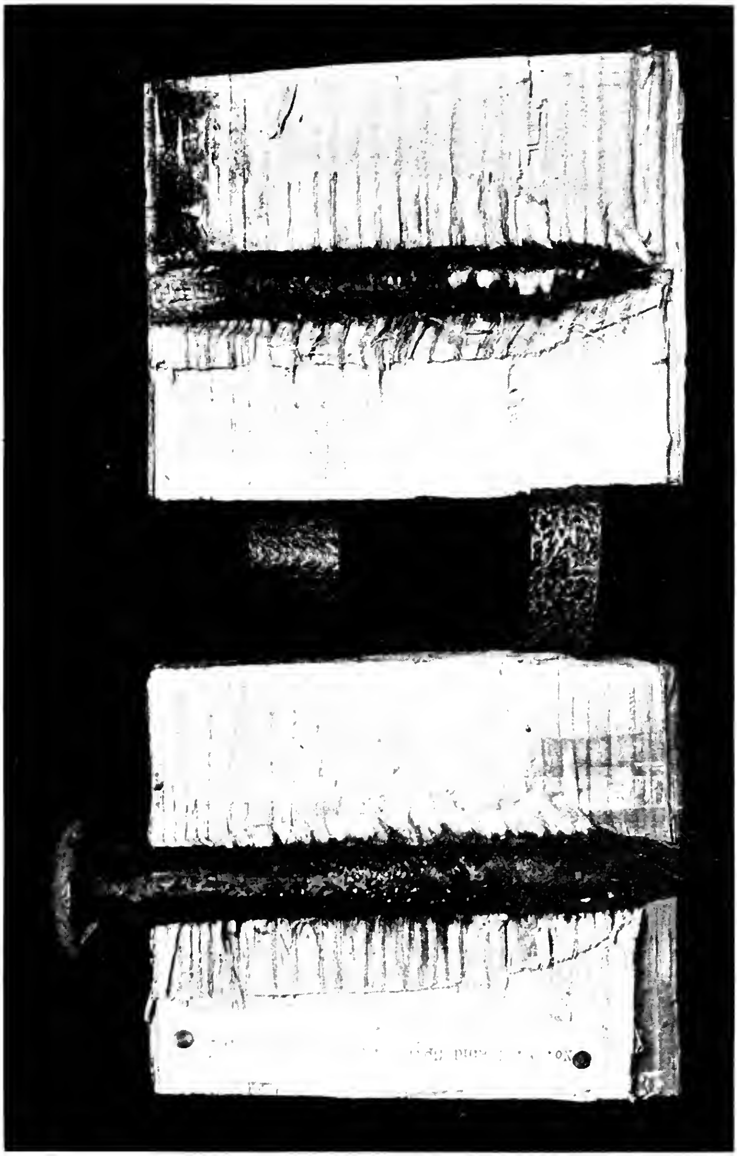
Cut Spike in Bored Pine Tie. Fibre Not Damaged.



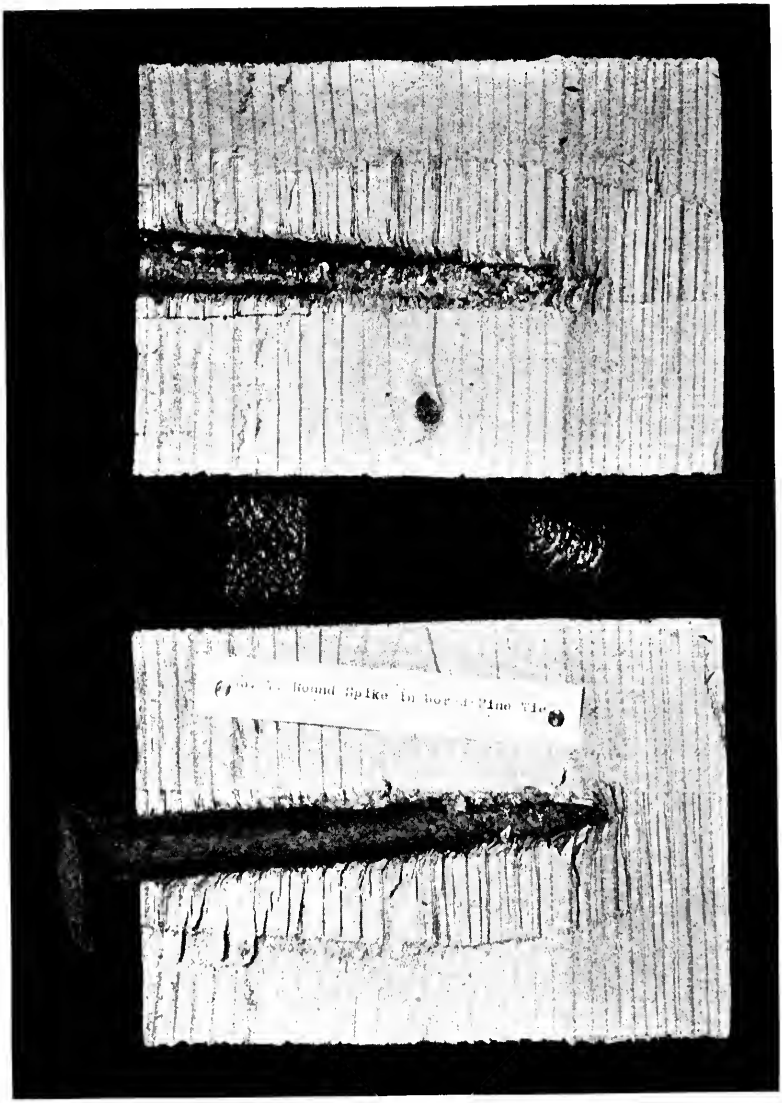
Round Spike in Oak Tie. Not as Good as Cut Spike.



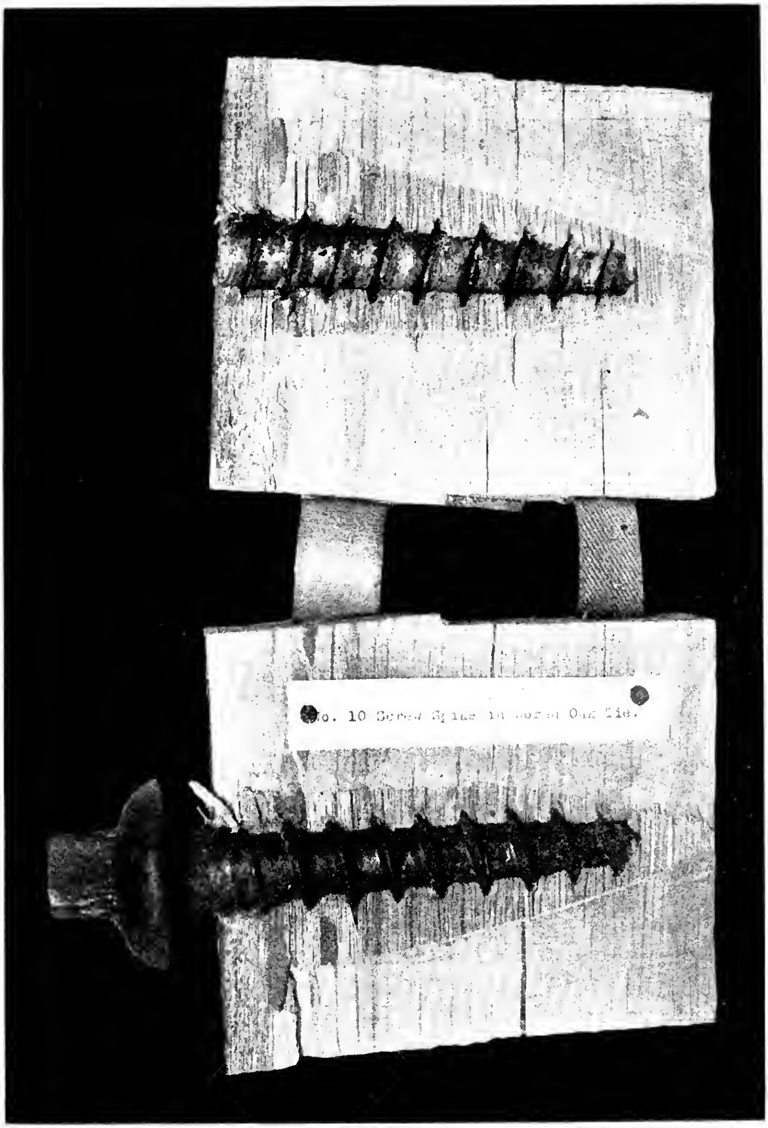
Round Spike in Pine Tie. Example of Spike Killing.



Round Spike in Bored Oak Tie.



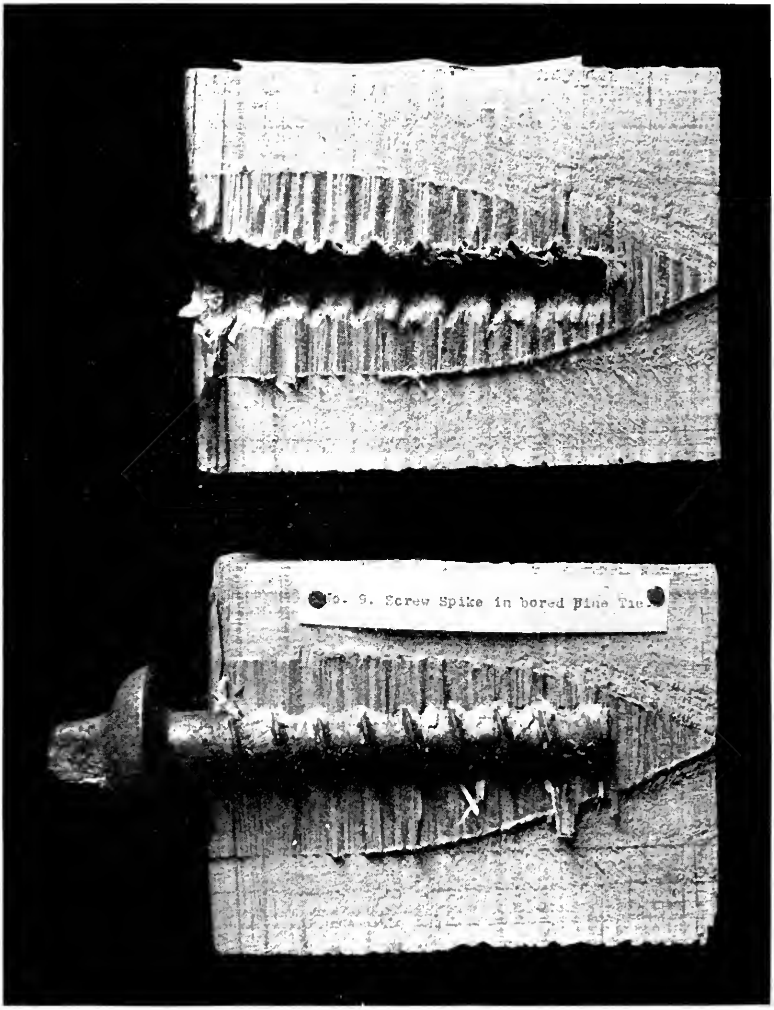
Round Spike in Bored Pine Tie. Fibres Not Disturbed.



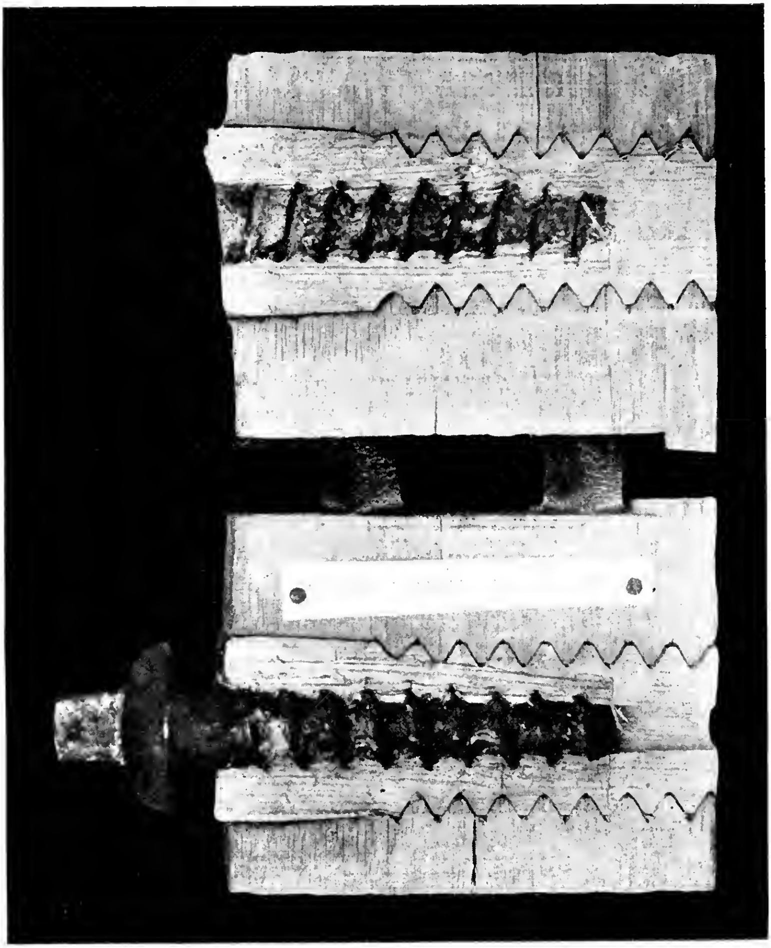
Screw-Spike in Bored Oak Tie, Showing Perfect Bedding and Fibres Undisturbed.

very slight. It will also be noted that this tie had four dowels, or spike holes.

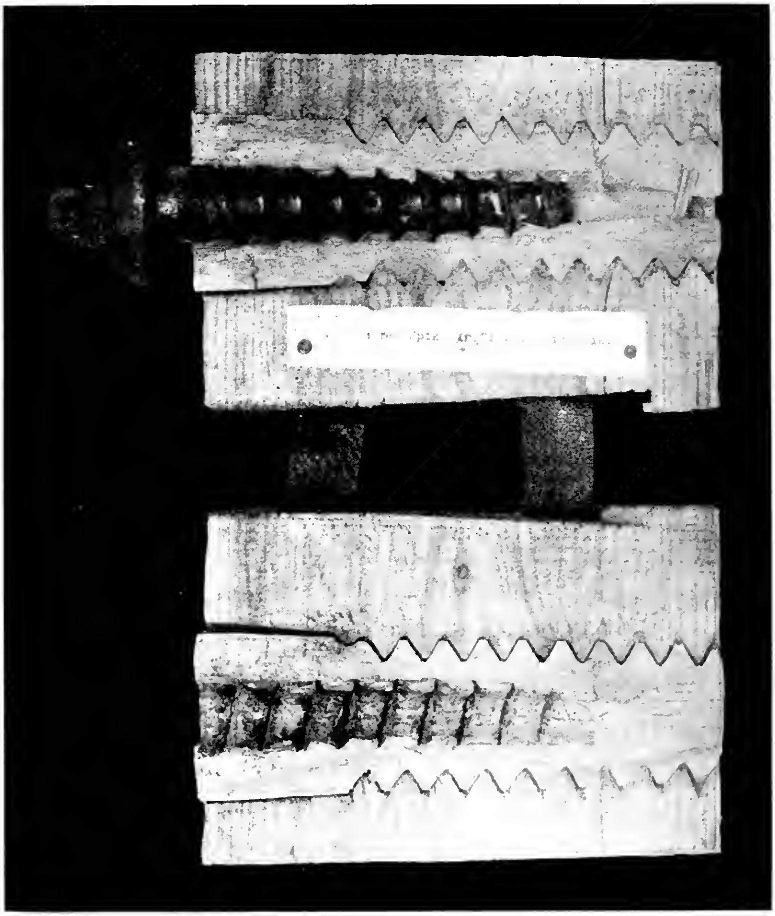
The cut showing the tie indicates its impregnation by creosote, this being represented by the dark section. The light section is the heartwood, into which it is impossible to force creosote. The radial checks are caused by shrinkage. Although the penetration of creosote into the heartwood on the lower section of the tie is very slight, it has been sufficient to cause it to withstand decay, although, of course, the road is well ballasted and drained, as is stated by the description shown in the cut.



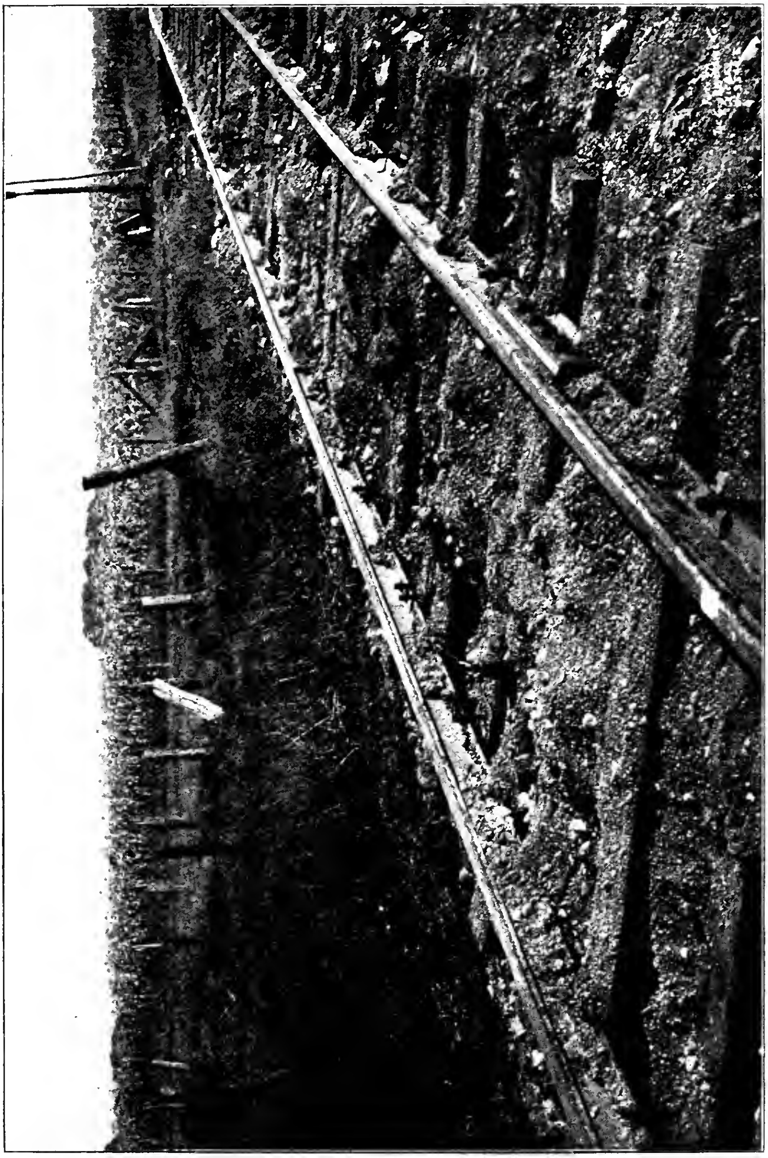
Screw-Spike in Bored Pine Tie.



Screw-Spike in Plug in Oak Tie.

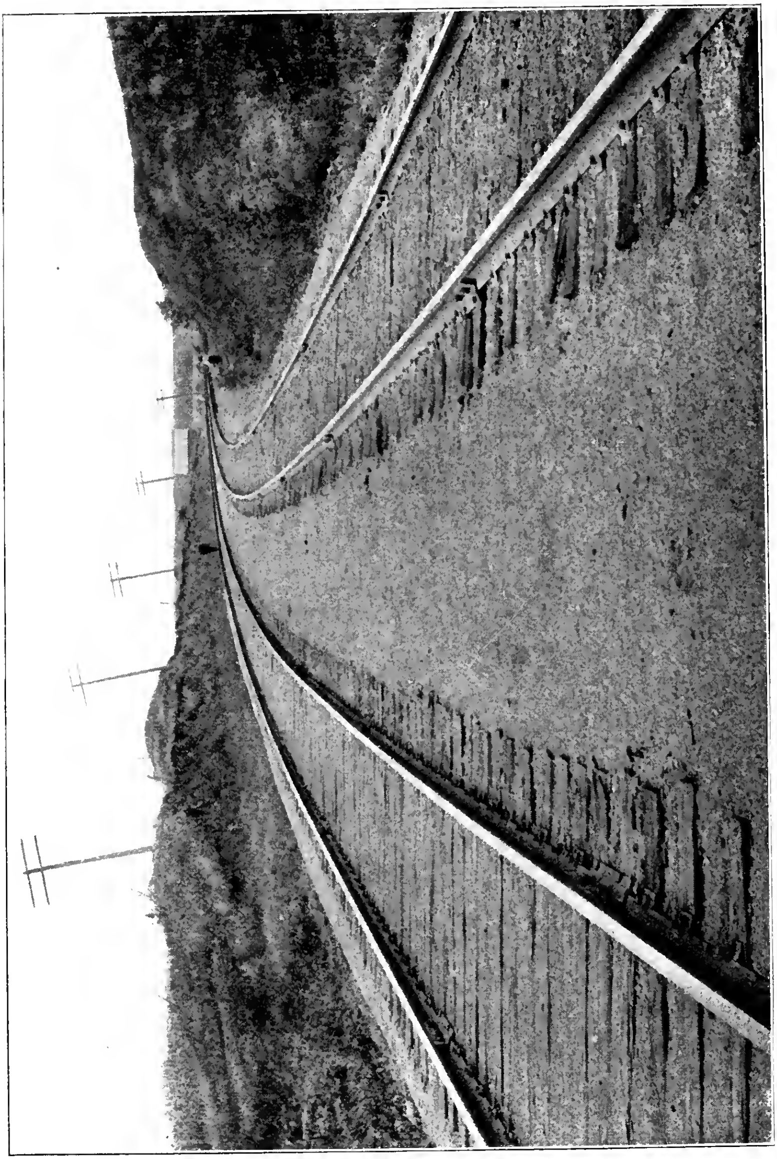


Screw-Spike in Plug in Pine Tie.



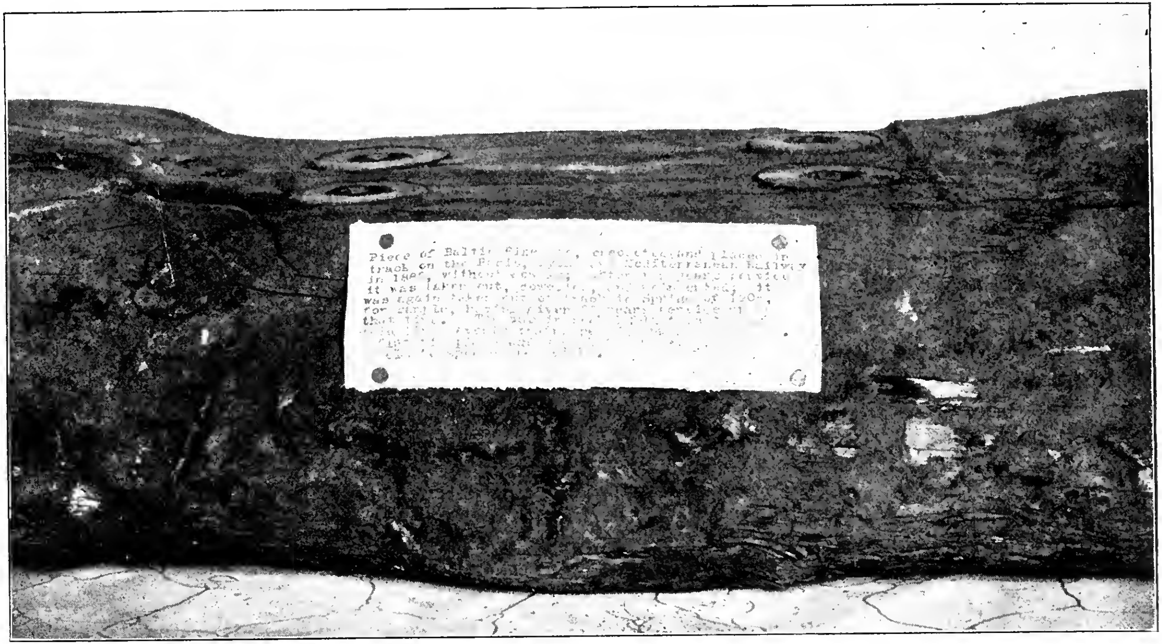
Screw-Spikes Ready to Be Driven by Machine.

Screw-Spikes Just Applied to Track by Machine.



Track with Screw-Spikes and Heavy Tie-Plates, on Curve.

Creosoted Baltic Pine Tie in Service on Paris, Lyons & Mediterranean Railway for Twenty-six Years, and Still Sound. An Average of Seventy Trains Per Day Runs Over This Track.



Side View of Treated Baltic Pine Tie, Twenty-six Years in Service on Paris, Lyons & Mediterranean Railway.

End View of Treated Baltic Pine Tie, Twenty-six Years in Service on Paris, Lyons & Mediterranean Railway.

If ties serve their purpose for upwards of 25 years on European roads and are afterwards useful, as is the case, for fence posts and other purposes, there is no good reason why approximately the same longevity should not be obtained in American practice. In order to secure this result it is necessary to

First, treat the ties with some preservative to prevent decay.

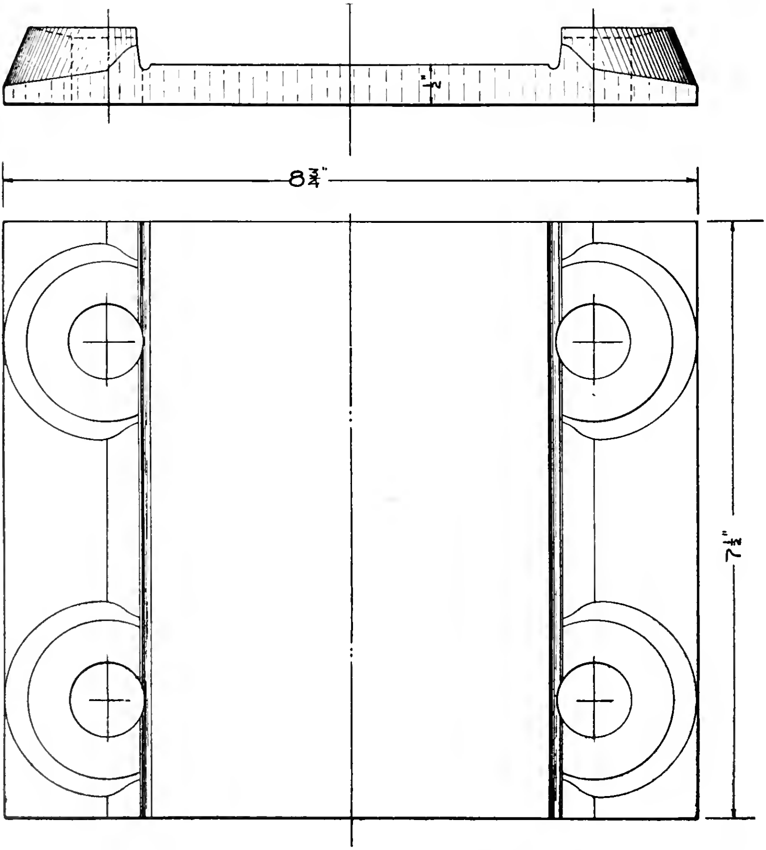
In doing this first cost is of comparatively minor importance. The best proven treatment should be used, and there is no doubt that creosoting satisfies this requirement better than any other method. Ties may be fully creosoted, i. e., impregnated with all the creosote that the wood will take; they may be impregnated by the Rueping Process, in which a portion of the creosote is extracted by exudation resulting from the expansion of the air forced into the wood cells during the process of treatment, and by the after application of a vacuum. They may be treated by a mixture of zinc chloride and creosote, or by any other method that is proven. It is not the purpose of the writer to discuss the relative merits of various methods of tie preservation. It seems sufficient to emphasize the necessity for using only such processes as have been proven. Proof does not depend upon actual practical use of ties in track. The growth of the Fungus that produces decay can be stimulated, and results can be obtained in a few months that would require years of actual service to develop. The A. T. & S. F. Ry. has adopted the Rueping Process for the treatment of ties at its plant in Somerville, Texas, which has a capacity of about 2,500,000 ties annually. It uses crude oil with an asphaltum base at its plant in Albuquerque, N. M., which has a capacity of about 750,000 ties annually. The oil treatment is considered experimental, and its adoption was based upon the results obtained in its experimental track on the Beaumont Division in southeastern Texas, where ties treated in this way were perfectly sound after a period of 5 years, and are still in that condition after the expiration of 7 years from the time of their insertion. Untreated ties made of the same wood placed in this track decayed within 9 months.

The Rueping Process is rapidly taking the place of the Full Creosote treatment, which has been followed for years in Europe. This is especially true in Germany, where the relative value of treatment with various preservatives has been determined by exhaustive tests at Stendal, and possibly at other places where simliar plants are employed.

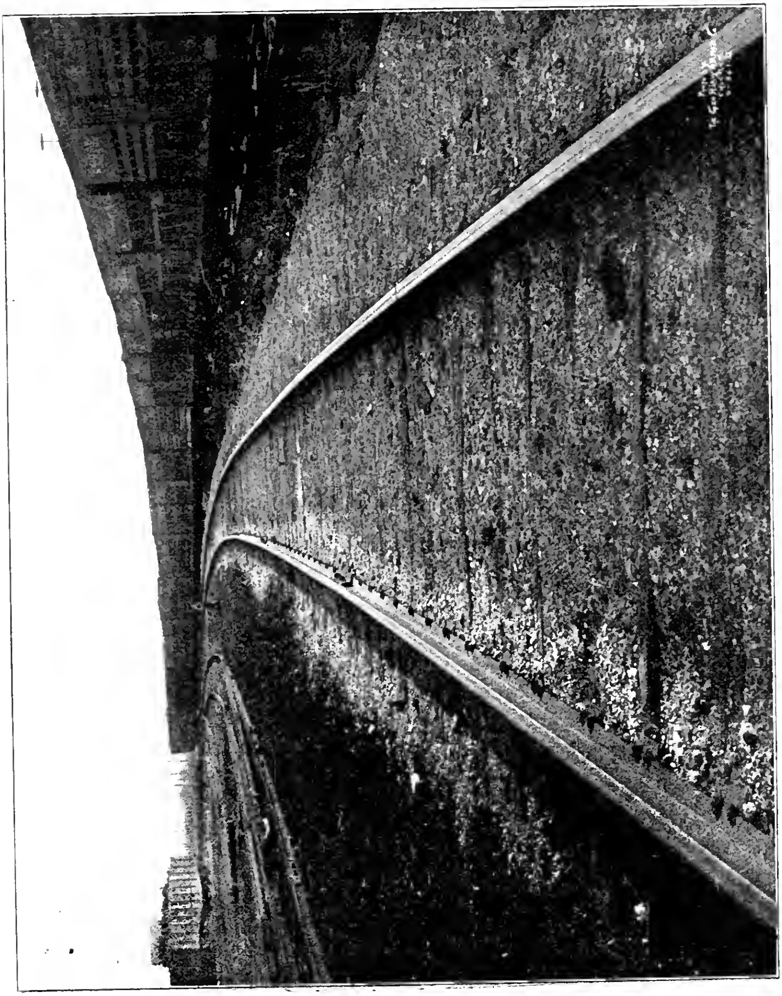
Second, tie plates of adequate length, width and thickness should be used in order to properly distribute the maximum pressures transmitted through the base of the rails to the upper surface of the ties.

The properties of various kinds of wood, with respect to their ability to resist compressive strains, have been determined repeatedly. As the majority of the ties that will be used in future will, as at present, be made of the soft and inferior varieties of wood, it is desirable to reduce the pressure upon the wood fibers to about 700 pounds per square inch. The maximum weight on a single engine driving wheel is about 30,000 pounds. It will probably be sufficient if we add 50 per cent to this to represent the effect of a suddenly applied load, in other words, to provide for the effect of impact. The rails and tie plates being securely fastened to the ties by screw spikes, the transmission of the effect due to the load on any wheel will be much more uniform than when cut spikes are used, in accordance with prevailing practice.

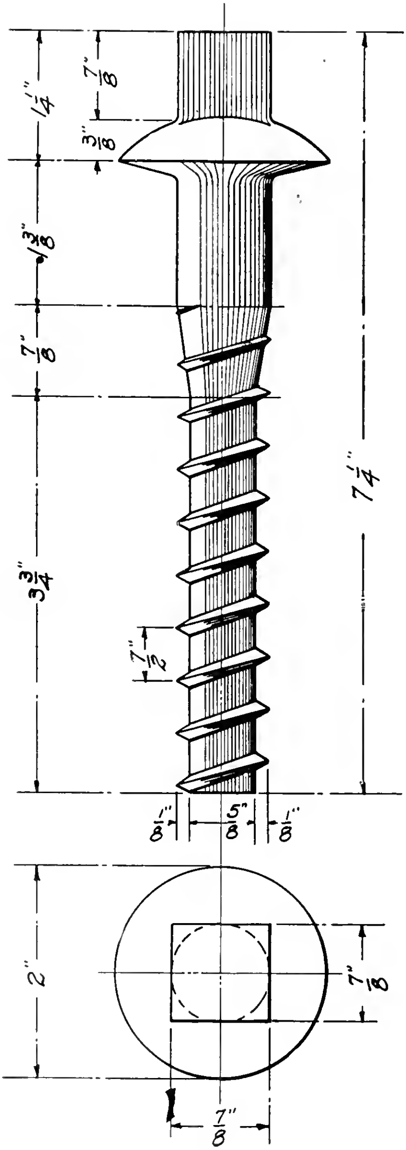
The accompanying cut of a tie plate shows one which has been adopted, among others, by the A. T. & S. F. Railway. This plate is 8¾x7½ inches, and a half inch thick. The effective area is therefore about 63 inches, and the pressure on the tie incident to a load of 45,000 pounds is just 700 pounds per square inch. The thickness (one-half inch) has been found sufficient as a result of service under the heaviest power during a period of more than two years. It may be said that the width of this tie plate, 7½ inches, will require a change in tie specifications, but in the interests of economy this change should be made. Narrower ties cannot be protected from wear, and, consequently it will be unwise to go to the expense of treating them with preservatives. This tie plate is designed



Tie-Plate Designed with Sufficient Area and Stock, for Use with Screw-Spikes. Only Two Spikes Are Used in Ordinary Track.



Track with Substantial Tie-Plates and Cut Spikes.



Standard Screw-Spike for A. T. & S. F. Ry. System.

to support the head of the spike in its entirety, and this is very necessary for the purpose of securing satisfactory results.

Third, screw spikes should be so designed as to facilitate driving without injuring the shank.

Where spikes are driven by hand this is not so important, but the only reason for tapering the head is the fancied advantage in forging the spikes. It is practicable to forge them with cubical heads, and these are preferable. It is impracticable to apply screw spikes by hand in this country, without unnecessary expense, on account of the high wages that must be paid for labor, and the application of a machine driven tool to a truncated pyramidal head has been found to be difficult on account of the tendency of the tool to engage, then slip, so rounding the head as to impair its value for the purpose for which it is intended.

Reference is made to the illustration showing the spike which has been adopted by this railway.

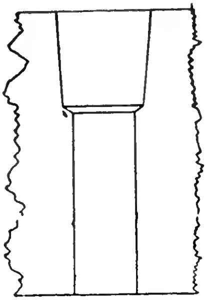
Fourth, it is desirable to introduce wooden screw dowels or plugs bored in the center to receive the screw spikes.

The office of these wooden dowels is referred to in a preceding paragraph. The tie should be bored and threaded to receive these plugs at the treating plant, and before treatment, as impregnation by the preservative generally will be very much more thorough than if these holes are prepared after treatment. This method of procedure is considered very important because it is impossible to secure the impregnation of heartwood by any preservative, at least to any great extent, and if the tie is treated first and bored afterwards, the portion which is unimpregnated will be opened for the admission of moisture, and fungi spores, which cause decay.

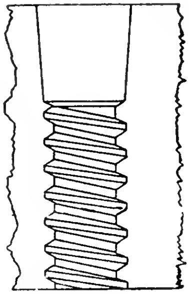
The plugs, or dowels, should also be impregnated before they are inserted. The bearing surface of the ties should be sized, and the plugs cut off at the same operation, to receive the tie plates, and thus insure proper and uniform bearing.

Reference is made to the illustration which shows the sections of ties in which wooden dowels have been inserted.

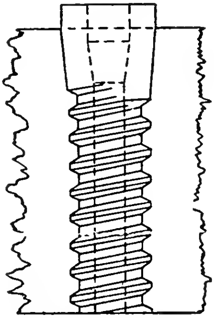
The question will naturally be asked as to the relative cost of adopting this form of construction as compared with that now in use. A proper machine at the treating plant will bore and plug 600 ties with 8 plugs each, per day of 10 hours, at a cost of 3½ cents per tie. The cost of making the plugs will be about 1½ cents each. The cost of screw spikes will be 2.7 cents each; of tie plates 21 cents each. The cost of cut spikes will be 1.06 cents each. Assuming 3,000 ties per mile of track, with 4 spikes per tie, assuming that the same types of tie plates are used both with screw and cut spikes, and that 8 wooden dowels are provided for the plates with screw spikes, and no dowels are provided for cut spikes, the relative cost per mile of track would be as follows:



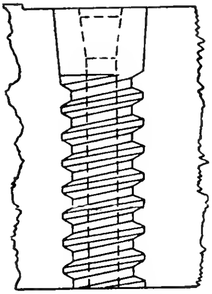
Tie Bored for Dowel or Plug.



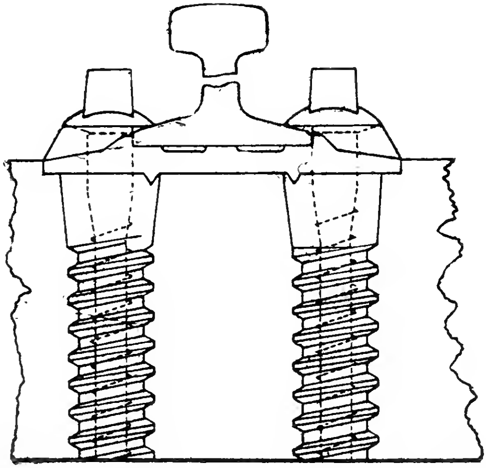
Tapped or Threaded for Dowel.



Dowel in Place.



Tie and Dowel Cut Off.



Screw-Spikes and Dowels in Place Complete.

ONE MILE OF TRACK WITH SCREW SPIKES AND DOWELS.

12,000 spikes at 2.7 cents each	$ 324.00
6,000 tie plates at 21 cents each	1,260.00
Boring ties for, and driving, 24,000 dowels, at 1 cent each	240.00
24,000 wooden dowels at 1½ cents each	360.00
Driving screw spikes (per mile)	150.00
Total	$2,334.00

ONE MILE WITH CUT SPIKES.

12,000 spikes	$ 127.20
6,000 tie plates at 21 cents each	1,260.00
Driving cut spikes (per mile)	150.00
Total	$1,537.20

The difference in cost is considerable. The calculation assumes that tie plates will be used in either case, and true economy requires that this be done. The estimated cost of driving screw spikes is based upon work actually done under unfavorable conditions on a section of track about 5 miles in length, on the Illinois Division of this railway, last fall. Unfortunately, the holes in the tie plates were a little too small, so that the screws acted as reamers to enlarge the holes before they could be driven home. The record of cost for driving 4,200 track feet—the best progress made in one day—indicated that there would be little or no difference between the cost of applying screw spikes and of driving cut spikes.

The element of increased cost is one which enters into any construction of superior type, and the real question is: IS IT WORTH WHILE? If this process is followed, the average life of ties on American railways would, very conservatively speaking, be 21 years instead of about 7, that is, they would last three times as long as at present. Screw spikes should be applied as ties are renewed. Then at the end of a period of from 7 to 10 years any line of railroad pursuing this course would have provided its track with treated ties, screw spikes, and so forth. Let us consider what this would mean if the railroad mileage of the United States were reconstructed in these respects:

Present (1910) trackage U. S. Steam railroads	350,000 miles
At present in track, about	1,000 million ties
Present annual requirements	150 million ties
Average trackage added per year for past 7 years	10,000 miles
Requiring yearly for new track	30 million ties
Present average life of ties	7 years
Requirements, assuming annual increase in trackage, of 10,000 miles, for next 21 years	4,000 million ties
Corresponding to over	200 billion board feet timber

Or 1-12th of our present standing forest.

Cost for 21 years with cut spikes:

Present cost per tie, including treatment, tie plates, spikes, etc.	$1.00 to $1.15
At present rate of increase in timber prices, cost as above, in 1931	$1.75 to $2.00
Average cost during next 21 years, approximately	$1.55
Total investment in ties, present practice, to 1931	$5,500,000,000

Cost for 21 years, with screw spikes:

Present cost per tie, average only 20 cents more than for cut spikes.	
Average present cost	$1.35
Average cost during next 21 years, if all renewal and new construction is made with screw spikes, approximately	$1.65
Tie requirements to 1931	less than 1,600 million ties.
Cost of same	$3,500,000,000
Saving from use of screw spikes	$2,000,000,000

These figures are sufficiently large to command respectful attention. They will be proportionately correct for any mileage that may comprise any system, or any mileage that may be assumed. They may err in gross, because of the impossibility of determining the relative number of ties used in main lines, which should be so treated, and in yards, where such treatment would not be generally followed.

With the national timber supply only sufficient to last 30 years,* with the certainty that the cost of ties will increase more rapidly in the future than it has in the past, with the necessity for conserving the timber supply of the country in the interests of economy and in order that timber may be obtainable for purposes for which no other materials are suitable, there can be no question that the time has come when this very important problem should receive the serious attention of everyone having to do with maintenance of track. The saving that can be effected will represent an addition to the net earnings of the railroads of the country. The total saving indicated by the above statements amounts to 4 per cent upon the enormous sum of *fifty billions of dollars.*

That this method was not introduced and used long ago is due to the fact that the timber supply of the United States has, until late years, been constantly referred to as inexhaustible. Sinful waste has characterized its use. Various lands have been cut over and only the most desirable and soundest trees of chosen varieties have been taken. They have been cut over again and all the timber that was then merchantable has been removed. Again, for the third time, they have been cut over and practically everything that would make a lath has been removed and utilized. Sections of the country which are still blessed by the possession of extensive forests, are prodigal in the use of timber, but the time will come within the next decade, or certainly within the next twenty years, when there will be no such sections, and no one now living can foretell with any accuracy what the price of timber and ties will then be.

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* Mr. Pinchot's estimate; see page 581.

Other very important savings in connection with this method are those incident to the reduction in the enormous cost of transporting the greater number of ties that are now required as compared with the lesser number that will be required if the sensible and more economical practice of European countries is followed. The average haul of crossties in 1905 being 500 miles, assuming the actual cost of transportation to the railroads to be 3 mills, the cost per tie transported was about 8 cents, and the cost of transporting the ties used annually, an average of 200 million for the next 21 years, would amount to $16,000,000 per year. If the life of the tie be increased three-fold, the cost of the transportation will be decreased almost to one-third of this amount, or to $6,400,000 per year, and the difference between these two costs represents an annual saving to the railroads of the United States of $9,600,000 or about $200,000,000 for the period.

Again, a common estimate of the cost of inserting a new tie is 15 cents. This includes all the operations necessary for removing the old tie, inserting a new one, and restoring the ballast. Applying the cost of 15 cents to the number of ties annually used results in showing a cost to the railroads of the Nation for removing old ones of $30,000,000 annually, whereas, if the foregoing arguments are correct this amount could be reduced to $12,000,000; and, really, the saving of $18,000,000 per year, or $378,000,000 for the period of 21 years, constituting the difference between these two sums does not represent the entire saving because the re-ballasting or re-surfacing is not completed at the time of the tie insertion, but in the aggregate, vast indeterminate sums of money must be spent to restore the track to standard condition, subsequent to tie renewals.

These computations do not take into consideration the cost of providing the enormous number of cars and locomotives required for the transportation of ties, or a fair compensation to the railroads for the use of such equipment. If they are not required for this purpose, it will either be possible to get along with less equipment or to use them for the transportation of revenue business.

The above computations, which show the apparent saving due to the adoption of a more rational and thorough system of track construction, do not take into account any interest charges which will properly accrue in connection with that portion of expenditures for ties used in construction, which are paid for with the proceeds from the sale of bonds.

The interest alone would amount to another vast indeterminate sum, according to the rate percent, whether applied to the whole investment or only to that in new track, whether compounded, etc. In any case it would run into the hundreds of millions.

It may be said that some substitute will be found for wooden ties. If the figures representing the average cost of ties during a period of 21 years are correct—and that cost is $1.55—there is very little probability that steel ties can be economically used. In the first place, they are not successfully used anywhere. Perhaps this statement is a little too positive, yet the testimony of American engineers who have investigated the subject abroad is to the effect that the men actually having to do with maintenance of track, even those who have had the longest experience with various types of steel ties, have very little to say in their favor.

It must be remembered, too, that the cost of steel is destined to increase, not in the same ratio as the cost of timber, perhaps,—still it must increase appreciably. It is believed at the present time that all of the large existing bodies of ore have been located and approximately defined. If this is true, the exhaustion of these measures will be similar to that which must take place in our forest supplies. The coal measures of the United States, and the tonnage that can be extracted therefrom, can be computed at the present time with comparative accuracy. Without doubt, the cost of coal must increase, and if it is also true, of which there can be no doubt, that the consumption of steel will increase enormously, its cost is bound to be higher. Of course, a satisfactory steel tie will be found, but the writer believes that it will be a combination tie made of steel and wood. If so, the problems of tie preservation and protection against mechanical wear will be similar to those which must be considered in connection with ties made entirely of wood.

No success has attended efforts to make ties of concrete, and if such a tie is finally constructed it must, in the opinion of the writer, be as a result of a combination of steel, concrete and wood, or some fibre which will afford the elasticity necessary to prevent the destruction of the rails.

The purpose of this paper is to draw attention to the magnitude of the problem, to its vastness. Some better and cheaper method of accomplishing the ends herein referred to may be discovered, but none has been, and the writer presents the problem to the American Railway Engineering and Maintenance of Way Association for consideration, with the hope that its study will result in the invention of expedients and methods superior to those suggested.

REPORT OF COMMITTEE XVI—ON ECONOMICS OF RAILWAY LOCATION.

(Bulletin 120.)

To the Members of the American Railway Engineering and Maintenance of Way Association:

The present year's work of the Committee on Economics of Railway Location was inaugurated Aprii 22, 1909, when the chairman issued a circular letter to the committee members outlining his ideas with reference to the work. Each member was requested to state which particular portion of the work he preferred for special study. All except two members responded either verbally or by letter and sub-committees were formed. Only two meetings have been held during the year, the first being an informal meeting of the Eastern members held in the office of Mr. Francis Lee Stuart in New York. The following members were present: Vice-Chairman Allen and Messrs. Stuart, Webb, Begien, Lavis and Parker. The second meeting was held at the Congress Hotel, Chicago, on November 16, 1909, those present being Chairman Shurtleff and Messrs. Begien, Dennis, Howard, Schwitzer and Webb.

The work of the Committee has been mostly toward presenting to the Association a few conclusions which will give a practical base or foundation on which to establish a method of estimating the relative economic values of various locations. In some cases the Committee's conclusions are radically different from accepted views of the past, but the conclusions are founded on practical tests and conditions as they exist, so far as possible.

There are two fundamental points which must be considered in order to base deductions with reference to the various elements entering into the question of economic location, namely: *Power and Resistance.* In many different practical tests variations in results have occurred owing to differences in standards of maintenance of track and equipment, and differences in details of construction of equipment. Exact rules for determining the power and resistances, which will apply in all cases, cannot be deduced; but approximations can be made of sufficient practical value when applied for the purposes intended.

POWER.

It is essential to know the useful power of the locomotive considered in estimating the relative economy of various locations. Where actual tests have been made under the prevailing local conditions, the problem is simple, as the actual available power for various speeds should be used. Where such tests have not been made, the problem is more complex.

The prevailing custom has been to calculate the power by using an arbitrary *Mean Effective Pressure* curve. With our modern large locomotives it has been impossible to realize the power calculated by this curve, particularly in sections of the country where the fuel is not of a very high thermal value.

The tractive power of a locomotive depends primarily on its steam-producing capacity, boiler pressure and size of cylinders and drivers. The steam-producing capacity fixes the maximum velocities that can be maintained at various cut-offs without reducing the boiler pressure, the cylinder measuring out the steam in fixed quantities depending on the length of cut-off. The greatest available power at any speed is the power obtained at the longest possible cut-off for that speed which does not affect the boiler pressure. Full cut-off and a high drawbar pull can be maintained up to a velocity where the cylinder displacement plus the amount of steam lost by leakages, condensation and through parts other than the cylinder, equals the steam-producing capacity of the boiler.

The most important points affecting the steam-producing capacity of a locomotive are the *quality* of fuel, *quantity* that can be properly fired in long continuous work and the ratio of heating surface to grate area. Location of heating surface and other details of design also affect the question, but to cover all the items producing the variables would be too complex a matter for this discussion, even were the information available. Information covering extensive tests is available only for locomotives burning fuel of the nature of semi-bituminous, bituminous and lignite coals, but these are the fuels used on the major portion of the mileage of the American Continent. In thermal value these fuels vary from 10,000 to 15,000 B.T.U. per pound. The fireman cannot handle any more of the lower grade coal in a given time than of the higher, consequently the same locomotive will produce a greater quantity of steam with the higher grade coal than with the poorer fuel under equal firing.

For estimating purposes it will be of sufficient accuracy to rate the steam-producing capacity of a locomotive directly proportional to the heat units in the fuel where the pounds of fuel fired of either quality is the same. As a matter of fact, other variables would enter here, since the quantity of ash and tendency to "clinker" would affect the combustion of fuel and consequently the steam production.

The locomotive tests at the St. Louis Exposition give considerable information with reference to evaporative tests. The fuel used was a high grade bituminous coal varying from 14,000 to 15,000 B.T.U. per pound, the greater portion being near the higher figure.

Locomotive No. 1499 had the lowest ratio of heating surface to grate area, being 50.4 to 1. Three of the locomotives were of about a ratio of 60 to 1, No. 535 representing the average evaporation of these three. No. 734, having a ratio of 75.3 to 1, was fired to the highest quantity per square foot of grate area per hour of any of the locomotives.

The evaporative performance of these three locomotives corrected for 15,000 B.T.U. fuel where the thermal value of fuel used in the various tests was less, has been platted and the following table shows the average equivalent hourly evaporation from and at 212 degrees per square foot of heating surface. The other locomotives tested did not have a sufficient number of tests within the practical limits of operation to calculate average curves.

Locomotive	No. 1499	No. 535	No. 734
Ratio H. S. to G. A.	50.4:1	60:1	75.3:1
Coal per sq. ft. G. A. per hour.	Pounds Equivalent Evaporation per sq. ft. heating surface.		
40	7.77	7.00	5.97
50	9.14	8.24	7.02
60	10.35	9.32	7.95
70	11.40	10.27	8.76
80	12.32	11.10	9.46
90	13.13	11.82	10.08
100		12.46	10.62
110		13.01	11.10
120		13.50	11.51
130			11.87
140			12.19
150			12.47

It will be noted that the increment of steam produced in each locomotive gradually decreased with each succeeding given increment of coal. Also that with a given quantity of fuel per square foot of grate area, the evaporation per sq. ft. of heating surface decreases as the ratio increases. Diagram No. 1 illustrates this point, the curves being produced beyond the limits of actual tests to a ratio of 95 to 1. The results for the higher ratios may be somewhat at variance with actual averages for these higher ratios, but until further tests are available it is assumed that their use will not cause great error in estimating for present purposes. At the St. Louis tests from one and one-half to three per cent. of water evaporated was lost in leakages and used for other purposes than through the cylinders. In actual road work there would be loss from radiation owing to movement of locomotive, also loss through whistle, air pump, etc.; consequently the actual useful steam produced would be at least five per cent. less than shown at testing plant, and in case of water troubles, necessitating frequent blowing off, or where scale forms in boilers, the heat losses would be much higher.

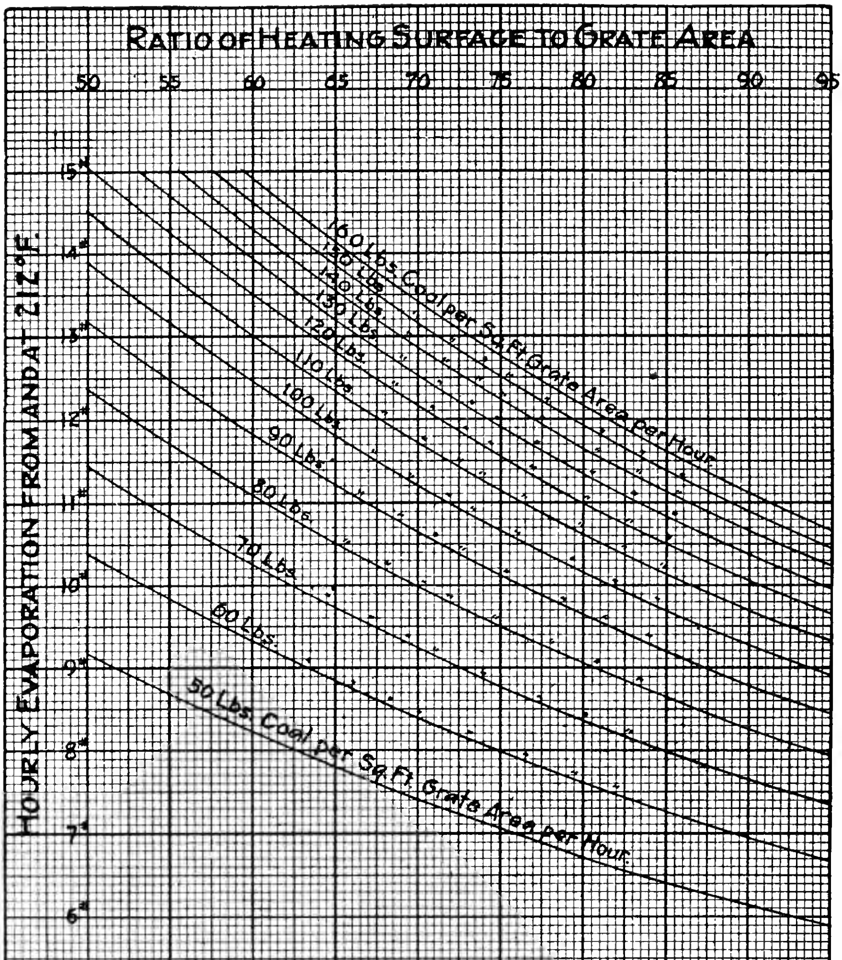

DIAGRAM Nº 1.

EQUIVALENT HOURLY EVAPORATION FROM AND AT 212° PER SQ. FT. HEATING SURFACE FOR VARIOUS QUANTITIES OF FUEL AVERAGING 15000 B.T.U. PER POUND.

TABLE Nº 1.

AVERAGE HOURLY EVAPORATION PER 1000 FT. OF HEATING SURFACE FOR VARIOUS RATIOS OF HEATING SURFACE TO GRATE AREA AND FOR VARIOUS RATES OF FUEL CONSUMPTION BASED ON USE OF BITUMINOUS COAL TESTING 15000 B.T.U. PER POUND.

RATIO	LBS. COAL PER SQ. FT. GRATE AREA PER HOUR										
	60	70	80	90	100	110	120	130	140	150	160
R=50	8136	8965	9690	10324	10879	11365	11790	12162	12487	12771	13020
R=55	7697	8480	9165	9764	10288	10747	11149	11501	11809	12079	12314
R=60	7295	8037	8686	9254	9751	10186	10567	10900	11191	11446	11669
R=65	6913	7617	8233	8772	9244	9657	10018	10334	10610	10852	11064
R=70	6566	7234	7818	8329	8776	9167	9509	9808	10070	10299	10500
R=75	6238	6874	7430	7917	8343	8716	9042	9327	9576	9794	9985
R=80	5939	6542	7070	7532	7936	8289	8598	8868	9104	9311	9492
R=85	5677	6255	6761	7204	7591	7930	8227	8487	8714	8912	9085
R=90	5440	5993	6477	6900	7270	7594	7878	8126	8343	8533	8699
R=95	5211	57.41	6205	6611	6966	7277	7549	7787	7995	8177	8336

ABOVE TABLE ASSUMES FEED WATER AT AVERAGE OF 60° F. AND BOILER PRESSURE 200 LBS. FOR 160 POUNDS BOILER PRESSURE APPROXIMATELY ONE HALF PER CENT GREATER QUANTITY WOULD BE EVAPORATED.

FOR COAL OF DIFFERENT THERMAL VALUE THAN 15000 B.T.U. MULTIPLY TABULAR AMOUNTS BY FOLLOWING DECIMALS:

14500 B.T.U.	- 0.967	12000 B.T.U.	- 0.80
14000 "	- 0.933	11500 "	- 0.767
13500 "	- 0.900	11000 "	- 0.733
13000 "	- 0.867	10500 "	- 0.70
12500 "	- 0.833	10000 "	- 0.667

Table No. 1 is deduced from diagram No. 1 considering a "good water" district and deducting only five per cent. from the evaporation as shown at testing plants. This table shows actual evaporation from a feed water temperature of 60 degrees to a boiler pressure of 200 lbs. For a pressure of 160 lbs. the evaporation would be only one-half per cent. more, and as changes in details of boiler can often make a greater variance than this, the table can be used for all locomotive boiler pressures without great error. However, if bad water must be used, a proper deduction should be made from the figures given in the table. Where fuel is of different thermal value than 15,000 B.T.U., multiply the tabular value by the proper coefficient, as shown below table No. 1.

The quantities given in diagram No. 1 are less than the quantities given by G. R. Henderson in "Locomotive Operation," but his diagram was probably based on a higher rate of coal per square foot of grate area per hour than can be properly fired in our modern large locomotives. At St. Louis in the maximum firing tests they were obliged to give relief to firemen during the three-hour runs. It is a common occurrence for firemen to "play out" during the heat of summer in an attempt to handle the average tonnage. An average of two tons of coal (4,000 lbs.) per hour is believed to be a fairly high quantity of coal to be fired properly during heavy work of the locomotive, and in using the table it is recommended that the rate per square foot of grate area per hour be based on not more than this amount. For short periods, or after a rest at a station, the fireman will occasionally do better than this, but a study of the dynamometer record occasionally reveals the point where the fireman gradually tires and finally comes down to his steady capacity for long pulls.

The maximum velocity at which full cut-off can be maintained is obtained by dividing the total weight of steam produced per minute by the total weight given to the cylinders in one revolution of drivers, the result being the maximum number of revolutions of drivers per minute at full cut-off. This can readily be changed into velocity in miles per hour.

The weight of steam given to cylinders per revolution will vary in quantity for locomotives of same size high pressure cylinders but with different details with reference to steam-producing capacity, size of port opening and character of cylinder lagging. The steam furnished to cylinders can be divided into that which performs work and that which is lost by condensation, leakages, etc. The higher the number of revolutions made or the smaller the port openings, the more wire drawn the steam becomes and the less the quantity furnished. Wire drawing reduces the mean effective pressure and the temperature of the steam. With the slower speeds and with poorer lagging of cylinders, the loss by condensation is high. In average work the loss of steam at maximum velocity for full cut-off will practically offset the reduction in loss of pressure of useful steam; and the weight of steam used

TABLE Nº 2.

WEIGHT OF STEAM USED IN ONE FOOT OF STROKE IN LOCOMOTIVE CYLINDERS

CYLINDER DIAMETER IS FOR HIGH PRESSURE CYLINDERS IN COMPOUND LOCOMOTIVES

DIAMETER OF CYLINDER IN INCHES	WEIGHT OF STEAM PER FOOT STROKE FOR VARIOUS GAGE PRESSURES						
	220#	210#	200#	190#	180#	170#	160#
12	0.405 LBS	0.389 LBS	0.370 LBS.	0.354 LBS.	0.337 LBS	0.321 LBS.	0.304 LBS
13	0.475 "	0.456 "	0.435 "	0.415 "	0.396 "	0.376 "	0.357 "
14	0.551 "	0.529 "	0.504 "	0.482 "	0.459 "	0.436 "	0.414 "
15	0.633 "	0.607 "	0.579 "	0.553 "	0.527 "	0.501 "	0.476 "
15½	0.675 "	0.649 "	0.618 "	0.590 "	0.562 "	0.535 "	0.508 "
16	0.720 "	0.691 "	0.658 "	0.629 "	0.599 "	0.570 "	0.541 "
17	0.812 "	0.780 "	0.744 "	0.710 "	0.676 "	0.643 "	0.611 "
18	0.911 "	0.875 "	0.834 "	0.796 "	0.759 "	0.722 "	0.685 "
18½	0.962 "	0.924 "	0.881 "	0.841 "	0.801 "	0.762 "	0.724 "
19	1.015 "	0.975 "	0.928 "	0.887 "	0.845 "	0.804 "	0.763 "
19½	1.069 "	1.027 "	0.978 "	0.934 "	0.890 "	0.847 "	0.804 "
20	1.125 "	1.080 "	1.029 "	0.983 "	0.936 "	0.891 "	0.846 "
20½	1.181 "	1.134 "	1.081 "	1.032 "	0.984 "	0.936 "	0.888 "
21	1.240 "	1.191 "	1.134 "	1.083 "	1.032 "	0.982 "	0.932 "
22	1.361 "	1.307 "	1.245 "	1.189 "	1.133 "	1.078 "	1.023 "
23	1.487 "	1.428 "	1.361 "	1.300 "	1.238 "	1.178 "	1.118 "
28	2.204 "	2.117 "	2.017 "	1.926 "	1.835 "	1.745 "	1.657 "

FOR WEIGHT OF STEAM USED PER REVOLUTION OF DRIVERS AT FULL CUT-OFF:-

MULTIPLY THE TABULAR QUANTITY BY FOUR TIMES THE LENGTH OF STROKE IN FEET FOR SIMPLE AND FOUR CYLINDER COMPOUNDS. FOR TWO CYLINDER COMPOUNDS MULTIPLY BY TWO TIMES THE LENGTH OF STROKE at full cut-off can be estimated on the basis of an equal volume of steam at full boiler pressure.

Table No. 2 gives the weight of steam for one foot of stroke for various cylinder diameters and boiler pressures. In using this table in calculating steam used by compound locomotives, the diameters of high pressure cylinders must be used. For simple and four-cylinder compound locomotives multiply the tabular quantity per linear foot of cylinder by four times the length of stroke. For two-cylinder compounds, multiply by twice the length of stroke.

The revolutions per minute can be changed to velocity in miles per hour by dividing by "C," as given in Table No. 3.

TABLE NO. 3.

Values of coefficient "C" for changing revolutions per minute of drivers into velocity in miles per hour.

$$\text{"C"} = \frac{336.13}{\text{Diameter of drivers in inches.}}$$

$$\text{Miles per hour} = \frac{\text{Revolutions per minute}}{\text{"C"}}$$

Diam.	"C"	Diam.	"C"	Diam.	"C"	Diam.	"C"
50 in.	6.72	58 in.	5.79	66 in.	5.09	74 in.	4.54
51 "	6.59	59 "	5.69	67 "	5.01	75 "	4.48
52 "	6.46	60 "	5.60	68 "	4.94	76 "	4.42
53 "	6.34	61 "	5.51	69 "	4.87	77 "	4.36
54 "	6.22	62 "	5.42	70 "	4.80	78 "	4.31
55 "	6.11	63 "	5.33	71 "	4.73	79 "	4.25
56 "	6.00	64 "	5.25	72 "	4.67	80 "	4.20
57 "	5.89	65 "	5.17	73 "	4.60	81 "	4.15

As before stated, the losses of steam at higher velocities and shorter cut-offs are less than at the lower speeds and the wire drawing is greater, consequently the maximum possible cut-off does not decrease in the same proportion that velocity increases. Details of valves and valve motion will produce variables as to the rate of decrease in cut-off; also as to rate of steam consumption per I.HP. hour at the maximum cut-offs for the different velocities. Mr. Henderson's "Locomotive Operation" in the chapter on "Water Consumption" takes this question up, and Table No. 4 gives approximate cut-offs for various multiples of "M," or the velocity at which full cut-off can be maintained, which agree practically with Mr. Henderson's figures. The quantity of water per I.HP. hour are somewhat higher than the figures given on the diagram in "Locomotive Operation," but are from averages secured at the St. Louis testing plant and at the Purdue University plant when locomotives were worked at longest cut-off for given velocities and still maintained boiler pressure.

TABLE Nº4.

MAXIMUM CUT-OFF AND POUNDS OF STEAM PER I.H.P. HOUR FOR VARIOUS MULTIPLES OF "M".

"M" = MAXIMUM VELOCITY IN MILES PER HOUR AT FULL CUT-OFF. BOILER PRESSURE, 200 LBS.

VELOCITY	PER CENT CUT-OFF	LBS. STEAM PER I. H. P. HOUR	
		SIMPLE LOC.	COMPOUND LOC.
1.0 "M"	FULL	38.30	25.80
1.1 "	94.4	36.46	24.36
1.2 "	89.1	34.89	23.24
1.3 "	84.3	33.56	22.35
1.4 "	79.7	32.41	21.65
1.5 "	75.4	31.40	21.14
1.6 "	71.4	30.49	20.77
1.7 "	67.7	29.67	20.52
1.8 "	64.3	28.93	20.40
1.9 "	61.0	28.25	20.40
2.0 "	58.0	27.62	20.40
2.1 "	55.2	27.05	20.40
2.2 "	52.6	26.52	20.40
2.3 "	50.1	26.06	20.40
2.4 "	47.8	25.67	20.40
2.5 "	45.7	25.32	20.47
2.6 "	43.7	25.02	20.60
2.7 "	41.8	24.76	20.73
2.8 "	40.1	24.54	20.88
2.9 "M"	38.5	24.37	21.04
3.0 "	37.0	24.22	21.21
3.2 "	34.2	24.00	21.57
3.4 "	31.8	23.85	21.93
3.6 "	29.8	23.8	22.27
3.8 "	28.0	23.8	22.57
4.0 "	26.4	23.87	22.85
4.25 "	24.7	24.05	23.22
4.50 "	23.3	24.24	23.56
4.75 "	22.1	24.44	23.85
5.00 "	21.1	24.64	24.15
5.5 "	19.5	24.98	24.70
6.0 "	18.4	25.20	
6.5 "	17.6	25.45	
7.0 "	17.1	25.60	
7.5 "	16.7	25.70	
8.0 "	16.4	25.80	
9.0 "	16.1	25.90	

FOR STEAM PER I.H.P. HOUR FOR OTHER BOILER PRESSURES TAKE THE FOLLOWING PERCENTAGES OF VALUES GIVEN IN TABLE;

160 LBS. - 103%	190 LBS. - 100.6%
170 LBS. - 102.1%	210 LBS. - 99.5%
180 LBS. - 101.3%	220 LBS. - 99.2%

TABLE Nº5.

PER CENT CYLINDER TRACTIVE POWER
FOR
VARIOUS MULTIPLES OF "M"

"M" = MAXIMUM VELOCITY IN MILES PER HOUR AT WHICH BOILER PRESSURE CAN BE MAINTAINED WITH FULL CUT-OFF.

VELOCITY	COMPOUND %	SIMPLE %	VELOCITY	COMPOUND %	SIMPLE %	VELOCITY	COMPOUND %	SIMPLE %
START	(SIMPLE) 135.00	106.00	3.6 M.	32.40	44.75	6.4 M		23.59
0.5 M.	103.00	103.00	3.7 ″	31.25	43.56	6.5 ″		23.18
1.0 ″	100.00	100.00	3.8 ″	30.10	42.39	6.6 ″		22.79
1.1 ″	96.28	95.57	3.9 ″	29.14	41.24	6.7 ″		22.42
1.2 ″	92.55	91.53	4.0 ″	28.24	40.10	6.8 ″		22.06
1.3 ″	88.83	87.83	4.1 ″	27.38	39.00	6.9 ″		21.71
1.4 ″	85.12	84.46	4.2 ″	26.56	37.96	7.0 ″		21.38
1.5 ″	81.40	81.37	4.3 ″	25.77	36.97	7.1 ″		21.06
1.6 ″	77.68	78.55	4.4 ″	25.03	36.03	7.2 ″		20.75
1.7 ″	73.96	75.97	4.5 ″	24.34	35.13	7.3 ″		20.45
1.8 ″	70.25	73.60	4.6 ″	23.69	34.26	7.4 ″		20.16
1.9 ″	66.54	71.41	4.7 ″	23.07	33.41	7.5 ″		19.88
2.0 ″	63.21	69.37	4.8 ″	22.48	32.59	7.6 ″		19.61
2.1 ″	60.20	67.47	4.9 ″	21.92	31.82	7.7 ″		19.34
2.2 ″	57.48	65.67	5.0 ″	21.38	31.11	7.8 ″		19.08
2.3 ″	54.97	63.94	5.1 ″	20.87	30.42	7.9 ″		18.82
2.4 ″	52.68	62.22	5.2 ″	20.37	29.75	8.0 ″		18.57
2.5 ″	50.42	60.55	5.3 ″	19.89	29.10	8.1 ″		18.33
2.6 ″	48.16	58.92	5.4 ″	19.43	28.48	8.2 ″		18.09
27 ″	46.08	57.33	5.5 ″	18.99	27.87	8.3 ″		17.86
2.8 ″	44.10	55.78	5.6 ″		27.33	8.4 ″		17.64
2.9 ″	42 29	54.26	5.7 ″		26.81	8.5 ″		17.43
3.0 ″	40.57	52.78	5.8 ″		26.30	8.6 ″		17.22
3.1 ″	38.95	51.33	5.9 ″		25.81	8.7 ″		17.01
3.2 ″	37.42	49.91	6.0 ″		25.34	8.8 ″		16.82
3.3 ″	35.98	48.55	6.1 ″		24.88	8.9 ″		16.63
3.4 ″	34.66	47.24	6.2 ″		24.44	9.0 ″		16.45
3.5 ″	33.53	45.97	6.3 ″		24.01			

It will be noted that Table No. 4 is for boiler pressures of 200 lbs. The coefficients for other boiler pressures are given to make corrections for steam per I.HP. hour for the other pressures and agree closely with figures given by Professor Goss in a report to the Carnegie Institute of Washington (see Serial No. 66). Having obtained the value of "M," the cylinder or indicated horse-power of the locomotive at the different velocities can be obtained by dividing by the pounds steam per I.HP. hour corrected for the proper boiler pressure as given in Table No. 4. The horse-power can be converted into cylinder tractive power by multiplying horse-power by 375 and dividing the product by the velocity in miles per hour.

The percentage of indicated horse-power or percentage of indicated tractive power for any two simple locomotives at given multiples of "M" for each locomotive, will be the same regardless of the value of "M" for each locomotive, assuming the power at "M" as 100 per cent. To simplify the calculation Table No. 5 has been compiled showing percentages of cylinder tractive power for various multiples of "M," and after determining the I.HP. and cylinder tractive power for maximum velocity at full cut-off, the power at any other velocity can be determined by one operation.

It will be noted that the indicated or cylinder tractive power at velocity "M" is approximately equivalent to calculated power in the well-known formulas using 0.85 of boiler pressure in simple and two-cylinder compound locomotives and 1.7 boiler pressure in four-cylinder balanced compounds and Vauclain compounds. The general practice has been to use the decimals 0.8 and 1.6, respectively, for simple and four-cylinder compound locomotives, but with these lower decimals the power is assumed to be the power at rim of drivers, while figures given by recommended methods give the indicated power, the resistance through cylinders and mechanism of locomotive to the rim of the drivers being taken care of later.

The indicated tractive power at velocities below "M" is based on M.E.P. in cylinders of simple locomotives at starting, being 90 per cent. of boiler pressure and gradually decreasing to the power at "M" velocity. This is lower than has been shown in many tests at the very slow speeds, but as the resistance of locomotive at starting is undoubtedly higher than the frictional and other resistances after getting the journals warmed up, the 90 per cent. M.E.P. is considered a conservative figure to use. The compound locomotive is started working "simple" and the starting power is much higher in proportion than the power at "M" velocity. As a matter of fact, the majority of compound locomotives can "slip" the drivers when starting under full throttle.

Table No. 6 is given to eliminate one mathematical operation in changing horse-power to tractive power; multiplying the tabular values by the H.P., the product is the tractive power. The indicated power

TABLE Nº 6.

POUNDS TRACTIVE POWER FOR ONE HORSE POWER
AT
VARIOUS SPEEDS

Formula: $1\ \text{H.P.} = \frac{375}{\text{Velocity in Miles per Hour.}}$

VELOCITY.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
3	125.0	120.97	117.19	113.64	110.29	107.14	104.17	101.35	98.68	96.15
4	93.75	91.46	89.29	87.21	85.23	83.33	81.52	79.79	78.13	76.53
5	75.00	73.53	72.12	70.75	69.44	68.18	66.96	65.79	64.66	63.56
6	62.50	61.48	60.48	59.52	58.59	57.69	56.82	55.97	55.15	54.35
7	53.57	52.82	52.08	51.37	50.68	50.00	49.34	48.70	48.08	47.47
8	46.88	46.30	45.74	45.18	44.64	44.12	43.60	43.10	42.61	42.13
9	41.67	41.21	40.76	40.32	39.89	39.47	39.06	38.66	38.27	37.88
10	37.50	37.13	36.77	36.41	36.06	35.71	35.38	35.05	34.72	34.40
11	34.09	33.78	33.48	33.19	32.89	32.61	32.33	32.05	31.78	31.51
12	31.25	30.99	30.74	30.49	30.24	30.00	29.76	29.53	29.30	29.07
13	28.85	28.63	28.41	28.20	27.99	27.78	27.57	27.37	27.17	26.98
14	26.79	26.60	26.41	26.22	26.04	25.86	25.68	25.51	25.34	25.17
15	25.00	24.83	24.67	24.51	24.35	24.19	24.04	23.88	23.73	23.58
16	23.44	23.29	23.15	23.01	22.87	22.73	22.59	22.46	22.32	22.19
17	22.06	21.93	21.80	21.68	21.55	21.43	21.31	21.19	21.07	20.95
18	20.83	20.72	20.60	20.49	20.38	20.27	20.16	20.05	19.95	19.84
19	19.74	19.63	19.53	19.43	19.33	19.23	19.13	19.03	18.94	18.84
20	18.75	18.66	18.56	18.47	18.38	18.29	18.20	18.12	18.03	17.94
21	17.86	17.77	17.69	17.61	17.52	17.44	17.36	17.28	17.20	17.12
22	17.05	16.97	16.89	16.82	16.74	16.67	16.59	16.52	16.45	16.37
23	16.30	16.23	16.16	16.09	16.03	15.96	15.89	15.82	15.76	15.69
24	15.63	15.56	15.50	15.43	15.37	15.31	15.24	15.18	15.12	15.06
25	15.00	14.94	14.88	14.82	14.76	14.71	14.65	14.59	14.53	14.48
26	14.42	14.37	14.31	14.26	14.20	14.15	14.10	14.04	13.99	13.94
27	13.89	13.84	13.79	13.74	13.68	13.63	13.59	13.54	13.49	13.44
28	13.39	13.35	13.30	13.25	13.20	13.16	13.11	13.07	13.02	12.98
29	12.93	12.89	12.84	12.80	12.76	12.71	12.67	12.63	12.58	12.54
30	12.50	12.46	12.42	12.38	12.34	12.30	12.26	12.22	12.18	12.14
31	12.10	12.06	12.02	11.98	11.94	11.90	11.87	11.83	11.79	11.76
32	11.72	11.68	11.65	11.61	11.57	11.54	11.50	11.47	11.43	11.40
33	11.36	11.33	11.30	11.26	11.23	11.19	11.16	11.13	11.09	11.06
34	11.03	11.00	10.96	10.93	10.90	10.87	10.84	10.81	10.78	10.74
35	10.71	10.68	10.65	10.62	10.59	10.56	10.53	10.50	10.47	10.44
36	10.42	10.39	10.36	10.33	10.30	10.27	10.24	10.21	10.18	10.16

For intermediate velocities, values per horse power can be found by interpolation.

of locomotives having been obtained, the available drawbar pull on level tangent can be obtained by deducting the resistance of the locomotive.

The first step is resistance between cylinder and rim of drive wheels. On this subject Professor Goss says: "It is difficult to summarize the facts concerning engine friction. This is not due to defects in the experimental process underlying the data, but to the fact that the frictional resistance of the machinery of the locomotive varies greatly from day to day." Sufficient experiment has been made to demonstrate that for practical purposes the friction between cylinder and rim of drivers, when measured in total pounds resistance, averages about the same for a given engine regardless of speeds after the bearings have become warmed up. The figures also demonstrate that frictional resistance per ton of weight on drivers reduces as the weight per axle increases.

The following shows the average of several tests at Purdue and St. Louis testing plants:

			Weight on Drivers.			Resistance	
Loc. No.	Testing Point	Type	Total Tons	Tons Per axle	Number Tests	Average Total	Per Ton
2	Purdue	4-4-0	30.5	15.25	49	730 lbs.	23.9
734	St. Louis	2-8-0	81.3	20.33	14	1733 "	21.3
585	St. Louis	2-8-0	82.25	20.56	13	1828 "	22.2
2512	St. Louis	4-4-2	43.93	21.96	10	1032 "	23.5
628	St. Louis	4-4-2	32.68	16.34	10	764 "	23.4
3000	St. Louis	4-4-2	55.0	27.5	9	1190 "	21.6
			Average for all..........................				22.65

In the above table all tests have been omitted where grease was used as a lubricant and also such tests as appeared to vary widely from the majority of the tests, probably due to some condition arising which could not be discovered or accounted for at the time of test.

No great error would arise in using the average shown above of 22.65 lbs. per ton of weight on the drivers, but greater accuracy would be attained by considering the resistance between cylinder and rim of drivers under the formula A in Table No. 7, which takes into consideration not only the weight on drivers but the number of axles which carry the load.

The second step, or resistance of trucks under engine and tender, is cared for under formula B of Table No. 7. This formula also considers the number of axles carrying the load. No great error would arise in using an average of 4 lbs. per ton for this resistance, but the calculation of resistances on both formulas A and B is simple and greater accuracy would be obtained by their use. The standards of maintenance would affect the values of the factors applied to T in the formulas, but the factors given are probably best suited for average conditions.

TABLE No 7.

Locomotive Resistances

Ⓐ Cylinder to Rim of Drivers:
Total Pounds $R = 18.7T + 80N$
T = Tons weight on drivers
N = Number driving axles

Ⓑ Engine and Tender Trucks:
Total Pounds $R = 2.6T + 20N$
T = Tons weight on engine and tender trucks.
N = Number of truck axles

Ⓒ Head End or "Air" Resistance
$R = .002V^2A$;---- V = Velocity in Miles per hour
A = Area (Average for Locomotives,-125 sq. ft.)

Total $R = 0.25V^2$

Air Resistance (C) for Various Velocities.

Velocity	R	Velocity	R	Velocity	R	Velocity	R
1	0.25	11	30	21	110	31	240
2	1.00	12	36	22	121	32	256
3	2.25	13	42	23	132	33	272
4	4.00	14	49	24	144	34	289
5	6.25	15	56	25	156	35	306
6	9.00	16	64	26	169	36	324
7	12.25	17	72	27	182	37	342
8	16.00	18	81	28	196	38	361
9	20.25	19	90	29	210	39	380
10	25.00	20	100	30	225	40	400

Draw Bar Pull on Level Tang't equals the Cylinder Tractive Power less the sum of Engine Resistances.

AT LOW SPEEDS THE ADHESION OF DRIVERS SHOULD BE CONSIDERED AND AVAILABLE DRAW BAR PULL SHOULD NEVER BE ESTIMATED GREATER THAN
30% OF WEIGHT ON DRIVERS AT STARTING WITH USE OF SAND.
25% " " " " RUNNING SPEEDS.

The velocity or head end resistance is generally assumed to vary with the square of the speed. Professor Goss has placed this at $0.11V^2$. Authorities differ widely as to the factor to be used per sq. ft. of sectional area. F. J. Cole, of the American Locomotive Works, in a recent study of "Train Resistance" for the Railroad Age Gazette (Railroad Age Gazette, October 1, 1909), places the resistance at $.002V^2$ per sq. ft. area. Table No. 7 gives the values for various velocities on this basis, using 125 sq. ft. area as an average, a somewhat higher area than assumed by Mr. Cole in his paper.

Attention is called to the fact that should the calculated drawbar pull on level tangent exceed 30 per cent. of the weight on drivers at starting, with use of sand, or 25 per cent. at running speeds, the percentages of driver weights given should be used for drawbar pull at the respective speeds rather than the higher values obtained by calculation.

Appendix A shows a number of diagrams of calculated drawbar pull on the basis outlined herein and actual recorded drawbar pull reduced to level grade at maintained velocities.

Your Committee recommends that the following conclusions and tables mentioned therein be adopted for publication in the Manual with a view of furnishing a reasonable and logical method of determining the available power of any given locomotive, it being distinctly understood that as further research and data are secured, the tables and rules can be changed when considered advisable.

CONCLUSIONS AND RECOMMENDATIONS.

Power.

(1) Actual drawbar pull of the locomotive at various speeds should be used in making estimates with reference to economic value of various locations of line and grade, where such drawbar pull is known. Where not known, the drawbar pull should be calculated. In comparing a new line with an existing line the same percentage of efficiency of drawbar pull should be used in both cases.

(2) The tractive power of a locomotive depends on its steam-producing capacity, the boiler pressure, the adhesion, and the size of the cylinders and drivers.

*(3) The steam-producing capacity of a locomotive depends mainly upon the quantity and quality of the fuel burned, the amount of heating surface, and the ratio of heating surface to grate area.

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*Amend to read: "The steam-producing capacity of a locomotive depends mainly upon the quantity and quality of the fuel burned and the area of heating surface."

*(4) Knowing the areas of grate and heating surface, the average steam production of locomotives burning bituminous and similar coals can be estimated by the use of Table No. 1, assuming 4,000 lbs. of coal as the maximum quantity that can be properly "fired" per hour.

(5) The maximum velocity at which full cut-off can be maintained can be found by dividing the pounds steam produced per minute by the quantity of steam used per revolution of the drivers, as shown in Table No. 2. Dividing this quotient by the coefficient given in Table No. 3 for the diameter of the drivers will give the speed in miles per hour at which full cut-off can be maintained. This velocity is referred to as "M" in the tables.

(6) Tractive power of a locomotive is greatest at starting, gradually reducing to the maximum velocity ("M") at which full cut-off can be maintained. At speeds above this velocity the tractive power decreases more rapidly. The tractive power at any multiple of "M" is practically a fixed percentage of the tractive power at "M." The fixed percentages are different for compound types than for simple locomotives.

(7) Knowing the steam production of a locomotive and the maximum velocity at which full cut-off can be maintained ("M"), the indicated horse-power of the locomotive can be obtained for velocity "M" or higher velocities by dividing the total steam produced per hour by the quantity of steam used per I.HP. hour, as given in Table No. 4, after applying the corrections for proper boiler pressure.

(8) Horse-power can be converted into tractive power by the formula, tractive power equals 375 times the HP., divided by the velocity in miles per hour. To simplify the operation, the tractive power can be obtained by multiplying the HP. by the figures shown in Table No. 6.

(9) Where I.HP. at "M" velocity has been converted into cylinder tractive power, the cylinder tractive power at other multiples of "M" can be determined by using the percentages given in Table No. 5 without first calculating the I.HP. for the respective multiples of M.

†(10) Available drawbar pull on level tangent is the cylinder tractive power less the sum of the resistances from the cylinder to the rim of drivers, the resistance through the trucks of engine and tender, and the "head end" or velocity resistance. The formulas and data given in Table No. 7 are recommended for use in determining these resistances. †Available drawbar pull at starting, with use of sand, should not usually be considered as greater than 30 per cent. of the weight on locomotive drivers and at running speeds not greater than 25 per cent.

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*Amend to read: "Knowing the area of heating surface," etc.

†Amend to read: "Available drawbar pull at starting, with use of sand, should not be considered greater than," etc.

TRAIN RESISTANCE AND CURVE RESISTANCE.

While it is impossible to deduce rules for absolute freight tonnage rating between speeds of seven to thirty-five miles per hour, owing to variables which must be allowed for at the beginning of each trip, it is feasible to make a formula which will be sufficiently accurate for purposes of comparing locations, and one which may be used as a base to which corrections may be applied.

As is well understood, corrections must be applied for:

(1) Temperature (always allowed for).

(2) Condition of equipment.

(3) Amount and character of curvature. (Allowed for by adding to ruling grade if uncompensated.)

(4) Condition of roadbed, i. e., class of maintenance. (An important consideration not taken into account as it should be.)

(5) Local conditions, such as short passing sidings or limited facilities, which would curtail the length of a train.

(6) Length of grade. (Grades over five miles in length will cause reduction of train load with coal-burning engines.)

(7) Kind of fuel. (For instance, with oil fuel, engines will accelerate on long ruling grades, where, with coal, they might not haul their rating.)

(8) Efficiency of operatives.

(1) Formula of Mr. A. C. Dennis:

Under date of August, 1909 (Bulletin No. 114, A. R. E. & M. of W. Association), Mr. Dennis produced a formula

$$R = 2.6\,t + 85\,n$$

where t = tonnage of cars in train, and n = number of cars.

A little closer working of his data gives $R = 2.41\,t + 89.6\,n$

The cases cited show a remarkable uniformity, which would indicate that the conditions under which the results were attained were about the same. The cars were all box cars.

(2) Baltimore & Ohio Railroad Tests:

In April, 1904, certain tests were made on the Baltimore & Ohio Railroad with coal hoppers, which were conducted under such satisfactory conditions as to make some conclusions of value. Mr. J. R. Onderdonk, Engineer of Tests, conducted these tests. The accompanying record shows the data of some of the tests:

RECORDS OF DYNAMOMETER TESTS.

DATE	April, 1904 Constant Speed	April, 1904 Constant Speed	May, 1906 Constant Speed	April, 1904 Constant Speed	April, 1904 Constant Speed
Speed	10 M.P.H.	10 M.P.H.	6.5 M.P.H.	15 M.P.H.	15 M P.H.
Engine	2343	2343	2646	2343-1821-1403	2343
Location	North Mntn. Cut-off	North Mntn. Cut-off	Mt. Airy Hill	Mt. Airy Hill	Adamstown Cut-off
Grade	.3%	.3%	.85%	.85%	.30%
Curvature	Max. 4°	Max. 4°	2° 30′	Tangent	Tangent
Track	Good—Rock Ballast	Good—Rock Ballast	Fair—Cinder Ballast	Fair—Cinder Ballast	Fair—Cinder Ballast
Rail	85 lb.	85 lb.	85 lb.	85 lb.	85 lb.
Compensated	.03	.03	.03	....	....
Number of cars	38	38	26	32	32
Kind of Cars	36 loaded Coal Hoppers	36 empty Coal Hoppers	24 Coal Hoppers	30 loaded Coal Hoppers	30 loaded Coal Hoppers
Weight of Cars	687.5 tons	687.5 tons	468.0 tons	582 tons	582 tons
Caboose	9.5 tons	9.5 tons	9.5 tons	9.5 tons	9.5 tons
Dynamometer Car	17 tons	17 tons	17 tons	17 tons	17 tons
Total Number of Cars	38	38	26	32	32
Total Tonnage	2533	714	1513	2113	2113
Resistance by Dynamometer	27195	11504	34630	45600	23100
Resistance on level	12000	7220	8531	9679	10422
Formula deduced	....	....	$R = 2.68t + 143.8n$*	....	....
Resistance in lbs. per ton	4.73	10.11	5.64	4.58	4.92

*Deduced from the five tests cited.

From the foregoing tests it would appear that, on the class of line that is covered by the tests, coal hoppers need a higher factor than box cars. In the eastern part of the United States, especially among the mountains, alinement is crooked, and even if curvature is compensated long trains often get on two or more curves at once, with the result that compensation is not sufficient to offset the fact that the trucks do not straighten themselves out in accordance with the theory that they should do so. The result is a greater resistance than would be shown on a uniformly straight line. This fact may account for the high unit resistance shown on these tests.

OTHER FORMULAS FOR TRAIN RESISTANCE.

Based on a large number of tests made on the Baltimore & Ohio Railroad in 1904, a formula was evolved which has since been used by that road. When reduced to a form equivalent to Mr. Dennis', it is:

$$R = 2.78\,t + 113.9\,n$$

This formula has been found to meet working conditions fairly well when corrected to meet local peculiarities—temperature, etc. It would, however, call for a lower adjustment per car than the formula $R = 2.68\,t + 143.8\,n$, and accordingly would call for a higher rate of correction to meet loal conditions.

Following is an exposition of the formula with corrections for temperature and adjustments in tons per car:

SYSTEM TO DETERMINE RATING FOR LOCOMOTIVES.

Let P = Pulling power of locomotive (lbs.).
E = Weight of engine and tender (lbs.).
W = Weight of train (lbs.).
R = Rate of grade (tangent of angle).
K = Function of W (resistance).
N = Number of Cars.
C = Function of N (resistance).
and A = Rating.

Then as the general formula for train resistance

$$P = (E + W)\ (R + K)\ + N\,C \tag{1}$$

$$\frac{P}{R + K} - E = W + N\left(\frac{C}{R + K}\right)$$

$$\text{but } W + N\left(\frac{C}{R + K}\right) = A \tag{2}$$

$$\therefore \frac{P}{R + K} - E = A \tag{3}$$

TO DETERMINE VALUE OF K.

Let $\frac{P}{R' + K} - E = A'$ and $\frac{P}{R'' + K} - E = A''$ (Formula 3).

Then $P = (A' + E)\ (R' + K)$ and $P - (A'' + E)\ (R'' + K)$.

$\therefore A'R' + A'k + ER' + EK = A''R'' + A''K + ER''\ EK$,

from which we get

$$K = \frac{R''\,(A'' + E) - R'\,(A' + E)}{A' - A''}$$

Now by test, using E-24 engine,

When $R' = .003$, $A' = 6{,}970{,}000$ — .3% grade,

and when $R'' = .01$, $A'' = 2{,}480{,}000$ — 1% grade.

Also $E = 336{,}500$ weight of engine and loaded tender).

Substituting values for A′, A″, R′, R″, and E, we get,

$$K = \frac{.01\ (2{,}480{,}000 + 336{,}500) - .003\ (6{,}970{,}000 + 336{,}500)}{6{,}970{,}000 - 2{,}480{,}000}$$

or $K = .00139$ pounds per pound,

$= 2.78$ pounds per ton.

TO DETERMINE VALUE OF C.

Let $B = \dfrac{C}{R + K}$ = adjustment.

By test it is found that five tons is the proper adjustment for 1 per cent. grade, substituting values for B, R, and K,

$$10{,}000 = \frac{C}{.01 + .00139}$$

$$C = 113.9.$$

Example.—To determine adjustment for .3 per cent. grade knowing C and K,

$$B = \frac{C}{R + K}$$

Substituting values for C, R, and K, we get,

$$B = \frac{113 - 9}{.003 + .00139} = 25{,}945, \text{ or } 13 \text{ tons.}$$

TO DETERMINE VALUE OF P FOR E-24 ENGINE.

We have $A = \dfrac{P}{R + K} - E$ (Formula 3).

$\therefore\ P = (A + E)\ (R + K)$

As above when $R = .003$, $A = 6{,}970{,}000$.

E and K are known,

Substituting we get,

$$P = (6{,}970{,}000 + 336{,}500)\ (.003 + .00139)$$

$$P = 32{,}075.$$

TO DETERMINE THE RATING OF E-24 ENGINE ON VARIOUS GRADES.

We have from formula No. 3,

$$A = \frac{P}{R + K} - E$$

in which P, K, and E are known, substituting we get,

$$A = \frac{32075}{R + .00139} - 336{,}500$$

For example, to determine rating for a E-24 engine on .3 per cent. grade,

$$A = \frac{32075}{R + .00139} - 336{,}500$$

Substituting value R, we get, ...

$$A = \frac{32075}{.003 + .00139} - 336{,}500$$

$$A = 6{,}970{,}000$$

$$= 3{,}485 \text{ tons.}$$

TABLE SHOWING ADJUSTMENT FOR VARIOUS GRADES.

Per cent. of grade.	Adjustment in tons.
.3	13
.35	12
.4	11
.45	10
.5	9
.55	8
.6	8
.65	7
.7	7
.75	7
.8	6
.65	6
.9	6
.95	5
1.0	5
1.1	5
1.2	4
1.3	4
1.4	4
1.5	3
1.6	3
1.7	3
1.8	3
1.9	3
2.0	3
2.2	2
2.4	2
2.6	2

COMPARISON OF ADJUSTMENT AND RESISTANCE PER CAR BY DIFFERENT FORMULAS.

	R = 2.41t + 89 6n Resistance			R = 2.68t + 143.8n Resistance			R = 2.78t + 113.9n Resistance			R = 1.0769t + 138.46n Resistance		
Grade	Twenty-ton car	Seventy-ton car	Adjust	Twenty-ton car	Seventy-ton car	Adjust	Twenty-ton car	Seventy-ton car	Adjust	Twenty-ton car	Seventy-ton car	Adjust
Level..	138	258	37	197.4	331	54	169	308	41	159	213	128
.1%			23			30			24			45
.2%			14			21			17			27
.3%	258	678	11	317	751	16	289	726	13	279	633	19.5
.4%			8.6			13			11			15.2
.5%			7.2			11			9			12.5
.6%	376	1098	6.2	437	1171	9.7	409	1148	8	399	1053	10.59
.7%			5.4			8.5			7			8.18
.8%			4.8			7.6			6			8.10
.9%			4.4			6.8			6			7.25
1.0%	538	1658	4.0	597	1731	6.2	569	1708	5	559	1613	6.56
1.1%			3.6			5.7			5			6.00
1.2%			3.3			5.3			4			5.52
1.3%			3.1			4.9			4			5.11
1.4%			2.9			4.6			4			4.76
1.5%	738	2358	2.7	797	2431	4.3	768	2408	3	759	2313	4.45
1.6%			2.5			4.0			3			4.18
1.7%			2.3			3.9			3			3.94
1.8%			2.2			3.6			3			3.73
1.9%			2.1			3.4			3			3.54
2.0%	937	3058	2.0	997	3131	3.3	969	3108	3	959	3013	3.37

The Pennsylvania Railroad formula, as shown in Mr. Cole's article on Train Resistance, Railroad Age Gazette (page 547), Vol. XLVI, No. 13, as follows:

$$R = 1.0769\,t + 138.46\,n$$

This formula gives a higher rate of adjustment than any of the formulas shown so far. It is based on tests made by them in 1907, which gave the following results:

Weight of car.	Resistance on level tangents.	Number of tests.
20 tons	8 lbs. per ton	3
72 tons	3 lbs. per ton	15

It should be noted from the article in Railway Age Gazette that while resistance per ton increases slowly as weight increases after car passes weight of 60 tons, resistance per ton increases very rapidly as car is lighter than 20 tons. Between these two car weights resistance in pounds per ton is nearly proportional to the weight of car.

As it is out of the question and perhaps a refinement to have special formulas for different classes of cars, the following is recommended as being a combination of the result of Mr. Dennis' and Mr. Shurtleff's investigations, those of the Baltimore & Ohio Railroad and Pennsylvania Railroad, according to Railway Age Gazette.

	Resistance of 20-ton car on level tangent.	Resistance of 70-ton car on level tangent.
Dennis and Shurtleff	138	258
Selected tests Baltimore & Ohio Railroad	197	331
Baltimore & Ohio Railroad	169	308
Pennsylvania Railroad	159	213
Average of all	166	277

$$\text{Thus, }\begin{array}{r} 166 = K\,20 + C \\ 277 = K\,70 + C \\ \hline 111 = K\,50 \\ 2.22 = K \\ 121.6 = C \end{array}$$

Formula recommended: $R = 2.22\,t + 121.6\,c.$

Adjustments in tons per car from the formula.

Grade.	Tons per car.	Grade.	Tons per car.	Grade.	Tons per car.	Grade.	Tons per car.	Grade.	Tons per car.
Level	54	0.4%	12	0.8%	6.7	1.2%	4.6	1.6%	3.5
0.1%	29	0.5	10	0.9	6.0	1.3	4.3	1.7	3.3
0.2	20	0.6	8.5	1.0	5.4	1.4	4.0	1.8	3.1
0.3	14	0.7	7.5	1.1	5.0	1.5	3.7	1.9	2.9
								2.0	2.8

PER CENT. OF RATING TO BE USED FOR VARIOUS TEMPERATURES BASED ON TESTS ON .3%, 1% AND 2.6% GRADES.

Per cent. of grade.	A Above 45°	B 45° to 35°	C 35° to 20°	D Below 20°
.3	100	88	76	65
.35	100	90	80	69
.4	100	91	82	72
.45	100	91	83	74
.5	100	92	84	76
.55	100	93	86	78
.6	100	93	87	80
.65	100	94	88	82
.7	100	94	88	83
.75	100	95	89	84
.8	100	95	90	85
.85	100	95	90	85
.9	100	95	90	86
.95	100	96	92	87
1.0	100	96	92	88
1.1	100	96	92	89
1.2	100	97	93	90
1.3	100	97	94	91
1.4	100	97	94	91
1.5	100	97	94	92
1.6	100	97	94	92
1.7	100	98	95	93
1.8	100	98	95	93
1.9	100	98	96	94
2.0	100	98	96	94
2.2	100	98	96	95
2.4	100	99	97	96
2.6	100	99	97	96

STARTING RESISTANCES.

Starting resistances vary with temperature, loading, condition of equipment and character of roadway maintenance. In pounds per ton it will vary from forty to ten.

Trains are started by increments, so that starting resistances rarely become limiting.

TRAIN RESISTANCE AT SPEEDS BETWEEN SEVEN AND THIRTY-FIVE MILES PER HOUR.

Mr. Dennis is probably the first to call attention to the fact that speeds between seven and thirty-five miles per hour show a constant total train resistance, for the same train. Mr. Shurtleff further corroborates with personal experience.

On page 546, Railroad Age Gazette, Vol. 47, No. 13, it is stated that the Pennsylvania Railroad Company used resistance between five and thirty-five miles per hour as a constant. Further corroborative evidence is had from dynamometer experiments of the Baltimore & Ohio Railroad in 1904.

A summary of these tests is as follows:

Location of Test.	Grade.	Speed.	No. of Cars.		Tonnage.	Average Resistance Whole Runs.
			Loads.	Mtys.		
Cherry Run Low Grade	3% Comp. .03	10 M. P. H.	36	2	2533	27404
Cherry Run Low Grade	3% Comp. .03	15 M. P. H.	36	2	2533	25785
Cherry Run Low Grade	3% Comp. .03	10 M. P. H.	0	38	714	11598
Cherry Run Low Grade	3% Comp. .03	20 M. P. H.	0	38	714	11317

From the foregoing it may be seen that the runs at the higher speeds, over exactly the same track, show slightly less resistance than those at ten miles per hour. These tests were reliably made, and, like the others, were conducted by Engineer of Tests Onderdonk.

CURVE RESISTANCE.

We are interested in curve resistance chiefly from the standpoint of its compensation. In the location of a railroad curvature evils may be eliminated partially by reducing gradient on the curve by such an amount as to make the engine effort the same on curve as on tangent.

How much of a reduction shall be made? Under curve resistance it is proper to consider a few subheads:

Resistance of long curves.
Resistance of short curves.
Curve resistance at high speed.
Curve resistance at low speed.
Easements to curves.
Superelevation of curves—which rail, if either, should remain at grade.
Dynamometer tests.

(a) *Resistance of long curves.*

The resistance to traction of long curves is probably greater than short curves. If the curve is long enough to take the whole train at once, the engine is changing direction at the same time that it is pulling the train. All the trucks in the train are slewed around at the same time.

(b) *Resistance of short curves.*

In the case of short curves, however, only a part of the trucks are slewed at the same time, and for a proportion of the time the engine is working on straight track while it is pulling the train.

(c) *Curve resistance at high speed.*

On account of the trucks straightening up better at high speed, it is probable that the effect of curvature is dispelled sooner at high speed than at slow speed.

(d) *Resistance at slow speed.*

As an example of the way that trucks fail to straighten at slow speed, attention is called to the old single track bridge on the Baltimore & Ohio Railroad over the Susquehanna River.

The traffic is practically 100 per cent. loaded eastbound and about 40 per cent. westbound. At the eastbound approach to the bridge there was a 7° 30′ curve, running out on the bridge about 400 ft. The speed of eastbound trains at this point was ten miles per hour and the length of the bridge about one and one-eighth miles, leaving over a mile of tangent on the bridge.

The North rail on the bridge (which was the continuation of the high rail of the curve) was badly flange-worn throughout the mile length of the bridge—the first half-mile being as much worn as the high rail of the curve.

The North rail also crept much faster than the other, showing the pressure of the flanges.

The above would indicate that curve resistance at slow speed does not stop at the end of the curve.

(e) *Superelevation of curves:*

The easement to a curve serves the double purpose of an easy approach to the curve and a run-out to the superelevation. It should be noted that, with the inner rail held at grade, the center of gravity of the train must be raised through approximately one-half the superelevation. It would appear as if the logical superelevation would be a call for raising the outer rail by one-half the calculated superelevation. This would mean depressing the inner rail by the same amount. It would seem from a standpoint of resistance that the question should be given consideration. It is already the practice on many of the roads in the United States and Canada.

(f) *How much does Curve Resistance amount to in equivalent grade..*

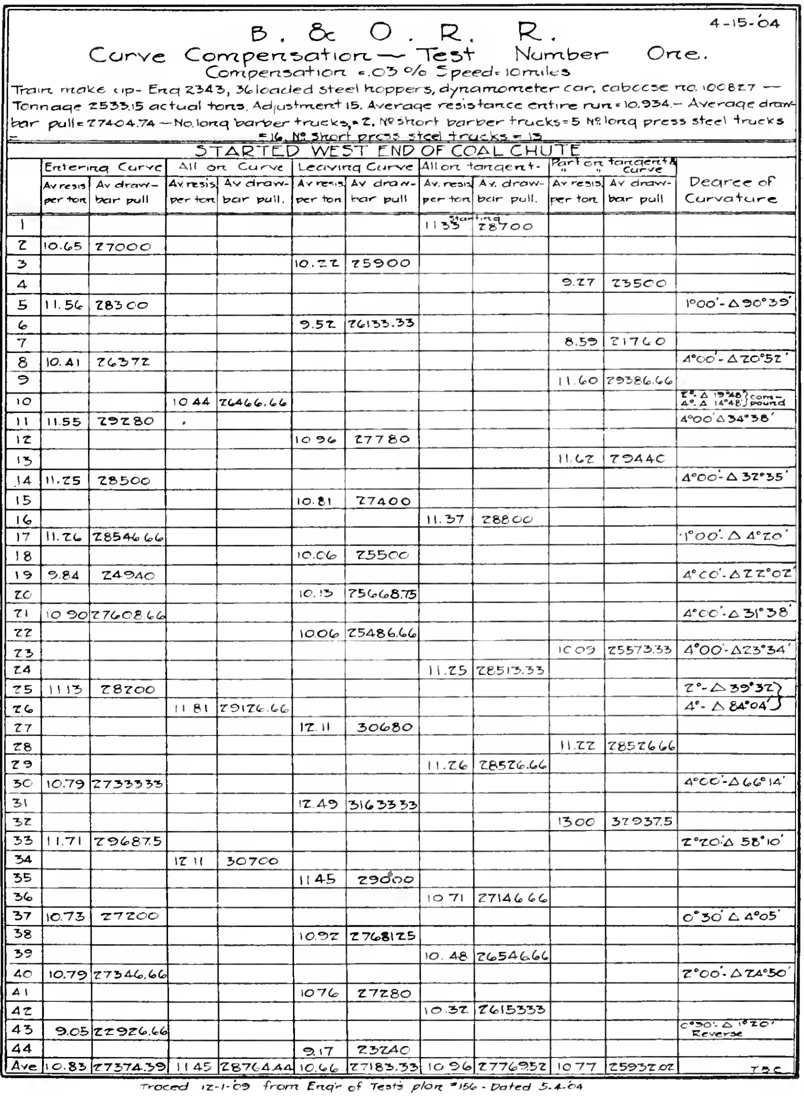
In April of 1904 tests were made on the Baltimore & Ohio Railroad, North Mountain Cut-Off and Mt. Airy Grade, to determine the effect of curve compensation. Certain parts of these lines were compensated at the rate of .03 and other parts at .04.

The following detailed results show that on the portion compensated .03 per cent., resistance on curve was greater than on tangent, and on the portion compensated .04 per cent., resistance on curve was less than on tangent.

The study in detail is appended. (See Tables.) These tests were conducted under the direction of Mr. J. R. Onderdonk, Engineer of Tests, Baltimore & Ohio Railroad, and the results were computed by him.

The following are the replies to a circular put out in 1907 for information on the same subject. The consensus of opinion was that .035 per cent. per degree gave the best results:

CHERRY RUN TO HEDGESVILLE, via NORTH MOUNTAIN CUT OFF-1



4-15-04

B. & O. R. R.

Curve Compensation — Test Number One.

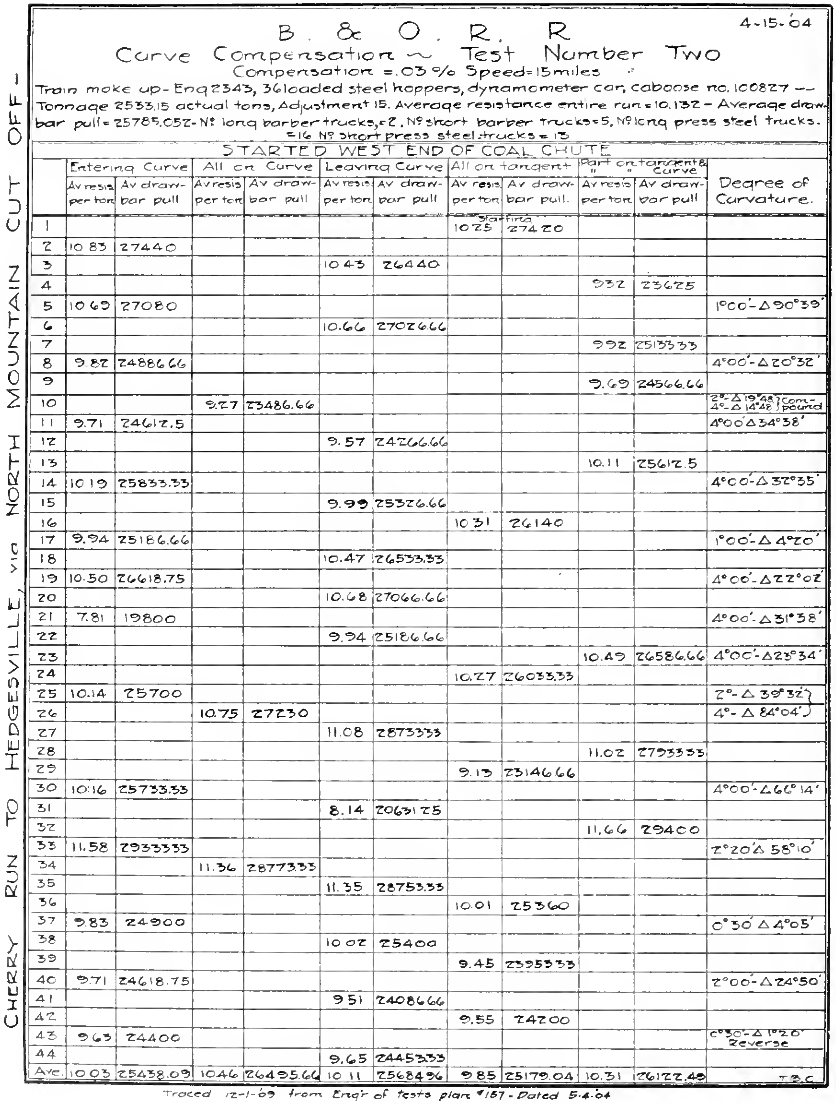
Compensation =.03 % Speed = 10 miles

Train make up- Eng 2343, 36 loaded steel hoppers, dynamometer car, caboose no. 100827 — Tonnage 2533.15 actual tons. Adjustment 15. Average resistance entire run = 10.934.— Average drawbar pull = 27404.74 — No. long barber trucks = 2. No. short barber trucks = 5 No. long press steel trucks = 16. No. short press steel trucks = 13.

STARTED WEST END OF COAL CHUTE

	Entering Curve		All on Curve		Leaving Curve		All on tangent.		Part on tangent & curve		Degree of Curvature
	Av resis per ton	Av draw-bar pull	Av. resis per ton	Av draw-bar pull.	Av resis per ton	Av draw-bar pull	Av. resis per ton	Av. draw-bar pull.	Av resis per ton	Av draw-bar pull	
1							1133	Starting 28700			
2	10.65	27000									
3					10.22	25900					
4									9.27	23500	
5	11.56	28300									1°00'-Δ 90°39'
6					9.52	26133.33					
7									8.59	21760	
8	10.41	26372									4°00'-Δ 20°52'
9									11.60	29386.66	
10			10 44	26466.66							2°-Δ 19°48' 4°-Δ 14°48' compound
11	11.55	29280									4°00' Δ 34°38'
12					10 96	27780					
13									11.62	29440	
14	11.25	28500									4°00'-Δ 32°35'
15					10.81	27400					
16							11.37	28800			
17	11.26	28546 66									1°00'-Δ 4°20'
18					10.06	25500					
19	9.84	24940									4°00'-Δ 22°02'
20					10.13	25668.75					
21	10 90	27608.66									4°00'-Δ 31°38'
22					10.06	25486.66					
23									10 09	25573.33	4°00'-Δ 23°34'
24							11.25	28513.33			
25	11 13	28200									2°-Δ 39°32'
26			11 81	29126.66							4°-Δ 84°04'
27					12.11	30680					
28									11.22	2852666	
29							11.26	28526.66			
30	10.79	2733333									4°00'-Δ 66°14'
31					12.49	3163333					
32									1300	32937.5	
33	11.71	296875									2°20' Δ 58°10'
34			12 11	30700							
35					11 45	29000					
36							10 71	2714666			
37	10.73	27200									0°30' Δ 4°05'
38					10.92	2768125					
39							10. 48	2654666			
40	10.79	27346.66									2°00'-Δ 24°50'
41					1076	27280					
42							10.32	2615333			
43	9.05	22926.66									0°30'-Δ 1°20' Reverse
44					9.17	23240					
Ave	10.83	27374.39	11 45	28764.44	10.66	27183.33	10 96	2776952	10 77	25932.02	T.B.C.

Traced 12-1-09 from Engr of Tests plan #156 - Dated 5.4.04



CHERRY RUN TO HEDGESVILLE, via NORTH MOUNTAIN CUT OFF—

4-15-04

B. & O. R. R

Curve Compensation ~ Test Number Two

Compensation =.03 % Speed=15 miles

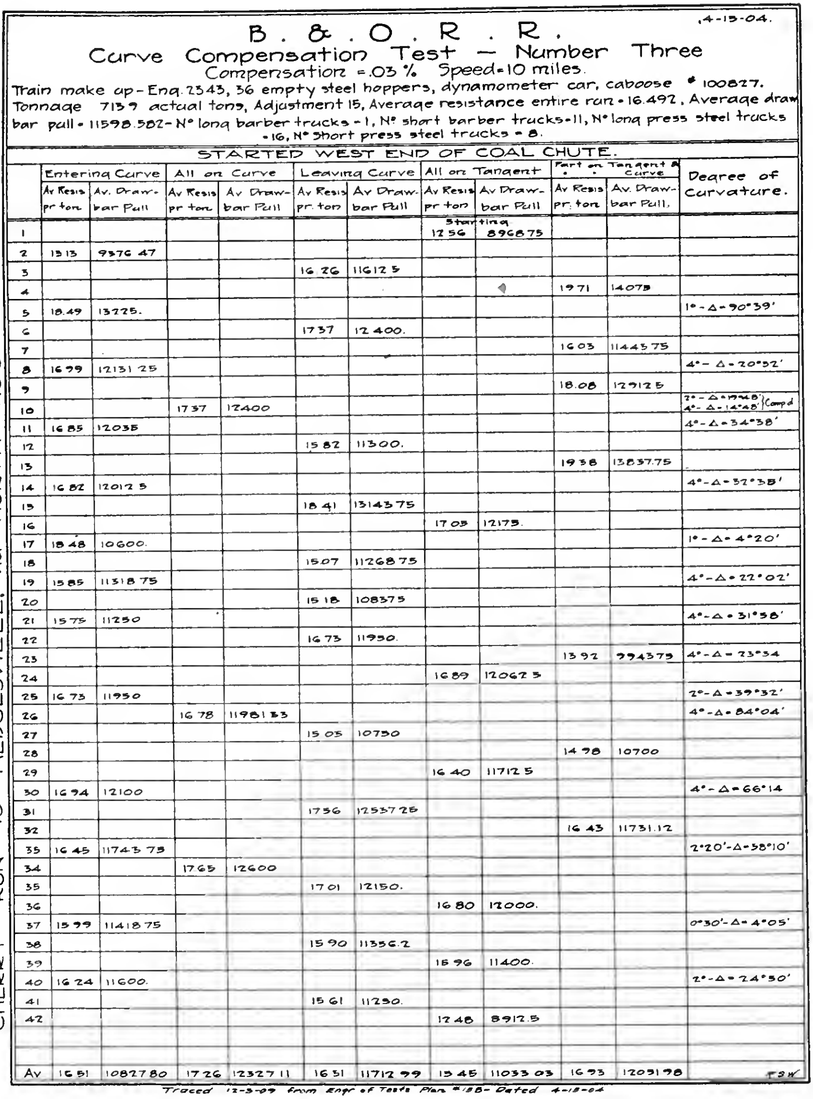
Train make up - Eng 2343, 36 loaded steel hoppers, dynamometer car, caboose no. 100827 —— Tonnage 2533.15 actual tons, Adjustment 15. Average resistance entire run = 10.132 - Average draw-bar pull = 25785.052 - No. long barber trucks = 2, No. short barber trucks = 5, No. long press steel trucks. = 16 No. short press steel trucks = 13

STARTED WEST END OF COAL CHUTE

	Entering Curve		All on Curve		Leaving Curve		All on tangent		Part on tangent & " " Curve		Degree of Curvature.
	Av resis per ton	Av draw-bar pull	Av resis per ton	Av draw-bar pull	Av resis per ton	Av draw-bar pull	Av resis per ton	Av draw-bar pull.	Av resis per ton	Av draw-bar pull	
1							Starting 10 25	27420			
2	10 83	27440									
3					10 43	26440					
4									932	23625	
5	10 69	27080									1°00'-Δ 90°39'
6					10.66	27026.66					
7									992	2513333	
8	9 82	2488666									4°00'-Δ 20°32'
9									9.69	24566.66	
10			9.27	23486.66							2°-Δ 19°48' } Com- 4°-Δ 14°48' } pound
11	9.71	24612.5									4°00' Δ 34°38'
12					9. 57	24266.66					
13									10.11	25612.5	
14	10 19	25833.33									4°00'-Δ 32°35'
15					9.99	25326.66					
16							10 31	26140			
17	9.94	25186.66									1°00'-Δ 4°20'
18					10.47	26533.33					
19	10.50	26618.75									4°00'-Δ 22°02'
20					10.68	27066.66					
21	7.81	19800									4°00'-Δ 31°38'
22					9.94	25186.66					
23									10.49	26586.66	4°00'-Δ 23°34'
24							10.27	26033.33			
25	10.14	25700									2°-Δ 39°32' }
26			10.75	27230							4°-Δ 84°04' }
27					11.08	2873333					
28									11.02	2793333	
29							9.13	2314666			
30	10:16	25733.33									4°00'-∠66°14'
31					8.14	2063125					
32									11.66	29400	
33	11.58	2933333									2°20' Δ 58°10'
34			11.36	2877333							
35					11.35	28753.33					
36							10.01	25360			
37	9.83	24900									0°30' Δ 4°05'
38					10 02	25400					
39							9.45	2395333			
40	9.71	24618.75									2°00'-Δ 24°50'
41					9 51	2408666					
42							9.55	24200			
43	9 63	24400									0°30'-Δ 1°20' Reverse
44					9.65	2445333					
Ave.	10 03	25438.09	1046	26495.66	10 11	2568496	9 85	25179.04	10.31	26122.49	T.B.C.

Traced 12-1-09 from Eng'r of tests plan #157 - Dated 5-4-04

CHERRY RUN TO HEDGESVILLE, via NORTH MOUNTAIN: CUT OFF.—



4-15-04.

B. & O. R. R.

Curve Compensation Test — Number Three

Compensation =.03 % Speed=10 miles.

Train make up-Eng. 2343, 36 empty steel hoppers, dynamometer car, caboose # 100827. Tonnage 7139 actual tons, Adjustment 15, Average resistance entire run = 16.492, Average draw bar pull = 11598.582 - N° long barber trucks = 1, N° short barber trucks = 11, N° long press steel trucks = 16, N° short press steel trucks = 8.

STARTED WEST END OF COAL CHUTE.

	Entering Curve		All on Curve		Leaving Curve		All on Tangent		Part on Tangent & Curve		Degree of Curvature.
	Av Resis pr ton	Av. Draw-bar Pull	Av Resis pr ton	Av Draw-bar Pull	Av Resis pr. ton	Av Draw-bar Pull	Av Resis pr ton	Av Draw-bar Pull	Av Resis pr. ton	Av. Draw-bar Pull,	
1							Starting 12 56	896875			
2	13 13	9376 47									
3					16 26	116125					
4									1971	14075	
5	18.49	13725.									1°-Δ=90°39'
6					1737	12 400.					
7									16 03	1144575	
8	16 99	12131 25									4°- Δ=20°32'
9									18.08	129125	
10			1737	12400							2°-Δ=19°48' 4°-Δ=14°48' } Comp'd
11	16 85	12035									4°-Δ=34°38'
12					15 82	11300.					
13									19 38	13837.75	
14	16 82	120125									4°-Δ=32°38'
15					18 41	1314375					
16							17 05	12175.			
17	18 48	10600.									1°-Δ=4°20'
18					1507	1126875					
19	15 85	11318 75									4°-Δ=22°02'
20					15 18	108375					
21	1575	11250									4°-Δ=31°58'
22					16 73	11950.					
23									13 92	994375	4°-Δ=23°34
24							16 89	120625			
25	16 73	11950									2°-Δ=39°32'
26			16 78	1198133							4°-Δ=84°04'
27					15 05	10750					
28									14 98	10700	
29							16 40	117125			
30	16 94	12100									4°-Δ=66°14
31					1756	1253725					
32									16 43	11731.12	
33	16 45	11743 75									2°20'-Δ=38°10'
34			1765	12600							
35					17 01	12150.					
36							16 80	12000.			
37	15 99	1141875									0°30'-Δ=4°05'
38					15 90	11356.2					
39							15 96	11400.			
40	16 24	11600.									2°-Δ=24°30'
41					15 61	11230.					
42							12 48	8912.5			
Av	16 51	1082780	17 26	1232711	16 51	11712 99	13 45	11033 03	16 93	1203198	F.S.W.

Traced 12-3-09 from Engr of Tests Plan #188- Dated 4-18-04

CHERRY RUN TO HEDGESVILLE, via NORTH MOUNTAIN CUT OFF—

4-15-04.

B. & O. R. R.

Curve Compensation Test — Number Four

Compensation =.03% Speed=20 miles.

Train make up-Eng 2343, 36 empty steel hoppers, dynamometer car, caboose # 100827
Tonnage 7139 actual tons, Adjustment 15, Average resistance entire run=16 04, Average draw bar pull=11317 62 — N° long barber trucks=1, N° short barber trucks=11, N° long press steel trucks =16, N° Short press steel trucks=8

STARTED WEST END OF COAL CHUTE

	Entering Curve		All on Curve		Leaving Curve		All on Tangent		Part on Tangent & Curve		Degree of Curvature
	Av Resis pr ton	Av Draw-bar Pull	Av Resis pr ton	Av Draw-bar Pull	Av Resis pr ton	Av Draw-bar Pull	Av Resis pr ton	Av Draw-bar Pull	Av Resis pr ton	Av Draw-bar Pull.	
1							—				
2	23 71	16933 33									
3					20.66	14753 33					
4									16 77	11973 33	
5	10 70	12160									1°-Δ=90°39′
6					17 61	12573 33					
7									8 53	6096 57	
8	15 82	11300.									4°-Δ=20°52′
9									18 60	13280.	
10			16 07	11746 66							2°-Δ=19°38 4°-Δ=34°38 Comp'd
11	16 64	11880									4°-Δ=34°38′
12					19 67	13946 66					
13									18 00	12853 34	
14	13 51	9646 66									4°-Δ=32°35′
15					18 12	12940.					
16							18 43	13160			
17	14.49	10246 66									1°-Δ=4°20′
18					13 81	9860					
19	12 63	9020									4°-Δ=22°02′
20					12 32	8800.					
21	13 08	9340.									4°-Δ=31°38
22					17 01	12146 66					
23									16 38	11700	4°-Δ=23°34′
24							15 99	11420.			
25	13 06	9326 66									2°-Δ=39°32′
26			15 43	11020							4°-Δ=84°04′
27					14.73	10520.					
28									14 12	10086 67	
29							15 72	11225.			
30	16 45	11746 66									4°-Δ=66°14′
31					15 34	10953 33					
32									16 41	11720.	
33	16 12	11513 33									2°20′-Δ=58°10′
34			19 84	14168 75							
35					15 82	11300					
36							15 82	11300.			
37	16 94	12100.									0°30′-Δ=4°05′
38					14 67	10473 34					
39							15 50	11066.67			
40	15 41	11000									2°-Δ=24°50′
41					15 54	11100.					
42							15 49	11060			
43	15.49	11060.									0°30′-Δ=1°20′ Reverse
44					14 09	10060.					
Av.	15 29	10145 24	17 11	12311 80	16 10	11494 36	16 16	11535 28	15 54	11101 41	F.S.W.

Traced 12-3-09 from Engr of Tests Plan # 159 — Dated 5-4-04.

B. & O. R. R.

Curve Compensation Tests No's 5 and 6.

WASHINGTON JCT. TO ADAMSTOWN, TO REELS MILLS, TO TOP MT. AIRY VIA THE
ADAMSTOWN CUT OFF, MAIN LINE, AND MT AIRY CUT OFF.
Compensation from 1 to 17 = .04%, from 28 to 107 = .03% Speed 15mi,
Train make up eng's 2343, 1871 & 1403, 30 loaded steel hoppers, dynamometer car, caboose #100363
Tonnage = 2113.5 actual tons, Adjustment + 15
Average resistance entire run = 16.342 — Average draw-bar pull = 34982.494

STARTED WEST END OF ADAMSTOWN CUT OFF

	Entering Curve		All on Curve		Leaving Curve		All on Tangent		Part on tangent & " " curve		Degree of Curvature.	Remarks
	Av resis per ton	Av draw-bar pull	Av resis per ton	Av draw-bar pull	Av resis per ton	Av. draw-bar pull	Av resis per ton	Av. draw-bar pull.	Av. resis. per ton	Av. draw-bar pull.		
1			11.3	23906								
2					13.3	28185						
3	10.2	21655										
4					11.5	24352						
5	12.3	25952										
6									10.7	22768		
7							14.6	31015				
8	10.5	22352										
9					11.3	23872						
10							11.2	23785				
11	11.6	24326										
12					10.8	22959						
13							9.2	20618				
14	11.0	23106										
15					11.3	23452						
16							11.0	23139				
17	11.4	24233										
Av'g.	11.17	23604	11.3	23906	11.64	24564	11.5	24600	10.7	22768		
RUNNING ON MAIN LINE												
18									11.7	24919		Adamstown
19							11.42	24140				
20							10.3	21906				
21	10.5	22366										
22					8.5	18006						
23							9.1	19213				
24	11.3	23785										
25					9.9	20906						
26							10.1	21272				
27	5.4	11543										
COMPENSATION = 0.03 PER CENT REEL'S MILL TO TOP OF HILL -												
28					4.7	10012						Reels Mills, took on helper No. 1871
29	19.4	41266										
30					18.9	40059						
31									18.5	39072		
32	18.6	39439										
33					11.3	24528						
34									16.5	34853		
35	18.2	38485										
36					19.4	411.86						
37									20.2	42785		
38	21.2	44840										
39					19.0	40386						
40							13.6	28368				
41	9.5	19137										
42					14.7	31143						
43									12.2	25952		
44							9.7	20519				
45	13.2	27992										
46									13.3	28812		
47									14.7	31100		
48					15.3	32318						
49									13.0	27292		
50	13.3	28200										
51					17.3	36885						Reverse Curve

	Entering Curve		All on Curve		Leaving Curve		All on Tangent		Part on tangent & " " curve		Degree of Curvature.	Remarks
	Av resis per ton	Av. draw-bar pull	Av resis per ton	Av draw-bar pull	Av resis per ton	Av. draw-bar pull	Av resis per ton	Av. draw-bar pull.	Av. resis. per ton	Av draw-bar pull.		
52									16.1	34134		
53	16.48	34555										
54									14.9	31690		
55							15.2	32240				
56	9.9	21039										
57			13.7	29133								
58					12.6	26633						
59									1351	29572		Monrovia
60		Leaving here: were unable to maintain speed, so had to get another engine to										
61					help to the top of the hill-Helper #1403							
62	18.32	5873333										
63					20.75	43866						
64							2262	4718333				
65	2097	44313.33										
66					2504	52926						
67									2051	43360		
68	2251	47586.67										
69					23,54	49760						
70									23.17	4887333		
71	2141	45260										
72									21.60	45666.66		
73	2207	4664666										
74									2271	4801333		
75	21.67	45800										
76			2074	4385333								
77					2257	47133.33						
78									2256	47686.67		
79							21.14	44700				
80	20.84	44046										
81					21.05	44500						
82									21.92	4633333		
83	20.67	43700										
84			2134	45120								
85					2096	44300						
86									23.06	48746		
87	21.41	45260										
88			20.64	43640								
89					21.52	45500						
90									23.45	49580		
91	1850	39100										
92					21.75	45980						
93									26.07	55110		
94	21.40	45250										
95			21.41	4625333								
96					22.23	47000						
97	21.61	45680										
98					20.10	42486.66						
99							21.27	44960				
100	21.69	4585625										
101			21.12	44640								
102					19.90	42060						Tunnel
103	21.10	44600										
104			2204	46600								
105					17.71	37433.18						
106	20.77	43900										
107					1476	31312.5						
Ave	18.94	4002855	20.14	42748.52	1845	38937.12	17.25	36328.39	18.84	39927.96		T.O.C.

Traced 12-3-09 from Eng'r of Tests plan #160. Dated 5-5-04

BALTIMORE & OHIO RAILROAD ENGINE RATING.

Formula $R = 2.78\,t + 113.9\,n$..

	GRADIENT.	ADJUSTMENT.				CLASSES										FROM	TO
						E	E	E	E	E	B	E	B	B	K		
		A	B	C	D	24, 27 19, 19a	16 17 18	11, 12 13, 20 21, 22 B. 18	14 15	10 6/60	19	9	36	6	3		
1	30	13	20	26	33	3500	3150	3000	2900	2775	2650	2600	2500	2150	1750		
2	....	13	20	26	33	3400	3050	2900	2800	2700	2550	2500	2425	2075	1700		
3	....	13	20	26	33	3300	2950	2800	2700	2625	2500	2425	2350	2000	1650		
4	....	12	18	24	30	3200	2875	2700	2650	2550	2400	2375	2275	1950	1600		
5	35	12	18	24	30	3100	2800	2650	2600	2450	2350	2300	2225	1900	1550		
6	....	12	18	24	30	3000	2700	2550	2500	2375	2275	2225	2150	1825	1500		
7	....	11	17	22	28	2900	2600	2475	2400	2300	2200	2150	2075	1775	1450		
8	.40	11	17	22	28	2800	2500	2400	2350	2225	2100	2075	2000	1700	1400		
9	....	11	17	22	28	2700	2425	2300	2250	2075	2050	2000	1925	1650	1350		
10	.45	10	15	20	25	2600	2350	2225	2150	2050	1950	1925	1850	1575	1300		
11	....	10	15	20	25	2500	2250	2150	2050	1975	1900	1850	1775	1525	1250		
12	50	9	14	18	23	2400	2150	2050	2000	1900	1800	1775	1725	1475	1200		
13	....	9	14	18	23	2300	2075	1975	1900	1825	1750	1700	1650	1400	1150		
14	.55	9	14	18	23	2200	2000	1875	1850	1750	1650	1625	1575	1350	1100		
15	....	8	12	16	20	2100	1900	1800	1750	1675	1575	1550	1500	1275	1050		
16	.60	8	12	16	20	2000	1800	1700	1650	1600	1500	1475	1425	1225	1000		
17	....	8	12	16	20	1950	1750	1675	1625	1550	1475	1450	1400	1200	975		
18	....	8	12	16	20	1900	1700	1625	1575	1500	1425	1400	1350	1150	950		
19	.66	7	11	14	18	1850	1650	1575	1525	1475	1400	1375	1325	1125	925		
20	....	7	11	14	18	1800	1600	1525	1500	1425	1350	1325	1275	1100	900		
21	.70	7	11	14	18	1750	1575	1500	1450	1400	1325	1300	1250	1075	875		
22	....	7	11	14	18	1700	1525	1450	1425	1350	1275	1250	1225	1025	850		
23	.75	7	11	14	18	1650	1475	1400	1375	1300	1250	1225	1175	1000	825		
24	....	6	9	12	15	1600	1425	1375	1325	1250	1200	1175	1150	975	800		
25	.80	6	9	12	15	1550	1400	1325	1275	1225	1175	1150	1100	950	775		
26	....	6	9	12	15	1500	1350	1275	1250	1200	1125	1100	1075	925	750		
27	.85	6	9	12	15	1450	1300	1225	1200	1150	1100	1075	1025	875	725		
28	.90	6	9	12	15	1400	1250	1200	1150	1100	1050	1025	1000	850	700		
29	....	5	8	10	13	1350	1200	1150	1125	1075	1000	1000	975	825	675		
30	.95	5	8	10	13	1300	1175	1100	1075	1025	975	950	925	800	650		
31	1.00	5	8	10	13	1250	1125	1075	1050	1000	950	925	900	775	625		
32	1 05	5	8	10	13	1200	1075	1025	1000	950	900	875	850	725	600		
33	1 10	5	8	10	13	1150	1025	975	950	900	875	850	825	700	575		
34	1.15	4	6	8	10	1100	975	925	900	875	825	800	775	675	550		
35	1.20	4	6	8	10	1050	950	900	875	825	800	775	750	650	525		
36	1 25	4	6	8	10	1000	900	850	825	800	750	750	725	625	500		
37	1.30	4	6	8	10	950	850	800	800	750	700	700	675	575	475		
38	1.35	4	6	8	10	900	800	775	750	700	675	675	650	550	450		
39	1.40	4	6	8	10	850	750	725	700	675	625	625	600	525	425		
40	1.50	3	5	6	8	800	700	675	650	625	600	600	575	500	400		
41	1.60	3	5	6	8	750	675	625	625	600	550	550	525	475	375		
42	1.70	3	5	6	8	700	625	600	575	550	525	500	500	425	350		
43	1.80	3	5	6	8	650	550	550	525	500	500	475	475	400	325		
44	2.00	3	5	6	8	600	525	500	500	475	450	450	425	375	300		
45	2.10	3	5	6	8	550	500	475	450	425	400	400	400	350	275		
46	2.20	2	3	3	5	500	450	425	400	400	375	375	350	300	250		
47	2.40	2	3	3	5	450	400	375	375	350	350	325	325	275	225		
48	2 60	2	3	3	5	400	350	325	325	300	300	300	300	250	200		

Use A for over 45°.
Use B for 35° to 45°.
Use C for 20° to 35°.
Use D for under 20°.

October 1, 1907.

EXTRACTS FROM ANSWERS TO COMMITTEE CIRCULAR OF OCTOBER 19, 1907.

Authority.	Railroad Company.	Compensation per degree of curve.
E. H. McHenry	N. Y., N. H. & H	Found 0.03 per cent. compensation too light and 0.04 per cent. too heavy.
H. R. Talcott	B. & O	Found 0.03 per cent. compensation too light and 0.04 per cent. too heavy.
A. V. Kellogg	So. Pac. (Atlantic System)	Found 0.03 per cent. compensation too light and 0.04 per cent. too heavy.
J. B. Berry and A. K. Shurtleff	Rock Island	With new rail, trains at less than 10 M. P. H. retarded on 0.03 compensation and accelerated on same curves at higher velocities.
L. B. Merriam	G. T. Pac	0.04 per cent. too high for new rail.
George W. Kittredge	N. Y. C	0.03 per cent. made limiting grades on curves; 0.04 per cent. O. K.
Edwin F. Wendt	P. & L. E	0.035 per cent. proved O. K.
Francis Lee Stuart	Erie	0.035 per cent. O. K.
M. J. Caples	Carolina, C. & Ohio	Trains accelerate when loaded for 1 per cent. grade on curves compensated at 0.035 per cent.
W. H. Courtenay	Lou. & Nash	0.03 per cent. too low—somewhat higher necessary.
H. T. Douglas, Jr	W. & L. E	Used 0.03 per cent., but believes 0.04 per cent. better.
Chas. S. Churchill	N. & W	0.035 per cent. O. K. Finds that trains accelerate on 0.04 per cent.
J. E. Schwitzer	Can. Pac	Trains accelerate on 0.04 per cent. compensation.
A. C. Dennis	Can. Pac	0.04 per cent. O. K. up to 5 degrees. Too high for sharper curves.
V. G. Bogue	West. Pac	0.04 per cent. used, but is probably higher than necessary.
H. F. Baldwin	Wash. & Oregon	Heavy trains stalled or retarded on 0.04 per cent. and found 0.05 O. K.
W. S. Dawley	Alleghany Imp. Co	With 0.5 per cent. compensation found trains loaded for ten miles per hour on ruling grade tangents retarded on curves, while fifteen miles per hour trains accelerated.

CONCLUSIONS.

It is recommended that the following conclusions be adopted:

(1) Dynamometer tests to be of the greatest value should show the following:

(a) Dynamometer record (graphical) showing drawbar pull to nearest ten pounds, with horizontal scale not less than 400 ft. to one inch and in special cases a larger scale.

(b) Speed record to nearest tenth of mile per hour (graphical).

(c) Key to record mile posts.

(d) Condition of track surface (graphical).

(e) Steam pressure of boiler (graphical).

(f) Train line air pressure (graphical).

(g) Time record (graphical).

(Speed record may be independent record, and in this case time record is desirable.)

(h) Coal consumption (record of shovels of coal as used) (worked by hand in engine).

Requisite data to be taken:

Track.

(i) Office profile and alinement connecting with mile posts (so as to connect with 3).

(j) Section of rail.

(k) Condition of rail.

(l) Number of ties to rail (and rail length).

*(m) Kind of ballast.

Locomotive.

(n) Type (wheel arrangement, whether simple or compound and dimensions of locomotive).

(o) Total weight and weight on drivers.

Cars.

(p) Record of length, initial, number, class of each car of train, also weight empty and weight loaded.

(q) Kind of truck.

(r) Condition of car.

Weather.

(s) Temperature.

(t) Direction and force of wind and direction of train.

(u) State of weather (rain or clear).

(2) Resistance of freight trains shows practically no change of resistance between seven and thirty-five miles per hour.

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*Amend to read: "(m) Kind and quantity of ballast."

(3) It is recommended that for freight train resistances between seven and thirty-five miles per hour the formula,

$$R = 2.2\,T + 121.6\,C,$$

be used for comparing freight train ratings on different lines and grades.

R = total resistance on level tangent.

T = total weight cars and contents in tons.

C = total number of cars.

*(4) In order to equalize resistance on curve and tangent, curves should be compensated .035 per cent. per degree of curvature. Effect of curve resistance is dispelled more slowly at slow speed than at high speed.

†(5) Superelevation and depression should be equally divided between high and low rail of curve, in order to avoid shock in entering curve and exceeding maximum gradient on runoffs of curves.

(6) Condition of roadway maintenance has a great effect on train resistance.

‡(7) Condition of equipment has a great effect on train resistance.

¶(8) Train resistance is greater in cold weather than in warm. Per cent. of rating on account of variation in temperature, as shown in body of report, is recommended for use.

(9) Resistance of individual cars of same weight but of different type shows considerable variation. Sufficient data are not yet available to determine just how much the difference is.

(10) Starting resistance varies from 10 to 40 lbs. per ton, depending on loading, temperature and character of maintenance of roadway and equipment.

CURVATURE.

OBJECTIONS TO SHARP CURVES.

As far as known to your Committee, the rail wear and other expenses of maintenance on curves are approximately proportional to the number of degrees of central angle, but there are a number of reasons why light curves are better than sharp curves.

Sharp curves require greater elevation, which is objectionable and takes considerable care and close inspection to maintain correct and uniform.

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*Amend to read: "(4) In order to equalize resistance on curves and tangent, curves should ordinarily be compensated .035 per cent. per degree of curvature," etc.

†Amend by striking out conclusion 5.

‡Amend to read: "(7) Condition and design of equipment has a great effect on train resistance."

¶Amend to read: "(8) Train resistance is greater in cold weather than in warm. Per cent. of rating on account of variation in temperature, as shown in body of report, is recommended for use in comparing new lines and not for tonnage rating."

The track can only be elevated for one velocity, while speed of trains will necessarily vary.

Straight lines and light curves permit higher safe speeds. As a general rule, it is desirable on any railroad to have alinement such that trains can run as fast as possible with the greatest possible factor of safety against derailment.

Curves should be made as light as practicable down to a curve where any advantage gained by making it lighter would be offset by the difficulty of maintaining the alinement.

If on any curve a train runs at a speed greater (or less) than that for which track is elevated according to formula $E = .00066DV^2$ (page 61 of Manual), the amount of unbalanced centrifugal force and the difference in weights on the two rails will be represented by the approximate formulas:

Unbalanced centrifugal force, $f^1 - f = .0177 \ (a^2 - 1) \ WE$,

Difference in weight on rails $w^1 - w = .00753 \ (a^2 - 1) \ WEH$,

Where W = total weight on both rails, H = height of its center of gravity above the rails, E = the elevation of outer rail in inches, and a = the quotient obtained by dividing the actual speed by that for which track is elevated.

These unbalanced forces vary directly as the elevation; and therefore as the degree of curve where track is elevated for a given speed.

For example, if track is elevated for 50 miles an hour and trains run at different speeds, we would have for an engine of 100 tons with center of gravity 6 feet above the rails.

Actual speed 60 miles an hour,

$f^1 - f =$ 1.3 tons for a 1° curve.
5.2 tons for a 4° curve.
$w^1 - w =$ 3.3 tons for a 1° curve.
13.1 tons for a 4° curve.

Actual speed 15 miles an hour,

$f^1 - f = -$ 2.7 tons for a 1° curve.
$-$ 10.6 tons for a 4° curve.
$w^1 - w = -$ 6.8 tons for a 1° curve.
$-$ 27.1 tons for a 4° curve.

Both the unbalanced centrifugal force and the difference in weights on rails are four times as much on the four degree as on the one degree curve. At 15 mile speed on the 4° curve the weight on the inside rail is 63½ tons against 36½ on the outside, nearly as great a disproportion as for train standing still—which would be 65 and 35.

Where track is elevated for 50 miles an hour, as in the above examples, a speed of 83 miles an hour on a 1° curve will give the same unbalanced centrifugal force and difference in weight on rails as 60 miles on the four degree, and as far as these forces are concerned it is equally safe.

As a 10° curve for 30 miles an hour and a 2°30′ for 60 miles require the same elevation, the unbalanced centrifugal force and difference in weight on rails will be the same in each case for any given percentage of increase (or decrease) in speed over that for which track is elevated.

Your Committee believes that the unbalanced centrifugal force is an important objection to curves and diminishes the factor of safety against derailment; and that for slow trains the excess of weight on the inside rail tends to increase the elevation of track while the pressure is lightened on the outside rails.

OBJECTIONS TO CURVES INCREASE WITH SPEED.

Curvature is more objectionable at high speeds than low. As the energy of any jolt or rebound caused by imperfect surface increases with the square of speed, the factor of safety against derailment at high speeds is diminished to that extent. Therefore any additional reduction in the factor of safety caused by the introduction of curvature is more objectionable than it would be at lower speeds where the margin of safety is greater.

The field for study on the subject of Curvature is broad and the time of your Committee has been limited. It is fully realized that the subject has only been partially covered in the present report, and further data and study are needed in order to reduce to a minimum the portion of the work that must eventually rest upon the judgment of the engineer.

The following conclusions are recommended for present consideration and adoption:

CONCLUSIONS.

*(1) A straight line is the best alinement, and with the possible exception of very light curves, it is the safest.

(2) The justifiable expenditure to eliminate one degree of central angle in the alinement of roadway depends largely on the number of daily trains and the cost per train mile.

(3) As a general rule it is good practice to spend more money to take out one degree of central angle where the radius is small, requiring the maximum elevation of outer rail, than where the radius is large, requiring less elevation.

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*Amend by striking out all words after "alinement."

(4) As a general rule, it is justifiable to spend more money to take out one degree of central angle where trains run at a high rate of speed than where the speed is low.

Respectfully submitted,

A. K. SHURTLEFF, Office Engineer, Chicago, Rock Island & Pacific Railway, Chicago, Ill., *Chairman.*

C. FRANK ALLEN, Professor Railroad Engineering, Massachusetts Institute Technology, Boston, Mass., *Vice-Chairman.*

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R. N. BEGIEN, Division Engineer, Baltimore & Ohio Railroad, Philadelphia, Pa.

J. F. BURNS, Roadmaster, Louisville & Nashville Railroad, Elizabethtown, Ky.

A. C. DENNIS, Assistant Engineer, Canadian Pacific Railroad, Montreal, Canada.

C. P. HOWARD, Lake Shore & Michigan Southern Railway, Cleveland, O.

P. M. LABACH, Assistant Engineer, Missouri Pacific Railway, St. Louis.

FRED LAVIS, Consulting Engineer, New York.

L. B. MERRIAM, Consulting Engineer, Winnipeg, Man.

CHAS. J. PARKER, Principal Assistant Engineer, New York Central & Hudson River Railroad, New York, N. Y.

J. E. SCHWITZER, Assistant Chief Engineer, Canadian Pacific Railway, Winnipeg, Man.

FRANCIS LEE STUART, Chief Engineer, Erie Railroad, New York, N. Y

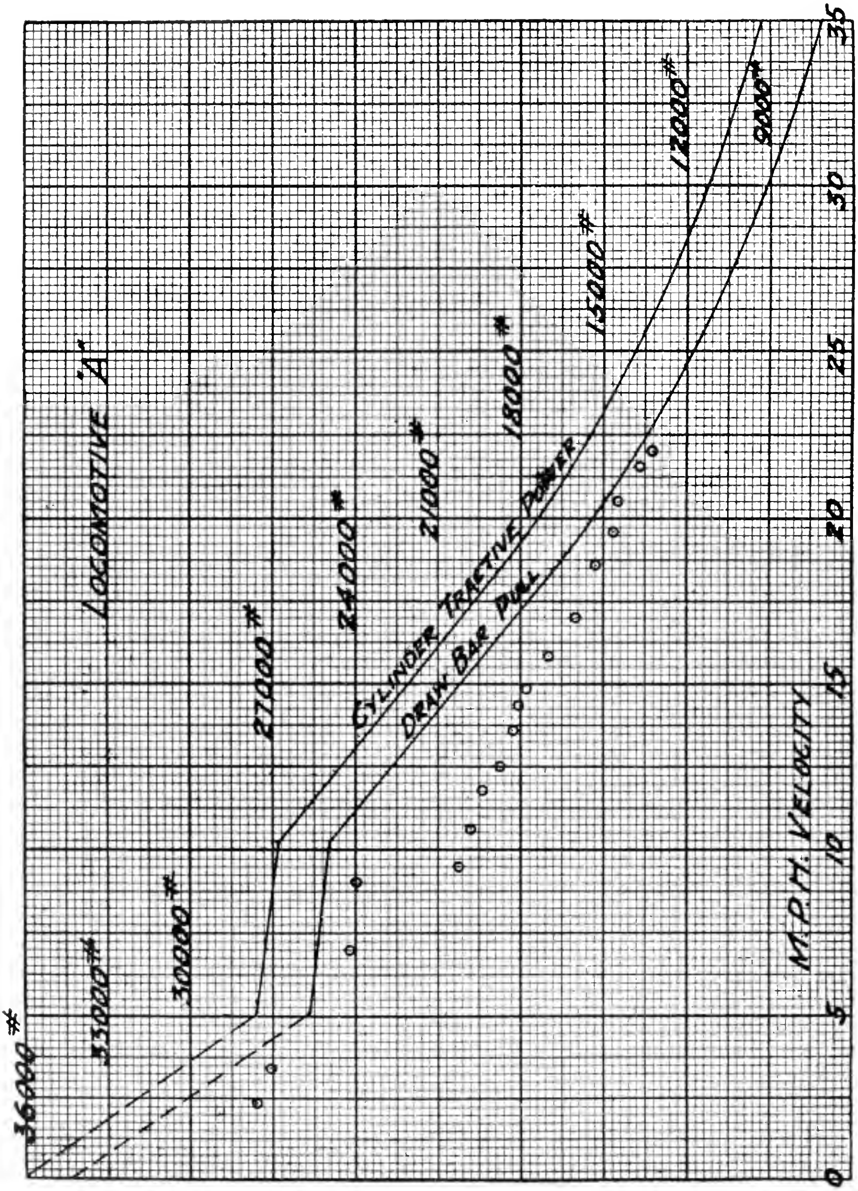
H. R. TALCOTT, Engineer of Surveys, Baltimore & Ohio Railroad, Baltimore, Md.

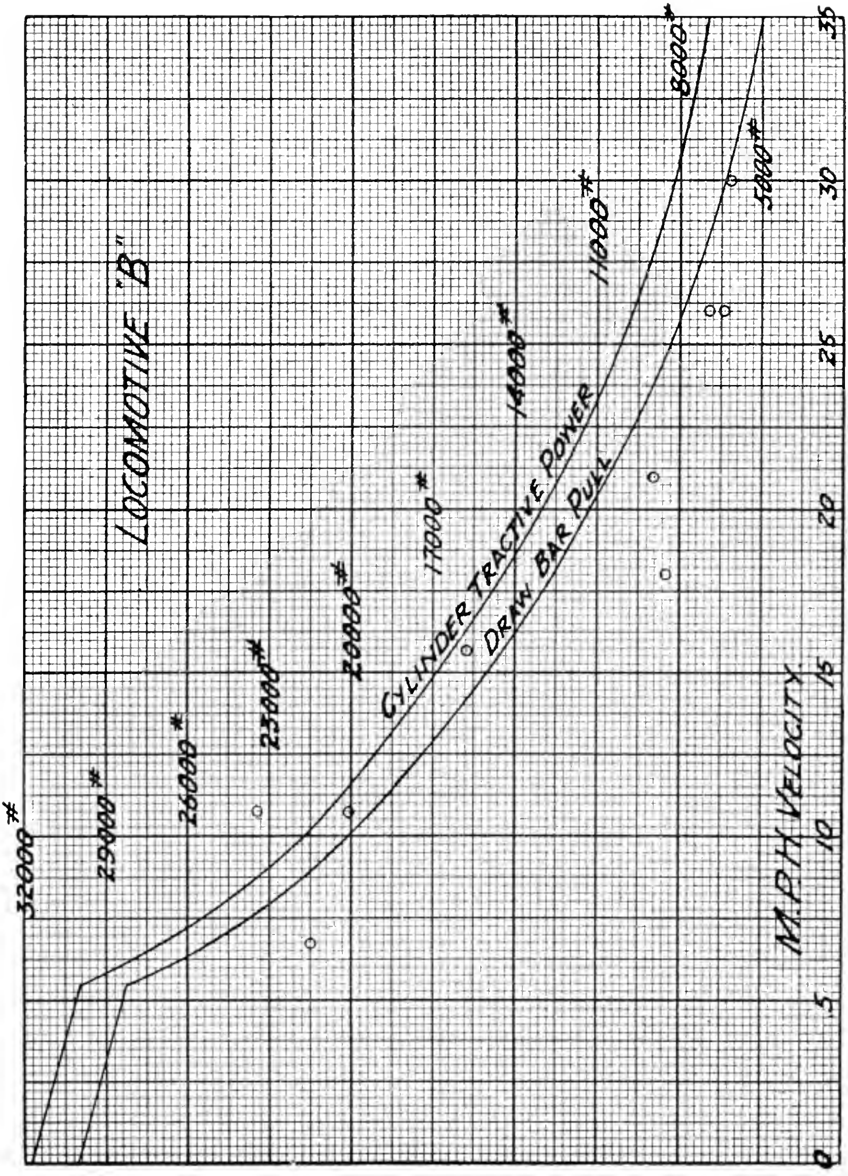
WALTER LORING WEBB, Consulting Engineer, Philadelphia, Pa.

Committee.

Appendix A.

In order to give an idea of a comparison between actual results obtained in road tests of locomotives and the calculated drawbar pull by the method within the body of the report, the following tables and diagrams are given:

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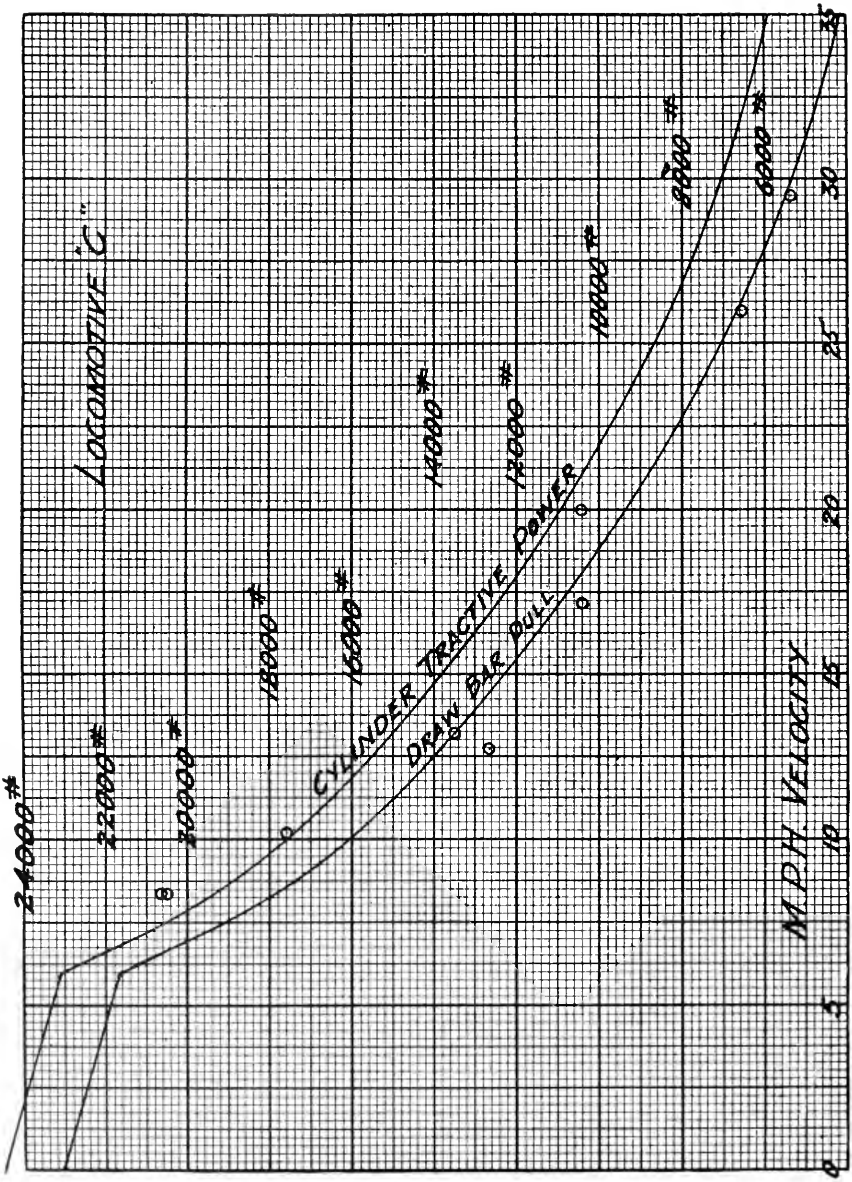
32000#
29000#
26000#
23000#
20000#
17000#
14000#
11000#
8000#
5000#
CYLINDER TRACTIVE POWER
DRAW BAR PULL
M.P.H. VELOCITY
0
5
10
15
20
25
30
35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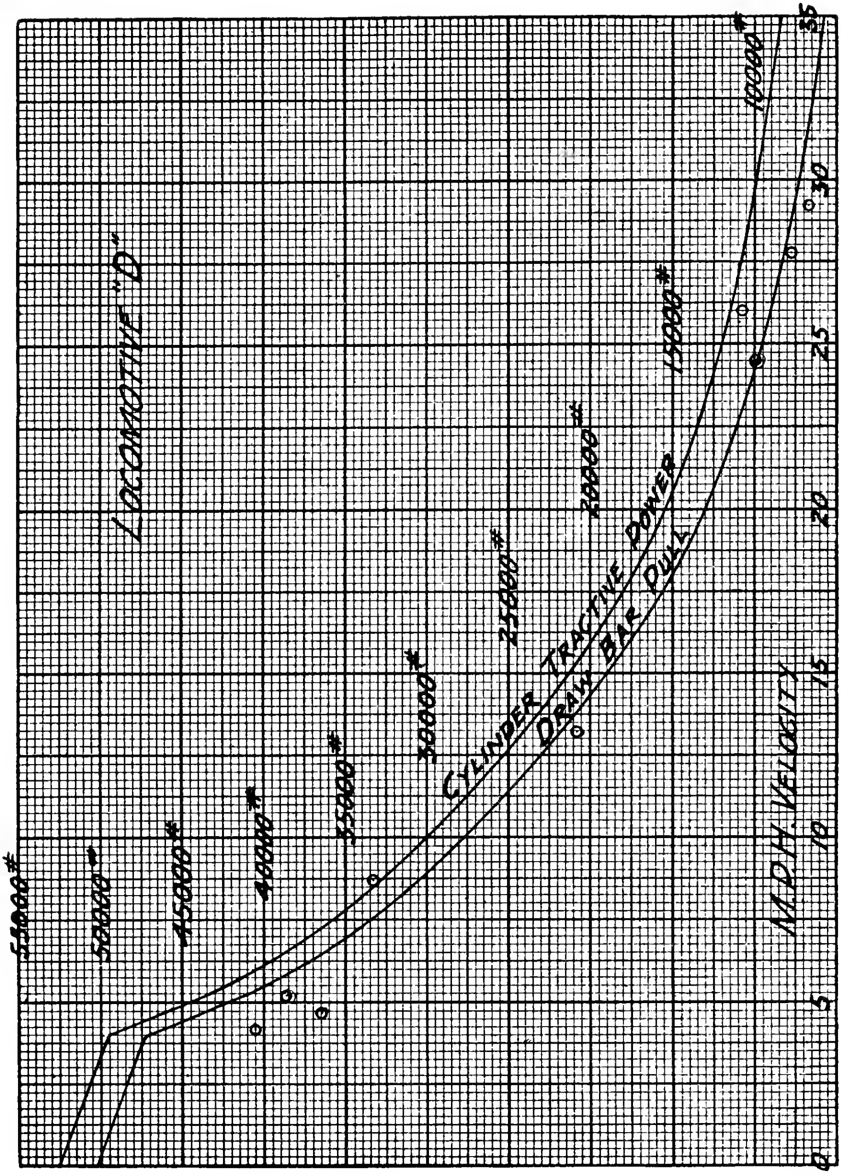
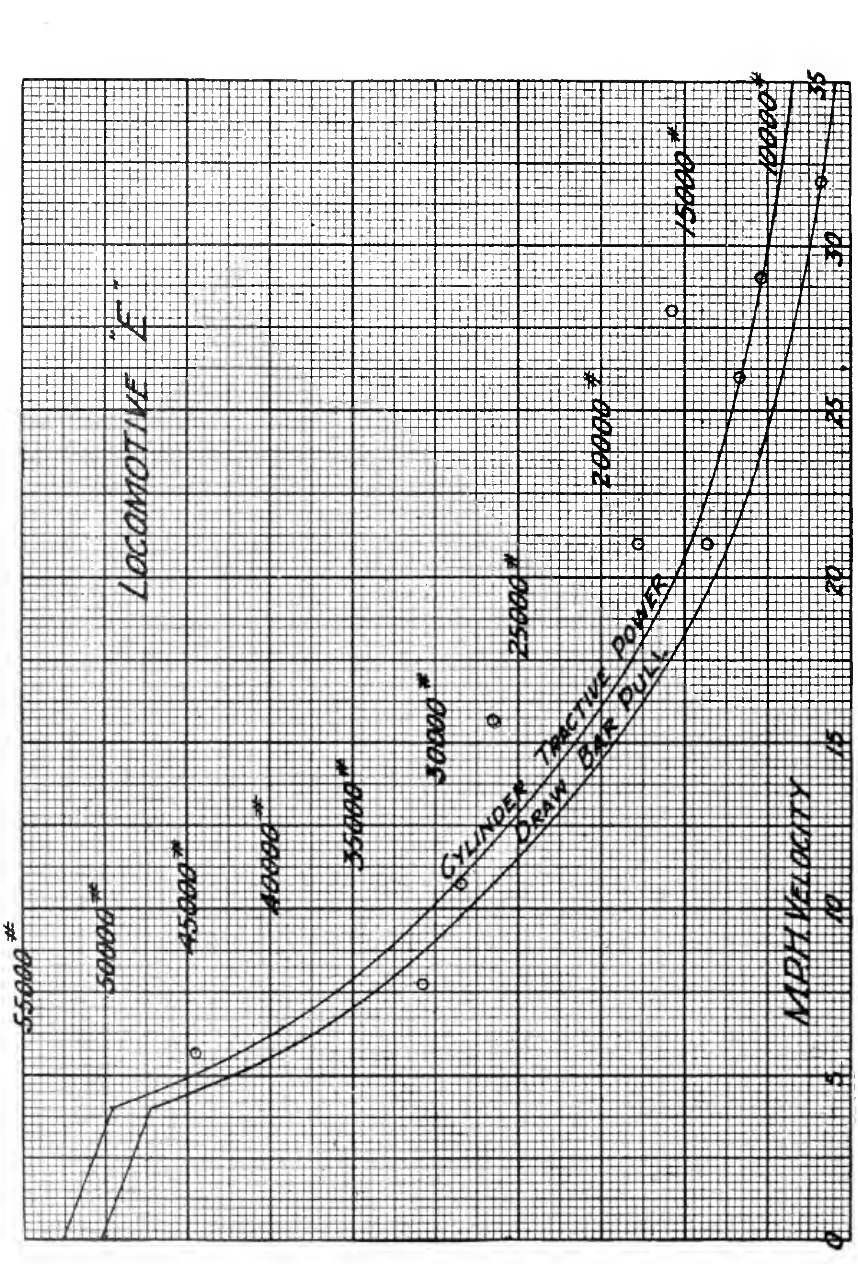
22000#
20000#
18000#
16000#
14000#
12000#
10000#
8000#
6000#
CYLINDER TRACTIVE POWER
DRAW BAR PULL
M.P.H. VELOCITY
0
5
10
15
20
25
30
35


LOCOMOTIVE "D"
CYLINDER TRACTIVE POWER
DRAW BAR PULL
M.P.H. VELOCITY
55000#
50000#
45000#
40000#
35000#
30000#
25000#
20000#
15000#
10000#
0
5
10
15
20
25
30
35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55000#
50000#
45000#
40000#
35000#
30000#
25000#
20000#
15000#
10000#
CYLINDER TRACTIVE POWER
DRAW BAR PULL
M.P.H. VELOCITY
0
5
10
15
20
25
30
35

Locomotive "A" was a Vauclain compound; the district was a "hard water" district and there is a probability that some scale existed in the boiler. Locomotives "B," "C," "D" and "E" were simple locomotives tested on the Illinois Central Railroad by the Railroad Engineering Department of the University of Illinois with Test Car No. 17. (See article on Tractive Power of Locomotives by Edward C. Schmidt, Associate Professor of Railroad Engineering, University of Illinois, in Railroad Gazette, Vol. XXXIV, No. 10, March 7, 1902.) The following table gives details of locomotives. The figures for steam production and tractive power at full cut-off are calculated on the basis outlined in the report estimating the fuel fired as 4,000 lbs. per hour. The diagram shows calculated cylinder tractive power, and drawbar pull on level tangent at maintained speeds. The small circles show actual recorded drawbar pull corrected for level tangent.

It may be claimed that by this method the calculated pull varies too much from actual results obtained, but it will be impossible to devise a formula that will come much nearer the actual results than the proposed method, with the meager information at hand with reference to the exact effect of each detail of locomotive on tractive power, and were information available, the method of calculation would be very complex.

Locomotive	"A"	"B"	"C"	"D"	"E"
Type	Compound	Simple	Simple	Simple	Simple
Wheel arrangement	4-6-0	4-6-0	2-6-0	2-8-0	4-8-0
Weight (tons):					
Drivers	70.03	61.85	53.2	92.4	90.7
Engine truck	22.57	20.25	9.8	9.1	20.0
Tender	66.10	51.00	40.0	52.5	52.5
Size of cylinders	15.5 in. and 26x28 in.	20x28 in.	19x26 in.	23x30 in.	23x30 in
Diameter of drivers	63 in.	63 in.	56.5 in.	57 in.	57 in.
Heating surface	2984	2396	1531	3211	3500
Grate area	47	27.29	25.75	38.5	37.5
Ratio H.S. to G.A.	63.5	87.8	59.4	83.4	93.3
Boiler pressure (lbs.)	200	200	165	210	210
B.T.U. per lb. coal	11000	12000	12000	12000	12000
Lbs. coal per hour (est.)	4000	4000	4000	4000	4000
Lbs. coal sq. ft. G.A. per hour	85	147	155	104	107
Evap. sq. ft. H.S. per hr.	6.34	6.91	9.31	6.28	5.83
Total lbs. evap. hourly	18918	16556	14255	20165	20405
Lbs. evap. per minute	315.3	275.93	237.58	336.08	340.08
Lbs. steam per revolution	5.77	9.60	6.79	14.28	14.28
Max. revolutions per minute full cut-off	54.64	28.74	34.99	23.59	23.81

Locomotive	"A"	"B"	"C"	"D"	"E"
Type	Compound	Simple	Simple	Simple	Simple
Equivalent velocity M.P.H.= (M)	10.25	5.40	5.89	4.0	4.04
Cylinder tractive power at "M"	26820	30000	23112	49594	49700
Resistance:					
Cylinders and drivers	1549	1397	1235	2048	2016
Trucks and tender	351	305	229	260	309
Total resistance except velocity	1900	1702	1464	2308	2325

Particular attention is called to locomotives D and E. The tables show only about 9 per cent. more heating surface in E than for D. The ratio H.S. to G.A. is higher in E with consequently a less evaporation per square foot than for D. By the Master Mechanics' M.E.P. curve, the tractive power of these locomotives would be the same and by the proposed method the power of E is but slightly greater than for D. The actual maximum pulls recorded for E are higher than the calculated pulls. There may be details of exhaust, valve, etc., that make E a more effective steam producer and user. There is also a possibility of the maximum pulls occurring at a time when the fireman was exerting his maximum efforts in serving coal to the fire box. The two diagrams represent fairly well the fact that exact results with the recommended formula cannot be obtained. For purpose of comparison of the estimated power of locomotives by the proposed method and by the general method of using an arbitrary M.E.P. curve for various piston speeds without consideration of quantity or quality of fuel burned, the following has been deduced, using the Master Mechanics' M.E.P. curve as the most conservative of the various curves:

Locomotive	"B"	"C"	"D"	"E"
Miles per hour—Full cut-off by M.M. curve	9.07	8.72	7.63	7.63
Cylinder tractive power at above speed,				
M.M. curve	28444	21928	46775	46775
Proposed method	22985	18920	35375	35614
Excess Est. Power by M.M.	5459	3008	11400	11161
Per cent. excess	24	16	32	31
Cylinder tractive power at 35 M.P.H.:				
M.M. curve	11733	8771	16079	16079
Proposed method	6978	5921	8386	8494
Excess Est. Power by M.M.	4755	2850	7693	7585
Per cent. excess	68	48	92	80

From the foregoing it can be seen that by the use of the arbitrary curve for M.E.P. the values obtained were high at velocities of 7.5 to 10 M.H.P., the speeds at which it is the custom to figure the train haul on long gradients where the time element may not enter into the question. The results from using this high estimate of power which is seldom attainable in actual practice in the major portion of this country, would be erroneous, as the train mileage or actual number of trains required to handle a given traffic would be much greater than calculated. This would be true for any maintained velocity on ruling grades, and as the velocity increases the per cent. of excess power grows larger. Errors in calculating lengths of velocity grades can be reduced by using methods of calculating available power which more nearly approach the average of actual results obtained.

Appendix B.

(Bulletin 115.)

CURVATURE.

By C. P. Howard.

The purpose of this paper is to discuss the general subject of curvature as it appeals to and must be considered by the Locating Engineer. We have little exact information on which to base some of our most important conclusions; perhaps we never shall have. We cannot reduce to a formula the general peace of mind of passengers, enginemen or roadmasters, but meanwhile we must locate and build railroads, spending large sums of money, and we cannot wait until all the data shall have been definitely determined. Necessarily, therefore, the suggestions here offered tentatively are matters more or less of judgment and opinion, and it is hoped that a discussion may bring out as far as possible the general opinion of members of the Association on the points considered.

IMPORTANCE OF CURVATURE.

Curvature has been termed a "minor detail" of location. Nevertheless, its financial importance is considerable. Comparatively speaking, it does not take much additional curvature per mile, with money at 4 per cent., to make a capitalized difference of $50,000 in ten miles, or $500,000 in 100 miles on a road running 60 trains a day. If the grades are flat and trains heavy, costing, say $1.60 per train mile, 10 degrees of central angle additional per mile would make the difference according to ordinary methods of figuring.

WELLINGTON'S FLAT RULE TO START WITH.

The usual values for one degree of curvature, based by Wellington's method on estimates or guesses as to the effect on operating expenses, are perhaps the best figures to start with. Thus, if the probable number and size of trains and the cost per train mile for running them are known, we can readily compute a *flat rule* per degree of central angle. (Wellington, page 322; J. B. Berry, Proceedings, 1904, page 706; Webb, Economics of Railroad Construction, page 262.) Further on we shall discuss the value of such a rule and suggest certain improvements.

FIXING THE MAXIMUM DEGREE OF CURVE; IMPORTANCE.

Knowing the maximum speed desired, we can readily fix a maximum degree of curve to correspond as that curve which requires a certain superelevation of outer rail, say six or seven inches. But if we are given a certain amount of traffic to take care of and wish to use the most economical curve, all things considered, the problem is not a simple one. We cannot tell whether such a maximum is the most economical or not, until we survey the line and make calculations to determine the relative cost of a higher or lower maximum.

It is an error to suppose that the character of the country will usually determine such matters. It is the writer's observation and experience that it usually does not. If anyone doubts this, let him look at some of the lines which have recently been rebuilt and note the difference between the long tangents of the new lines and the sinuosities of the old.

These questions are continually presented: Shall we build across the hollow or around it; shall we make two crossings of the stream or follow the curve of the bank; shall we tunnel the point or go around, etc., etc. Even in flat country a cheap right-of-way may require curves, and the facility of locating in moderately flat regions is apt to be neutralized by the modern necessity of obtaining light grades. In rolling country, as in the mountains, the alternatives of cutting across or going around are always present, and cannot be determined correctly except by a knowledge of the value of the curvature and distance saved.

The writer recalls an instance of such revision on one of our mountain roads. The old line followed the windings of the gorge, while the new tunneled the points and bridged the stream. Probably twelve to fourteen degree curves were used on the old line, and six degrees on the new. An engineer of the road remarked: "We are building a six-degree line in a sixteen-degree country." Either can generally be done, or any variation between the two, but the problems will not solve themselves, and differences in cost are large.

WHEN TO USE THE MAXIMUM.

Having selected a maximum degree of curve, the next question is when to use it. Here we have no rule except an implied one which we consider wrong in principle, and against good practice. This rule is that the negative value of a degree of central angle is independent of the radius; that a light curve is no better than the maximum. But we know sharp curves are objectionable. We take this to be the unanimous opinion of the public as well as the railroad men of to-day. None of us will put in a maximum curve where we can get a lighter one, and what is more, we will spend money to make them light.

OBJECTIONS INCREASE WITH SPEED.

Objections to curvature increase with the speed of trains. We assume this to be a fact; which is to say, it is justifiable to spend more money per daily train to take out one degree of central angle on a fast line between New York and Chicago, than on a slow-speed coal branch in the mountains. It is difficult to prove this by mathematics. The centrifugal force increases as the square of the speed. The superelevation of rail designed to resist this force is a palliative rather than a cure, and when elevated for high-speed trains, is charged with being a prolific cause of derailment for slow trains. Moreover, on track elevated for forty-five miles an hour, trains may run at fifty or sixty, and when elevated for sixty miles, a speed of seventy or eighty miles may sometimes be attained.

For freight trains the conditions are different. Wellington says (page 268): "It is fully as difficult and dangerous to run freight trains over sharp curves at twenty-five or thirty miles per hour as passenger trains at sixty miles per hour, owing to the difference in their mechanical construction." We may, therefore, take about one-half the passenger train maximum as a corresponding maximum for freight trains, and it may be sufficiently accurate in many cases to figure only on the speed of passenger trains on the assumption that the speed of freights will be proportionately lower so as to give about the same economy and safety in operating over any given curve.

Assuming the above to be true, that more money may be spent to eliminate the sharper curves, requiring the maximum superelevation of rail and that the objections to curvature increase with the speed. the next question is how much more can we spend. Frankly, we do not know. Any estimate will be largely a surmise. The important proposition is, however, that the objections to curvature *do increase* with both the speed and the degree of curve in *some proportion,* and that the objections due to increased speed are not sufficiently compensated for by the fact that we use correspondingly lighter curves for higher speed. The flange pressure against the rail due to rotation of trucks is possibly the same for all curves at all speeds (see Wellington, page 291); while the vertical jolt or rebound as stated above increases with the square of speed.*

But in order to eliminate some of the unknown quantities and replace with definite proportions, we have, as a preliminary, made these tentative assumptions, the Rules and Formula which follow being largely dependent on them:

(1) That the negative value of a degree of central angle increases in direct proportion with the speed of trains;

(2) That for any given speed of trains the negative value of a degree of central angle varies with the degree of curve and is twice as great on a curve requiring six inches elevation as on a curve requiring one inch elevation.

---

*We figure that when a train strikes an obstruction or a rough place in the track, the jolt, vertical rebound (or bounce) will be in proportion to the square of the speed. (Trautwine, pages 343-4, Ed. 1902.) If on a curve, and the bump is great enough, the wheel may climb the rail, while on a tangent the tendency is to continue on in a straight line and stick to the rails. So that on curves of the same radius the danger of derailment from small obstructions or bad surface may be considered to vary, more or less, as the square of the speed.

RULES FOR DETERMINING THE NEGATIVE VALUE OF ONE DEGREE OF CENTRAL ANGLE.

The best or ideal rate of curve for any given maximum speed is assumed to be that degree which requires an elevation of one inch for the maximum speed as determined by the formula, $E = .00066\ DV^2$ (Manual, page 61). Any sharper curve is considered more or less objectionable up to (and beyond) a curve requiring six inches elevation, whose negative value we assume to be twice that of the ideal curve, with other intermediate rates of curve in the same proportion. On this assumption the ideal rate of curve, and the curve requiring six inches elevation, for different maximum speeds are as follows:

Speed.	Ideal Curve.	Six-Inch Elevation Curve.
60 miles per hour	0° 25′	2° 31′
50 miles per hour	0° 36′	3° 38′
40 miles per hour	0° 57′	5° 41′
30 miles per hour	1° 40′	10° 06′
25 miles per hour	2° 25′	14° 33′

As stated in the Manual, page 62, the elevation should nowhere exceed eight inches (and it is probably not safe for the speed to exceed its elevation very much).

Wellington, page 270, gives as a limit of speed for safety that point where the centrifugal force amounts to one-fourth the weight, or $C = \frac{W}{4}$, permitting a speed of sixty miles an hour on a five-degree curve and forty miles an hour on a ten-degree. His table, page 273, gives the centrifugal force as more or less objectionable and dangerous between certain limits, the inferior limit occurring long before the maximum speed is reached for which it is safe to elevate. Six and one-half inches is a proper elevation for a two-degree curve for a speed of 70 miles an hour, but 41 to 130 miles are the limits given between which the centrifugal force is more or less objectionable and dangerous, the car overturning from centrifugal force at the latter speed.

Rule 1. Assume the value given on page 322 of Wellington as sufficiently correct, for an average curve at an ordinary speed, neglecting any deduction that might be made for compensation of grades. Take this figure, 0.000593, and multiply by the cost per train-mile (T), by 365, and by the number of trains (N), being the sum of trains in both directions, and divide by the rate of interest (r), to get the justifiable expenditure (A) to eliminate one degree of central angle for an ordinary maximum speed of 50 miles per hour on an average curve requiring 3½ inches elevation, or as a formula: $A = \frac{r}{0.216\ T\ N}$ this gives a flat value which takes no account of speed of trains.

RULE 2. For any other maximum speed, increase or decrease, the value of A in direct proportion.

RULE 3. To the value of A, obtained as above for a 3½-in. elevation curve at the given maximum speed, add one-third for a curve requiring 6 in. elevation; deduct one-third for a curve requiring 1 in. elevation, and make intermediate degrees of curve in proportion.

FORMULA.

Combining rules 1, 2 and 3 into the form of an equation, we have Equation (1), $A = \frac{T\ N\ V\ (E + 4)}{1732\ r}$ as the value of A for any maximum speed for any degree of curve elevated according to the formula $E = .0066\ DV^2$ and corresponding table on pages 61 and 62 of our Manual.

Example. What can we spend to eliminate one degree of central angle of a 2° 30′ curve; maximum passenger train speed (for which track is elevated) 60 miles per hour; number of passenger trains in each direction 15, number of freights each way 15, making a total of 60 trains a day; cost per train mile $1.60; money at 4 per cent. interest; and assumed that freight trains will run at a speed to give about the same economy and safety in operation as passenger trains at 6c miles. Then in Equation (1) we have $T = 1.60$, $N = 60$, $V = 60$, $E = 6$, $r = 4$ per cent. $= 0.04$, and $A = \frac{1.60 \times 60 \times 60 \times 10}{1732 \times 0.04}$ $= \$831.40$.

Were the degree of curve 0° 25′, requiring an elevation of one inch, the value of A would be one-half, or $415.70. If the maximum speed were 50 miles an hour instead of 60, the value of A for a 3° 38′ curve requiring 6 in. elevation would be $692.80; and $346.40 for a 0° 36′ curve of 1 in. elevation. If the rate of interest were higher, the values of A would be correspondingly less. Wellington, on page 323, uses 8 per cent. interest, which would reduce the values in this example by one-half.

Example 2. Given a branch line in the mountains with considerable traffic: What can we spend to eliminate one degree of central angle on a six-degree curve, maximum passenger train speed for which track is elevated, 30 miles per hour, freights to run at a speed to give about the same economy and safety in operation, number of trains each way 15, total number 30; cost per train-mile $1.20; money at 6 per cent. interest?

Here we have, $T = 1.20$, $N = 30$, $V = 30$, $E = 3½$, $r = 0.06$, and

$$A = \frac{1.20 \times 30 \times 30 \times 7.5}{1732 \times 0.06} = \$77.90.$$

If it is assumed that the cost of operation increases according to the square of the speed above 50 miles per hour, the corresponding formula for speeds above 50 miles per hour would be,

$$\text{Equation (2), } A = \frac{T\,N\,V^2\,(E + 4)}{86600\ r}$$

The maximum speed in the above formulas is understood to be the speed for which track is elevated according to the formula, $E = .00066\ DV^2$ and accompanying table on pages 61 and 62 of the Manual; but if important trains are likely to run at considerably higher speed, it might be well to make an increase in the value of A.

Finally, as a rough check or sidelight on calculations, the following is suggested:

Add up the total degrees of central angle on the whole line or division, as at first built or projected. Then consider how much more money the road would probably be worth to the Company in its present financial condition were all the curvature eliminated and the line straight from one end to the other; divide this amount by the total number of degrees of central angle.

*NOTE. In support of the proposition that the objections to curvature increase with the speed of trains, and are not sufficiently balanced by the fact that we use lighter curves for higher speed, we may note the following illustration of an extreme case of the increased liability to derailment:

Given a train going at 30 miles an hour on a 10-degree curve. Suppose a wheel on the outside of curve strikes an obstruction that causes it to rebound or bounce a vertical distance of one inch; then (Trautwine, page 348, Ed. 1902) we figure as follows:

$$\text{Time of rise (or rebound)} = \sqrt{\frac{.0833}{\tfrac{1}{2}\,g}} = 0.072 \text{ seconds} = .0012 \text{ minutes.}$$

The distance traveled during the rise at 30 miles per hour, or one-half mile per minute, will be 2640 × .0012 = 3.2 ft., and it would have gone 6.4 ft. before dropping back to a level. When it had traveled three-fourths of this distance, or 4.8 ft., it would still be elevated (in the air) about ¾-in. The wheel will have traveled straight on in a tangent, however, while the rail has curved inward in this distance 0.02 ft., or, in reference to its original position on the rail, the wheel is elevated ¾-in. and has moved out from the center of track ¼-in.

Similarly, suppose the velocity is 60 miles per hour instead of 30, and the wheel strikes the same obstruction, the vertical rise or bounce will be 4 in. instead of 1 in. But suppose the degree of curve is 2° 30′ instead of 10°, requiring the same elevation of rail, 6 in. as a 10°

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*It would be interesting to investigate how far the springs act in holding down the wheels and modifying the movements above noted.

curve for 30 miles an hour. Similarly as above the time of rise will be $\sqrt{\frac{.333}{\frac{1}{2}g}}$ = 0.144 seconds = 0.0024 minutes. The distance traveled before it would get back to a level would be 25.3 ft.; and at a distance of 19 ft., it would still be elevated (in the air) about 3 in. and will have gone forward on a tangent, moving out from the center of track a distance of 1 in. (or exactly 0.94-in.); and going at 60 miles an hour!

If in the above example we had used the same degree of curve for both speeds, we would have found the movement away from the center of track sixteen times greater for 60 miles an hour than for 30. Therefore, neglecting any modification of movements occasioned by the repressive action of the springs, the joining together of one or more axles in a truck, one or more cars in a train, etc., we may say that when a wheel on the outside of a given curve strikes an obstruction that causes it to bounce, the vertical movement will be as the square of the speed, but the side movement due to the centrifugal force will be approximately as the fourth power of the speed.

If, as in the above examples, the degree of curve is reduced for the higher speed so as to give the same elevation of outer rail for both speeds, the side movement will be approximately as the square of the speed.

Appendix C.

(Bulletin 114.)

THE BASIS OF VARIATION FOR OPERATING COSTS APPLICABLE TO THE DESIGN OF RAILWAY LOCATION.

By A. C. Dennis.

PASSENGER TRAIN RESISTANCE.

In the mass of information presented by the Committee on Economics of Railway Location regarding Train Resistance there is little regarding passenger train tests which is in sufficient detail as to be capable of analysis and the establishment of the general law of variation. The Baldwin formula seems preferable for fairly heavy passenger trains.

FREIGHT TRAIN RESISTANCE.

Published reports of heavy freight train tests are very few, and there are fewer still which give sufficient information regarding the cars composing the tested train as to make possible an analysis of the results. A paper before the Am. Soc. C. E., December, 1902, published in Transactions LI, Part I, it is believed first called attention to the fact that heavy freight train resistance did not increase with speed up to 35 miles per hour, as was generally assumed. This fact has been confirmed by Mr. Shurtleff's experiments, Proceedings Am. Ry. Eng. and M. W. Assn., Vol. 8, p. 235, and, while unaccepted generally, has never, within the writer's knowledge, been disproved by experiment.

The following are selected from trains tested with dynamometer as showing greatest variations in loading. These tests are on what may be classed as fair tracks and rather unfavorable weather conditions and cover speeds from 7 to 35 miles per hour. The resistance at speeds below 7 miles per hour increases at an increasing ratio as the speed is decreased, until at near 0 the resistance may be twice that of 7 miles per hour, while it may be less than a pound per ton more at 3 miles per hour.

Number of Cars.	TRAIN WEIGHTS IN TONS			Pounds of Total Resistance behind Tender	Pounds of Total Resistance per Ton of Train.]
	Contents.	Cars.	Total.		
105	nil.	1509	1509	13300	8.8
95	nil.	1286	1286	11600	9.0
83	226	1120	1386	10450	7.5
47	1216	721	1937	9100	4.7
52	1243	745	1988	9150	4.6
Mr. A. K. Shurtleff, Vol. 9, Page 791, gives the following:					
34	....	....	1355	6500	4.8

The apparent irregularity in rate of resistance per ton shown above and for other tests disappears when the resistance due to weight is separated from that due to the number of cars handled. The law of freight train resistance, as deduced from a number of tests under variable weather and track conditions as well as variable loading, shows a very remarkable uniformity. This law, using the coefficient applicable to the conditions under which these tests were made, is as follows:

Train resistance behind tender on straight level track for heavy freight trains for speeds from 7 to 35 miles per hour, and car weights from 12 to 45 tons, equals 2.6 lbs. per ton of train weight plus 85 lbs. per car, or, expressed in the symbols of the Committee, $r = 2.6t + 85n$.

Comparing the resistance, as calculated by this formula, with the resistance as shown by the tests, shows that the difference is unimportant.

$2.6 \times 1{,}509 + 85 \times 105 = 12{,}948$ lbs. Actual 13,300 lbs. Diff. —352 lbs.
$2.6 \times 1{,}286 + 85 \times 95 = 11{,}419$ lbs. Actual 11,600 lbs. Diff. —181 lbs.
$2.6 \times 1{,}386 + 85 \times 83 = 10{,}659$ lbs. Actual 10,450 lbs. Diff. +209 lbs.
$2.6 \times 1{,}937 + 85 \times 47 = 9{,}031$ lbs. Actual 9,100 lbs. Diff. — 69 lbs.
$2.6 \times 1{,}988 + 85 \times 52 = 9{,}589$ lbs. Actual 9,150 lbs. Diff. +439 lbs.
$2.6 \times 1{,}355 + 85 \times 34 \div 6{,}413$ lbs. Actual 6,500 lbs. Diff. — 87 lbs.

The formula $r = 2.6t + 85n$ gives resistance for different weights of cars as follows:

Average weight of car, tons.......	12	15	20	25	30	35	40	45
Resistance per ton, lbs..............	9.6	8.3	6.9	6.0	5.4	5.0	4.7	4.5

Mr. Shurtleff's values (Vol. 8, p. 239) are 1.4 lbs. less than the above, the rate of variation being the same, however. Without questioning the correctness of his results for favorable conditions, it is considered safer to use the higher value as being better applicable to the yearly average, which must cover unfavorable conditions.

If experience shows the formula $r = 2.6t + 85n$ to give resistance too high for the average conditions considered, it can be modified by reducing the coefficient 2.6. The coefficient 85 is believed to be a constant for box cars within the limits of these tests.

While the coefficient to be used with "t" must vary under different conditions, the general law that resistance is independent of speed within limits, and that it varies directly as the weight of train plus a constant per car, can be considered as established. The acceptance of this law will do much to clear up the confusion on this important subject.

MAKE-UP OF FREIGHT TRAINS TO EQUAL LOCOMOTIVE RATING.

The formula $r = 2.6t + 85n$ forms a useful basis for making up trains of a desired total resistance from cars of any weights. The total train resistance is 2 lbs. per ton, per tenth of gradient, which may be called "gradient resistance" or "gradient acceleration;" plus 2.6 lbs. per ton, independent of gradient, which may, for the sake of distinguishing it, be called "rolling resistance;" plus 85 lbs. per car for what may be called "car resistance."

It is convenient to make the unit for rating on a constructive or "rating ton" basis. This basis is the actual tons plus an allowance for car at a tonnage of equivalent resistance to the 85 lbs. car resistance. The "rating tons" corresponding to a 30-ton car for rating on 0.6 per cent. gradient, for example, would for the 85 lbs. "car resistance" be 85 ÷ 14.6 (gradient and rolling resistance) for this gradient or 5.8 tons. The actual tons (30) plus the constructive (5.8) equals the rating tons (35.8).

With the Locomotive Rating given them in "Rating Tons" and the proper tonnage to be allowed for each car of the train, the yard men can readily make up a train of the required rating without any tables or diagrams for equating light loads.

The following allowance per car for gradients shown are to be added to the actual tons to convert to "rating tons:"

Gradient per cent.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0	3.0	4.0
Tons Car Allowance	33	19	13	10	8.1	6.8	5.8	5.1	4.5	4.1	3.8	3.2	2.8	2.5	2.2	2.0	1.4	1.0

LOCOMOTIVE RATING.

Locomotive rating for a small class of roads when ruling gradient is high, and a small part of the run may be on the basis of locomotive adhesion for starting or tractive power at 7 to 10 miles per hour over the ruling gradient forms a basis of rating which is usually independent of boiler capacity. Such rating also requires that the trains be few and the class of traffic such that time in transit does not matter.

The usual basis, and tending to become common usual with low gradients and pressure of train movements, is that dependent on the boiler capacity of the locomotive rather than adhesion. The time required to run the division limits the rating, instead of the stalling limit. This difference in rating method should be kept in mind when designing a location, since the rate of gradient is the limiting factor in locomotive capacity in the first case, while in the second it may be immaterial. For a light rating, based on time requirements, the amount of rise is the governing consideration. A broken gradient line of considerably higher maximum gradient has the same operating value, where rating is based on time, as a long, straight gradient line of the same rise and fall. The tonnage hauled, time, foot-tons of work or horse-power hours required, are the same by the straight gradient as the broken, provided the broken gradient is such that the locomotive can be worked its full horse-power without exceeding the speed limit.

Running time, exclusive of any Stops.	Delay for Water and orders	NUMBER OF OPPOSING TRAINS FOR 24 HOURS.															
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		TOTAL TIME, INCLUDING STOPS.															
4.0..................	1.0	5.0	5.1	5.3	5.5	5.7	6.0	6.2	6.4	6.7	7.1	7.4	7.8	8.2	8.7	9.3	10.0
5.0..................	1.0	6.0	6.2	6.4	6.7	6.9	7.2	7.5	7.8	8.2	8.6	9.0	9.5	10.0	10.6	11.2	12.0
6.0..................	1.0	7.0	7.2	7.5	7.8	8.0	8.4	8.7	9.1	9.6	10.0	10.5	11.0	11.7	12.4	13.1	14.0
7.0..................	1.0	8.0	8.3	8.6	8.9	9.2	9.6	10.0	10.5	11.0	11.5	12.0	12.7	13.4	14.2	15.0	16.0
8.0..................	1.0	9.0	9.3	9.6	10.0	10.3	10.8	11.2	11.8	12.4	12.9	13.5	14.2	15.1	16.0	16.9	18.0
9.0..................	1.0	10.0	10.3	10.7	11.1	11.5	12.0	12.5	13.0	13.6	14.2	15.0	15.7	16.6	17.5	18.7	20.0
10.0..................	1.0	11.0	11.4	11.8	12.2	12.8	13.2	13.7	14.3	15.0	15.6	16.5	17.4	18.3	19.3	......	......
11.0..................	1.0	12.0	12.4	12.9	13.3	13.9	14.5	15.1	15.7	16.5	17.2	18.0	18.9	20.0	......	......	......
12.0..................	1.0	13.0	13.5	14.0	14.5	15.0	15.7	16.3	17.0	17.9	18.6	19.5	......	......	......	......	......

Time is in hours and tenths of an hour.

The operating costs will be practically the same except that horse-power hours, which are equal for the two lines, will be developed for the broken gradient at slightly higher fuel consumption because of the irregular speed.

The economical locomotive rating is largely a traffic matter, but some general approximation is possible, notwithstanding the many variable influences. In order to illustrate the rating based on time, the following is assumed. Run must be made at average of 10 miles per hour. Stops for water and orders take up one hour. Meeting each opposing train takes 25 minutes. Opposing trains take the same time as the train considered. The line is single track.

It appears from the above that for a division of 125 miles, with 13 daily trains, that the running time, exclusive of stops, must not exceed six hours if the total time is not to be in excess of 12.5 hours. This means that the locomotive, while running, must make better than 20 miles per hour on the average and as a necessary consequence be very lightly loaded in comparison with the loading if rated for a low speed. With six opposing trains, the time without stops would be nine hours.

Mr. Shurtleff's locomotive and train A (Vol. 9, p. 775, and following), if run over 120 miles of straight 0.3 per cent. gradient, would make about 13 miles per hour only, though loaded only for 0.5 per cent. gradient, and require about 9.25 hours for running time without stops. Even with the loading reduced to that possible on 0.5 per cent. the train could not be operated over this 0.3 per cent. maximum and meet four opposing trains without exceeding the time limit of 12 hours.

Should traffic be on the basis of 10 daily trains each way, and neglecting the effect of favorable gradient on the time of opposing trains, the above conditions would require a running time, exclusive of stops of seven hours, or 17 miles per hour. The rating corresponding to 17 miles per hour on 0.3 per cent. gradient is 1,440 tons in 25-ton cars. This tonnage can be handled over 0.82 gradient at 10 miles per hour.

This 120 miles of +0.3 per cent., if being located for 10 daily trains, could be broken up into any combinations of plus gradient from level to 0.8 per cent. maximum without decreasing the train loads or changing the cost of operation appreciably. The costs of traffic in the opposite direction will be the same as for 0.3 per cent. except for such energy as it might be necessary to destroy by brakes in excess of that necessary over the —0.3 straight gradient.

Such an extreme case of continuous low gradient is not liable to occur, neither are the 10 daily trains during the early years of a road's operation, and no claim is made as to the assumptions being in agreement with operating conditions; but is intended to show that expenditure may be made for low gradients where a higher one would be just as good in its traffic efficiency and cost less.

On a division of quite heavy traffic and considerable rise in one direction there was a gradient reduction made from 0.5 per cent. maximum to a new 0.3 per cent. maximum. There were only a few miles of 0.5 per cent., but the approaches and length was such that momentum was exhausted and locomotive maintained a low, even speed when the top was reached. There was no adverse gradient on the part to be reduced. This expenditure produced no measurable change in operating costs. The locomotive work was not reduced, neither could the train weights or time be improved.

The advantages from a low gradient in handling heavier trains during the period when trains are few and slow speed is practicable, can only apply to a few trains. When the trains become many and the saving would seem to be large, it entirely disappears, since the demands of a congested traffic necessitate a reduction in rating to a point where several tenths higher maximum gradient would serve as well.

The low gradient has then only a prospective value, which would be available when the line should be double tracked, making slower speed practicable.

The use of development in very low gradient lines to maintain this ruling gradient over a considerable part of a division at the expense of considerable extra distance is very probably an error in designing the location. Considered only by itself, without reference to its incidental value as making available a greater tonnage capacity on the adjoining line, no development is economically justified until the gradients are such that the locomotive gradient resistance and difficulty of controlling trains become the governing considerations. Considered by divisions, it is generally good economics to adopt a gradient to fit the country after having found the country permitting lowest gradient, rather than force an unnatural gradient, especially a low one, by development distance. Rise, rather than the rate of rise, is generally the limiting consideration in locomotive rating, and the governing factor in fuel consumption.

That the rating in practice is largely independent of ruling gradients is shown by the rating in both directions, being the same on a division of 0.5 per cent. maximum one way, and 1.0 per cent. in the other. Two adjoining divisions, each having 1.0 per cent. maximum gradients, have a difference of over 100 tons in the average train load, for no apparent reason than the greater rise on the division of lesser tonnage.

FREIGHT TRAIN MILES.

The rating, having been determined for the average or the typical locomotive in rating tons or actual tons, and divided into the tonnage on the same basis for a given period each way, will give the trains required. The direction of greatest train requirements determines the number of trains or locomotives in the opposite direction which must be the same no matter how little traffic there is to move that way. Trains should be figured separately for each month when the direction of greatest requirements changes. There are often certain trains run daily, even if traffic for full loading is not available and other trains are run regularly at reduced rating. The number of trains each way multiplied by the length of run gives the train miles.

The train mile is the usual unit for estimating operating costs, but is unsuited as a base, except for train wages and supplies and locomotive repairs. The usual cost of these items is 18 cents and 8.5 cents, respectively, or, say, 27 cents to cover increasing locomotive weights.

The locomotive mileage, exclusive of helper locomotives, may be figured at train mileage rate. Regular helper locomotives are best provided for at a monthly rate.

PASSENGER TRAIN MILES.

Rating for passenger trains is almost always on a time basis. A small additional tonnage results in another section being run. The determination of the probable regular passenger and number of sections can best be fixed on a new railway from comparison with the most similar existing one. Passenger train miles may be figured at 25 cents to cover wages and locomotive repairs where actual cost is not available.

FUEL.

Fuel consumed is dependent on work performed by the locomotive through the draw-bar pull, the working and gradient resistance of the locomotive and tender, firing up and maintaining fire while standing or drifting down grade, braking and other items. The determination of the theoretical coal consumption for all these purposes is difficult and unsatisfactory. The foot-tons required for the train behind tender, while being by no means equal to the total foot-tons of work obtained from the coal, is found to be fairly proportional to the coal consumption, and the most satisfactory basis for its estimation. The approximate foot-tons were derived as follows: The train resistance is changed to its equivalent in rise. The average car weight at 25 tons has a resistance of 6 lbs. per ton, or equivalent to 0.3 per cent. gradient. With curve resistance added, its resistance may be equivalent to 0.4 or 0.5 per cent. gradient. On a small scale profile, the rise for each mile, if any above this, —0.3, —0.4 or —0.5 gradient, as the case may be, depending on the curvature, was scaled off and the total each way obtained. The variation of gradients within the mile was disregarded unless there was a summit higher than either mile point. The total feet thus determined in each direction multiplied by the tonnage in this direction gives the foot-tons covering rise and train resistance. For convenience 1,000 foot-tons is used as the unit and written M. F. T., the single foot-ton being too small as a unit. The M. F. T. for the year each way divided into the coal used in freight service for the year gave a fairly uniform rate of 8 lbs. per M. F. T. in the direction of heaviest locomotive requirements and a higher and more variable rate in the opposite direction. Adding the M. F. T. both ways and dividing into the total coal weight gives 9 to 13 lbs. per M. F. T. with an average of a trifle under 10 lbs.

This 8 lbs. in heavy direction is quite constant for heavy direction on 26 divisions covering widely different classes of gradient tonnage and locomotive service and different coal, though none of the coal could be considered poor. The 10 lbs. is a general average of the 26 divisions in both directions.

The locomotive was left out as tending to equalize the rate per M'. F. T., which shows a tendency to fall below the average on divisions of steep gradient. The inclusion of the locomotive while approaching more nearly the real M. F. T. would destroy the regularity of rate unless the other items largely independent of gradient can be added to correspondingly raise the M'. F. T. of the lower divisions.

The M. F. T. has an extreme variation of 7.5 to 14 lbs., and the cost per train-mile for fuel 13 to 58 cents, the corresponding weights being 113 lbs., and 387 lbs. at their respective prices. The cost per 1,000 ton-miles is 12 to 55 cents, corresponding to 104 and 306 lbs. at their respective prices. High train-mile and high ton-mile costs do not occur on the same division. The M. F. T., though unsatisfactory, seems the best basis and runs quite regularly generally, notwithstanding the large variation of extreme cases. The variation does not follow that of the train-mile or ton-mile.

Passenger service, though subject to higher train resistance and less fuel economy, due to high speed, does not appear from the inconclusive investigation made, to require over 10 lbs. of coal per M. F. T. when figured at the same rate per ton as freight. The greater uniformity of locomotive work may be the compensating cause.

Fuel used is seen to be quite independent of mileage or gradients and dependent entirely on the rise and tons. The mileage indirectly adds to rise a resistance equivalent of 15 feet or more per mile, which, unlike the actual rise, is a resistance in both directions.

CURVATURE.

Except for the modification due to the unbalancing of the centrifugal and gravity influences when speed and superelevation do not correspond, it can be demonstrated mathematically that tread and flange pressures are equal for all curves and that the skidding is proportional to the central angle and independent of speed. The destruction of rail and wheels will then be proportional to the central angle, and the coal required to accomplish this destruction is likewise proportional.

It may be possible that some mechanical connection between trucks will be devised so that the forces tending to turn one truck across the track on curves can be utilized to balance the similar forces in the other truck, thus relieving the flange reaction which now balances these forces. With the truck taking the position of the chord of the curve, much of the curve expense would be eliminated.

The fuel consumed per 100 degrees of central angle per 1,000-ton train at a curve resistance rate equal to .035 per cent. gradient is equivalent to 3,500 foot-tons; which, at 10 lbs. of coal per M. F. T. = 35 lbs. coal, which costs at $3.00 per short ton, 5.25 cents. 365 days × 5.25 ÷ 100 = 19 cents per year per degree for one daily train, one way. The capitalized value at 5 per cent. of 19 cents is $3.80. The fuel expense for curvature is best included with other resistances in the estimate based on M. F. T.

The added cost of track and rolling stock maintenance, if applicable cost statistics are not available, may be taken as equal to the interest on $2.20 for each degree of central angle by number of trains over it yearly.

There is another expense due to the unbalanced force of gravity and centrifugal force as superelevation or speed is relatively excessive. The excessive superelevation of a succession of 4° curves with little tangent between them showed for a low-speed freight train 4 lbs. above the tangent train resistance. Excessive superelevation in this case apparently causes 50 per cent. additional fuel, and presumably 50 per cent. extra maintenance over that of the same curves when the superelevation corresponded with the speed.

The financial effect of speed being in excess of superelevation in its relation to passenger revenue is indeterminate. Some estimate may, however, be made of the cost of slowing down, so as to avoid the apprehension of danger or discomfort on the part of the passenger. Assume the bad case of a 6-degree curve of 6 in. superelevation at the foot of a sag when a 500-ton passenger train would pass at 60 miles per hour if alinement were good, but, because of the curve, reduces to 40 miles per hour, the speed suitable for this superelevation and degree of curve. The loss in velocity head reducing from 60 to 40 miles per hour is 72 ft. The foot-tons destroyed by this speed reduction is equal to 72 ft. × 500 tons = 36,000 foot-tons. This destroyed energy must be replaced in the case of a sag. The yearly fuel cost for one daily fast train each way for this curve, in addition to its cost, figured on the basis of central angle is 36,000 foot-tons by 10 lbs. per M. F. T. × 365 × 2 = 131 short tons, cost at $3.00 = $393 yearly; the capitalized value of which is, say, $7,860 for these two fast trains, with a possible additional value from time saved. Some fuel may also be saved freight trains by decreasing the degree of this curve by reason of some conservation of energy in utilizing their momentum more fully if able to pass the sag at a higher speed. No value would attach to reducing this curve to one of lower degree, if situated at a summit or other point where range in speed would not be so great that a large unbalanced force of gravity or centrifugal force must result. The amount of this unbalanceable force varies with the degree of the curve, but as the square of the speed. A four-degree curve for 60 miles per hour is twice as objectionable as regards the balancing of centrifugal force as an 8-degree curve for 30 miles per hour.

MAINTENANCE.

Maintenance depends on so many variables that any general law based on train-miles, ton-miles or wheel loads is impracticable. Comparison with the cost of an existing line, similar with respect to class of line, climate, prices and tonnage will give the most reliable basis for estimating maintenance. The mile appears the best unit for measuring this cost. In a general way main lines cost from $1,000 to $1,500 and branch lines $750 yearly.

INTEREST.

Interest, at the rate the railway company must pay, on the cost of construction and equipment, is to be included with the varying operating expenses as above, to compute the relative economy of alternate lines considered.

EARNINGS.

The estimation of future earnings from an undeveloped country requires the greatest judgment and experience. The Interstate Commerce Commission reports, and other information regarding earnings from similar country, are helpful. The estimated net earnings from local traffic of each alternate line should be deducted from its operating and interest costs to arrive at their relative economy. Additional tonnage movement opposite to the direction of greatest train requirements does not add anything to train wages or locomotive repairs; usually adds nothing to fuel except for the loading in the car, the empty movement being necessary anyway; adds nothing measurable to maintenance or other items.

OTHER COSTS.

There are many items practically independent of location design which may, if not definitely obtainable, be assumed at 45 cents per train mile, and added to the above variable costs, if total cost is desired.

SUMMARY.

The bases and approximate costs for designing location or comparing alternate route are as follows:

(1) Train Wages and Locomotive Repairs. Basis Train Mile. Rate 27 cents. Dependent on rating in direction of greatest locomotive requirements by length of line.

(2) Fuel. Base, 1,000 foot-tons. Rate 10 lbs. coal per M. F. T. Dependent on train resistance, including curvatures plus rise.

(3) Curvature. Base one degree of Central Angle for one daily train. Rate capitalized at $2.20. Additional per curve, for sharp curvature and high speed at no regular rate.

(4) Maintenance. Basis Mile. Rate average $1,200 main lines and $750 branch lines.

(5) Interest at company's rates on construction and equipment.

(6) Net earnings on local business as credit.

(7) Fixed Expenses. Base Train Mile—Rate 45 cents. Independent largely of Train Mile, but based on it, for want of a better unit.

Appendix B.

RAIL WEAR.

By Walter Loring Webb, Consulting Engineer.

Reliable statistics regarding the rate of rail wear are so scarce that there is very great value in the work that has been done since 1900 on the Northern Pacific Railroad in compiling reliable information regarding the rate of rail wear, both on tangents and on curves Although the work already done is not sufficiently extensive to definitely establish the rate of rail wear as affected by tonnage, weight of rail, rate of grade, degree of curvature and the various other modifying causes, nevertheless the figures point almost unmistakably to the truth of certain laws. The conclusions are the more remarkable since they seem to contradict some of the commonly accepted opinions regarding the rate of rail wear—opinions which were formed chiefly from theoretical considerations. It is to be hoped that the conclusions which may be drawn even from the figures already obtained will be found so valuable that other railroads will be induced to make similar tests, especially since the cost of making these tests is comparatively insignificant.

The method of testing may be briefly described as follows: A some place where some new steel was to be laid, ten rails, or five on each track, were carefully weighed before being placed in the track. In most instances the weight was determined to the nearest quarter pound. Each year thereafter, during the life of the rail, the rails were taken from the track long enough to be cleaned, weighed and replaced. The loss in weight in one year varied from a fraction of a pound to as much as 30 lbs. in extreme cases. These figures, determined each year, throw a flood of light on the rate of rail wear as affected by the age of the rail, and, by inference, conclusions may be drawn as to the effect of the form of the head of the rail on the rate of wear. The complete records cover tests on 104 rails. In several of the localities six of the ten rails were 66-lb. Bessemer steel rails, while the other four were 72-lb. Basic Open-Hearth rails. Since for each locality all of the ten rails were subjected to the same tonnage and were equally affected by grade and curvature, it is hoped that some conclusions may be drawn as to the comparative value of the two types of rails.

TABLE I—RAIL WEAR ON TANGENTS. NORTHERN PACIFIC RAILROAD.

Rail No.	Weight		Loss in weight each year—pounds and per cent.													
	Nom. per yard	Actual total weight	1		2		3		4		5		6		Total	
				%		%		%		%		%		%		%
2-9	66	596½	3¾	0.63	2¼	0.38	0¾	0.13	2½	0 42	1¼	0.19	...	....	10½	1.76
2-10	66	596¼	3½	0.59	2¼	0.38	4¾	0.80	4½	0.75	2¼	0.38	...	....	17¼	2.89
2-7	66	654¾	1½	0 23	4¼	0.65	3¼	0.50	6½	0.99	2¼	0.34	...	....	17¾	2.71
2-8	66	664½	4¾	0.71	2¾	0.41	2¼	0.34	4¼	0.64	6¼	0.94	...	....	20¼	3.05
2-5	66	661¾	3	0.45	3	0.45	3	0.45	3¼	0.49	6	0.91	...	....	18¼	2.76
2-6	66	653	3¼	0.50	3¼	0.50	2¾	0.42	2¼	0.34	2¼	0.34	...	....	13¾	2.11
Aver.	66	Bess.	...	0.52	...	0.46	...	0.44	...	0.61	...	0.52	...	....	...	2.55
2-1	72	724½	6¼	0.86	2¾	0.38	1½	0.21	3¼	0.45	3½	0.48	...	....	17¼	2.38
2-2	72	727½	5¼	0.72	0¼	0.03	4¼	0.58	5¾	0.79	1¾	0.24	...	....	17¼	2.37
2-3	72	727	2¾	0.38	2¾	0.38	2¾	0.38	3½	0.48	6¼	0.86	...	....	18	2.48
2-4	72	723½	4¼	0.59	2¾	0 38	3¾	0.52	2¼	0.31	7½	1.04	...	....	20½	2.83
Aver.	72	O.H.	...	0.64	...	0.29	...	0.42	...	0.51	...	0.65	...	....	...	2.51
5-9	66	650½	1¾	0.27	3¾	0.58	0¾	0.12	1	0.15	2¼	0.35	32¾	5.04	42¼	6.50
5-10	66	649½	2¾	0.42	1¾	0.27	0¼	0.04	0½	0.08	2	0.31	32¼	4.96	39½	6.08
5-7	66	660¼	2	0.30	3¼	0.49	0¼	0.04	0½	0.08	8½	1.29	31¾	4.81	46¼	7.00
5-8	66	647	2¼	0.35	2¾	0.43	0	0.00	0¾	0.11	10¼	1 59	23½	3.63	39½	6.10
5-5	66	659¼	2½	0.38	4¼	0.64	0¾	0.11	1½	0.23	9	1.37	30¾	4.66	48¾	7.39
5-6	66	642	0¼	0.04	3¼	0.51	0½	0.08	4¾	0.74	7	1.09	20¾	3.23	36½	5.68
Aver.	66	Bess	...	0.29	...	0.49	...	0.07	...	0.23	...	1.00	...	4.39	...	6.46
5-1	72	705½	3¼	0.46	1¾	0.25	0¾	0 11	2¾	0.39	5¾	0.82	23¾	3.37	38	5.39
5-2	72	728	2¾	0.38	3¼	0.45	0¼	0.03	3¼	0.45	14	1.92	7¼	1.00	30¾	4.22
5-3	72	707¼	2½	0.35	3¼	0 46	0½	0.07	0¼	0.04	4¾	0.67	29	4.10	40¼	5.70
5-4	72	719¼	1	0.14	1¾	0.24	2¾	0.38	3½	0.49	6¼	0.87	29½	4.10	44¾	6.22
Aver.	72	O. H.	...	0.33	...	0 35	...	0.15	...	0.34	...	1.07	...	3.14	...	6.03
Gen. Aver. Bess.	66	......	...	0.14	...	0.47	...	0.25	...	0.42	...	0.76	...	....	...	....
Gen. Aver. O. H.	72	......	...	0.48	...	0.32	...	0.28	...	0.42	...	0.76	...	....	...	....

General average loss on tangent, first group, in 5 years, 2 53 per cent.
General average loss on tangent, second group, in 6 years, 6.29 per cent.
General average loss on tangent, second group, first in 5 years, 2.29 per cent.

RELATION OF RAIL WEAR TO THE LIFE OF RAILS.

In Table I is given the percentage of loss during each year for five or six years of 20 different rails, all of which were laid on tangents and on low grades, one-half of them being on a 0.3 per cent. grade and the other half on a 0.525 per cent., which changed to a

0.128 per cent. grade. The figures near the bottom of the table show that the loss in weight during the third year is less than at any time in the history of the rail. For the first four years the loss is fairly uniform, averaging nearly 0.4 per cent. per year. During the fifth year the loss averaged 0.76 per cent., while for the ten rails that were left down six years, the loss during the sixth year averaged 3¾ per cent. Both the Bessemer and the Open-Hearth steel rails seem to follow the same general law regarding rate of rail wear in its relation to the life of the rail, the variations not being such as to indicate any marked difference in favor of either kind. Although the *percentage* of loss of weight averages less for the 72-lb. rails than for the 66-lb. rails, the average actual loss in weight is very slightly more.

TABLE II-A.—RAIL WEAR ON CURVES. NORTHERN PACIFIC RAILROAD.

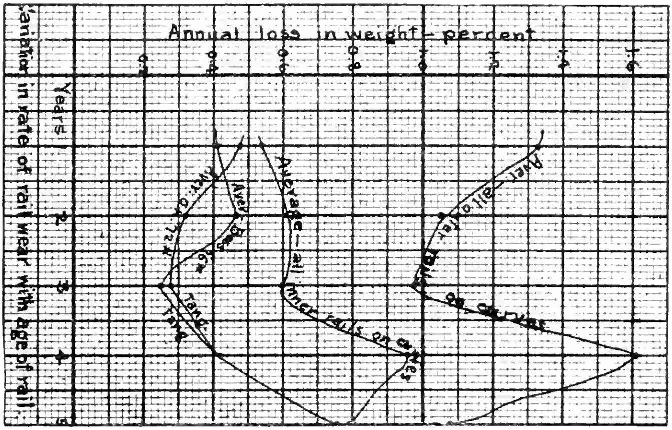
	Rail No.	Weight		Loss in weight each year—pounds and per cent.													
		Nom. per yard	Actual total weight	1		2		3		4		5		6		Total	
					%		%		%		%		%		%		%
Inner rail 4° 04′	4-6	66	650½	3¾	0.58	1¼	0.19	1¾	0 27	2¼	0.35	9¼	1.42	25¾	3.96	44	6.76
	4-8	66	666¾	3	0.45	1¾	0.26	1¼	0 19	2	0.30	6¾	1.01	37½	5.63	52¼	7.84
	4-10	66	664¼	3½	0.53	1¼	0.19	3¾	0 56	1¾	0.26	5	0.75	36½	5 50	51¾	7.79
	Aver.	66	......	...	0.52	...	0 21	...	0.34	...	0.30	...	1.06	...	5 03	...	7.46
	4-2	72	720½	4¾	0.66	0¾	0.10	1¼	0.17	2½	0.35	5¼	0.73	33	4 58	47½	6 59
	4-4	72	717¼	3½	0.49	1¾	0.24	1¼	0.17	1	0.14	5½	0.77	32¼	4.50	45¼	6 31
	Aver.	72	......	...	0.57	...	0.17	...	0 17	...	0.24	...	0.75	...	4.54	...	6.45
Outer rail 4° 04′	4-5	66	647	7¾	1.20	7¾	1.20	6¾	1 04	6½	1.00	5	0.77	24¾	3.36	55½	8.58
	4-7	66	673	8¼	1.23	9¾	1.45	6¼	0.93	7¾	1 15	8¾	1 30	31¼	4 65	72	10 70
	4-9	66	663	6¾	1.02	8¾	1.32	4¾	0.72	5	0.75	5½	0.83	30¾	4.64	61½	9.28
	Aver.	66	......	...	1.15	...	1 32	...	0 90	...	0.97	...	0 97	...	4 22	...	9 52
	4-1	72	726	6¼	0.86	4¼	0.59	3¾	0 52	2¼	0 31	4½	0.62	34	4 68	55	7.58
	4-3	72	710½	4	0.56	6¼	0.88	5¾	0.81	3¼	0 46	4¼	0 61	26¼	3.69	49¾	7 00
	Aver.	72	......	...	0.71	...	0.73	...	0.66	...	0 38	...	0.61	...	4.18	...	7 29
	Aver. all inner				0.54	...	0.20	...	0.27	...	0.28	...	0.94	...	4 83	...	7 06
	Aver. all outer				0.97	...	1.09	...	0.80	...	0.73	...	0.83	...	4.20	...	8.63
Inner rail 5° 12′	1-5	66	635	3¼	0.51	4¾	0.75	4¾	0.75	3¼	0.51	1½	0.24	...	....	17½	2.76
	1-7	66	673¾	4½	0.67	4¼	0.63	3¾	0.56	5¼	0.78	2	0.30	...	....	19¾	2 93
	1-9	66	672¼	4	0.60	5¼	0.78	5¾	0.86	5	0.74	6¼	0.93	...	....	26¼	3.91
	Aver.	66	......	...	0 51	...	0.72	...	0.72	...	0.68	...	0.49	...	....	...	3.20
	1-1	72	724¼	2½	0.35	4¾	0.66	1¼	0.17	13½	1.86	2½	0.35	...	....	24½	3.38
	1-3	72	721¾	0	0 00	4¾	0.66	3¼	0.45	16½	2.29	2¼	0.31	...	....	26¾	3.71
	Aver.	72	......	...	0.18	...	0.66	...	0.31	...	2.08	...	0.33	...	....	...	3.55
Outer rail 5° 12′	1-6	66	643½	8¼	1 28	7¼	1 13	5¼	0.82	19	2.93	2½	0.39	...	....	42¼	6.56
	1-8	66	651¾	4½	0.69	5¾	0.88	2¾	0.42	12½	1.92	2¼	0.35	...	....	27¾	4.26
	1-10	66	648¼	8½	1.31	7¼	1.12	3¾	0 58	6½	1.00	9¼	1.43	...	....	35¼	5.44
	Aver.	66	......	...	1.09	...	1.04	...	0.61	...	1.95	...	0.72	...	....	...	5.42
	1-2	72	718¾	5½	0.77	2¼	0.31	4¼	0 59	7¼	1.01	2½	0.35	...	....	21¾	3 03
	1-4	72	719¼	3½	0.49	4¼	0.59	0¾	0.10	27¾	3.86	1¾	0.24	...	....	38	5.28
	Aver.	72	......	...	0.63	...	0.45	...	0.35	...	2.43	...	0.30	...	....	...	4.15
	Aver. all inner				0.43	...	0.70	...	0.56	...	1 24	...	0.43	...	....	...	3.34
	Aver. all outer				0.91	...	0.81	...	0.50	...	2.14	...	0.55	...	....	...	4 91

In Table II is given the percentages of the rail wear for the inner and outer rails of four curves varying from 4° 04′ to 10° 13′. These figures give the wear on forty rails. As in the case of the tangents, the rate of rail wear during the third year is usually the minimum. The wear during the fifth year is usually considerably greater than during any previous year; while the wear during the sixth year was more than during the previous five years. A study of these figures would seem to point to the conclusion that the extra wear during the first year or two is due to the wearing away of the sharp corner of the rail, which has a less radius of curvature than the flange angle of the wheel. After two or three years' wear, when the

TABLE II-B.—RAIL WEAR ON CURVES. NORTHERN PACIFIC RAILROAD.

	Rail No.	Weight		Loss in weight each year—pounds and per cent.											
		Nom. per yard	Actual total weight	1		2		3		4		5		Total	
					%		%		%		%		%		%
Inner rail 10° 13'	6-5	66	647	4¼	0.66	6¼	0 97	5¾	0.89	7½	1 16	7¼	1.16	31	4.79
	6-7	66	656¾	3	0.46	4¾	0.72	2¾	0.42	4	0.61	6¼	0.95	20¾	3.16
	6-9	66	669	3¾	0.56	5¼	0.78	5¼	0.78	4	0.60	5	0.75	23¼	3.48
	Aver.	66	....	...	0.56	...	0 82	...	0 70	...	0 79	...	0.94	...	3.81
	6-1	72	700¼	4	0.57	5¾	0.82	0½	0.07	0¾	0.11	6¼	0.89	17¼	2.46
	6-3	72	730½	1¾	0.24	7¾	1.06	2¼	0 31	3½	0.48	8¼	1.13	23½	3.22
	Aver.	72	....	...	0.41	...	0.94	...	0 19	...	0.29	...	1.01	...	2.84
Outer rail 10° 13'	6-6	66	657½	13¾	2.09	13¾	2.09	11¾	1.79	18¼	2.78	21	3.19	78½	11.94
	6-8	66	653	11¾	1.80	9¾	1.49	9¾	1.49	12	1.84	13½	2.07	56¾	8.69
	6-10	66	650½	13¼	2.04	9¾	1.50	9¾	1.50	16½	2.54	21¼	3.27	70½	10.84
	Aver.	66	....	...	1.98	...	1.69	...	1.59	...	2.39	...	2.84	...	10.49
	6-2	72	720½	5¾	0.80	7¼	1.01	1¾	0 24	4½	0.62	11¼	1.56	30½	4.23
	6-4	72	715½	9¾	1.36	7¼	1.01	5¾	0.80	7	0.98	15¾	2.20	45½	6.36
	Aver.	72	....	...	1.08	...	1.01	...	0.52	...	0.80	...	1.88	...	5.29
	Aver. all inner				0.50	...	0.87	...	0.49	...	0.59	...	0.97	...	3.42
	Aver. all outer				1.62	...	1.42	...	1.16	...	1.75	...	2.46	...	8.41
Inner rail 10° 08'	3-6	66	655¾	5	0.76	4¼	0.65	6¾	1.03	20	3.05	2¾	0.42	38¾	5.91
	3-8	66	667¼	5½	0.92	6¾	1.01	9¼	1.39	11½	1.72	12½	1.87	45½	6.82
	3-10	66	632½	4¾	0.75	4¾	0.75	10¼	1.62	12¼	1.94	5½	0 87	37½	5.93
	Aver.	66	....	...	0.78	...	0.80	...	1.35	...	2.24	...	1.05	...	6.22
	3-2	72	708	4¾	0.67	2¾	0.39	3¾	0.53	6¾	0.95	2¾	0.39	20¾	2.93
	3-4	72	711	2¾	0.39	3¾	0.53	5¾	0.81	7¼	1 02	3½	0.49	23	3.24
	Aver.	72	....	...	0.53	...	0.46	...	0.67	...	0 99	...	0 44	...	3.09
Outer rail 10° 08'	3-5	66	650½	13¾	2.11	7¾	1.19	10¼	1.58	5½	0.84	19¼	2.96	56½	8 69
	3-7	66	664¾	13¾	2.03	5¼	0.79	9¼	1.39	19¼	2.90	6¼	0.94	53½	8.05
	3-9	66	664½	10¾	1.62	7¾	1.17	15¼	2.30	15	2 26	15	2.26	63¾	9.60
	Aver.	66	....	...	1.92	...	1.05	...	1.76	...	2.00	...	2.05	...	8.78
	3-1	72	739¾	12	1.62	4¼	0.57	4¾	0.64	15	2 03	2½	0.34	38½	5.20
	3-3	72	721½	12¼	1.70	4¾	0 66	9¾	1.35	7½	1.04	6¼	0.87	40½	5.62
	Aver.	72	....	...	1.66	...	0.62	...	1.00	...	1.53	...	0.60	...	5.41
	Aver. all inner				0.68	...	0.66	...	1.08	...	1.74	...	0.81	...	4.97
	Aver. all outer				1.82	...	0.88	...	1.45	...	1.81	...	1.47	...	1.43

rail has been worn down to fit the flange of the wheel, the rail wear is less. Later when the rail has become badly worn and the inner part of the rail head, which is perhaps softer, is exposed, the rate of wear is much more rapid. Since the loss in weight for many of these rails during one year was frequently less than one pound, the only figures which could properly be considered in estimating the relation of rail wear to the life of the rails were those in which the weight of rail was computed in each case to the nearest quarter of a pound. Therefore these conclusions are based on the loss of weight of 60 rails which were more carefully weighed than the other 44.



RATE OF RAIL WEAR AS AFFECTED BY TONNAGE.

In Table III figures have been compiled showing the percentage loss in rail wear of 38 rails, all of which were on tangents. In order to reduce the different cases to the same basis as nearly as possible, the rail wear for the first four years only was computed. There are still four elements of variable effect in comparing these figures—the total tonnage, the number of trains, the weight on the drivers and the grade. It is usually considered that the number of engines, in

TABLE III.—RATE OF RAIL WEAR AS AFFECTED BY TONNAGE.

Division of road	No. of rails	Group No.	No. of trains	Total Tonnage	Weight Engine Drivers	Grade %	Per cent. loss 4years	Per cent. reduced to basis of 10,000 trains
Pacific	10	(2-1 2-10)	37,658	29,862,738	170-180,000	0 3	1 .96	0 .25
Pacific	10	(5-1 5-10)	31,006	27,779,956	140-170,000	0 .128	1 .11	0 36
Minn.......	10	(Minn. 1-10)	27,008	27,021,227	86-110,000	0 0	0 .70	0 26
Rocky Mt.	8	(Ry. Mt. 17-24)	19,099	22,178,684	186,000	0 .0	0 .77	0 .40

connection with the weight on the drivers, is of far greater importance than the mere tonnage. On the assumption that the total percentage of wear would be proportional to the number of trains, the four percentages have been reduced to the basis of 10,000 trains during the four years. As might have been expected, the least percentage of wear occurs with the lighter weight on the drivers on the Minnesota division. The next higher rate of wear occurs on the rails having the next heavier weight of engine drivers. The comparatively high rate of wear of the first group of rails may be due to the grade. Although some of the engines on the Rocky Mountain Division were heavier than any used on the Pacific Division, it may be that a proportionately greater number of heavy engines were used on the Pacific Division than on the Rocky Mountain Division, and that this accounts for the added rail wear. This table is conspicuously too brief for the determination of any law of wear as respects variation in tonnage, but the figures seem to point to the great influence of the weight on the drivers.

RAIL WEAR ON INNER RAILS OF CURVES.

The extra rail wear on the inner rails of curves is chiefly that due to the longitudinal slipping which may occur on either rail, but which probably occurs chiefly on the inner rail. The wear on twenty inner rails, compared with the average rail wear on twenty rails on tangents, is shown in Table IV. All of these rails were subjected to substantially the same kind of traffic and the tonnage was so nearly the same that there is no appreciable error in reducing the rail wear to the basis of the same tonnage.

TABLE IV.—EXCESS RAIL WEAR ON CURVES.

Group Nos.	Aline-ment	Total Tonnage five years	Av. rail wear in'er rail five yrs.	Av. rail wear tan. five yrs.	Per cent. reduced to uniform ton of 40,000,000		Av. rail wear out'r rail five yrs.	Per cent. reduced to uniform ton. of 40,000,000	Excess of wear on curves			
									Inn. R'ls.		Out. R'ls.	
									T't'l in per ct.	Per deg. of c've	T't'l in. per ct.	Per deg. of c've.
(2-1 2-10)	Tan.	39,562,965+	....	2.53	.....	2.56	....	..... 2.56	....	....	....	..
(5-1 5-10)	Tan.	37,480,183	....	2.29	.....	2.44	....	..... 2.44	....	....	....	....
(4-1 4-10)	4° 04′	37,480,183	2.23	....	2.38	.....	4.42	4.71 ..	0.12	0.03	2.21	0.54
(1-1 1-10)	5° 12′	39,562,965	3.34	....	3.38	.....	4.91	4.96	0.88	0.17	2.46	0.47
(6-1 6-10)	10′ 13′	37,480,183	3.42	....	3.65	.....	8.41	8.96	1.15	0.11	6.46	0.63
(3-1 3-10)	10° 08′	39,562,965	4.97	....	5.02	.....	7.43	7.51	2.52	0.25	5.01	0.49

In so far as we may presume to deduce a law for the excess rail wear on the inner rail of a curve, the excess is apparently $\frac{0.12}{2.50}=4.8$ per cent. per degree of curve.

RAIL WEAR ON OUTER RAILS OF CURVES.

From Table IV we may similarly deduce that the extra rail wear on the outer rails of curves is $\frac{0.53}{2.50}=21.2$ per cent. per degree of curve; also that the excess rail wear on the outer rail is $\frac{0.53}{0.12}=4.4$ times what it is on the inner rail. If the average of these two are taken to represent the average effect of curvature on rail wear, we may say that the average excess of rail wear on a curve over that on a tangent is 13.0 per cent. per degree of curve. On this basis the excess wear on a $\frac{100}{13}=7.7^\circ=7^\circ\ 42'$ curve would equal that on a tangent, and therefore the rails on such a curve would wear out twice as rapidly.

In conclusion it should be repeated that the above tests are too few to determine positively the laws of rail wear, and especially to determine quantitative values, but it is believed that these tests show the possibilities of determining the various laws of rail wear with an accuracy unattainable by any other equally simple method, and that railroad managers should be urged to make these tests and send their results to the Committee on Economics, so that the results may be collated, and finally that authoritative values may be deduced. Since excess rail wear is one of the chief items in the cost of curvature, no reliable value for the economic value of 1 degree of curve can be calculated until this item has been more closely determined.

DISCUSSION ON ARTICLE ON RAIL WEAR.

By A. W. Thompson, Chief Engineer Maintenance of Way, Baltimore & Ohio Railroad.

The writer has been very much interested in reading the article on rail wear, prepared by Professor Walter Loring Webb, C. E., and has noted carefully the manner in which he has treated the subject. However, the experience which has been gained on the Baltimore & Ohio Railroad leads me to comment on several points which were brought out in the article.

RELIABLE STATISTICS.

The first statement of Professor Webb, to the effect that reliable statistics regarding the rate of rail wear are scarce, is perhaps not as generally true as he supposes. The writer very much doubts if many of the railroads have gone into this question as exhaustively or kept as proper tabulated results as they should have done, and they probably have not given the subject as serious thought as it deserves, but the writer is sure that much work has been done along the lines of gathering statistics on rail wear by many of the railroads of this country, and he is personally aware of quite a large number that have undertaken this work.

STATISTICS NOT PUBLISHED.

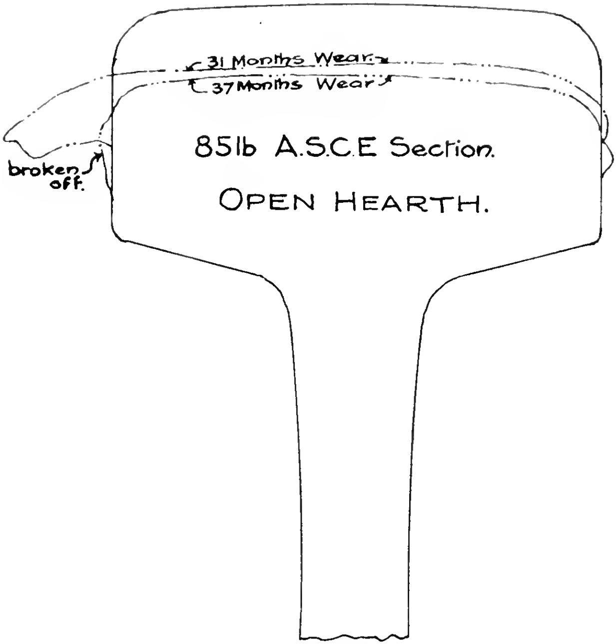
There are quite a number of good reasons why these statistics have not been published. As a rule, they have been used for the solution of the problems pertinent to each railroad, and the results of the various tests, including tests of rail wear, have not been given to the public or to manufacturers. The Baltimore & Ohio Railroad has for a number of years been carrying on a series of tests and keeping a large number of records of rail wear, giving careful consideration to actual track conditions and taking sections in the field with a rail section machine, and not relying on any theoretical calculaaions.

SECURING RATE OF WEAR BY A GIVEN LAW.

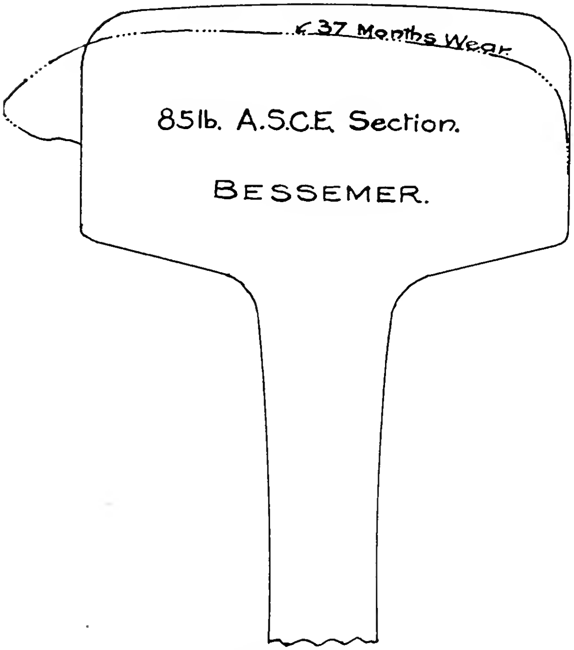
To the writer's mind it seems almost an impossibility to determine a law for rail wear as affected by tonnage, weight of rail, grade and degree of curvature. There are so many factors entering into the question other than those above mentioned that no law can be found applicable to all cases; for instance, quality of rail, condition of roadbed, kind of ballast, whether fast trains or slow trains or both use the same track, the thoroughness with which the roadbed is maintained and the elevation of the curves, are all factors which have a most direct and important influence.

To determine accurately a law of rail wear, the same rail would have to be placed under all known conditions. While a somewhat elaborate deduction is made by Professor Webb showing wear on both inner and outer rails on curves in comparison with rails on tangents, his deductions would be entirely lost if the elevation of the rail was excessive for the speed of heavy freight engines or not sufficient for fast passenger traffic. The comparative rate of wear of the two rails would be reversed under these conditions, and the elevation of curves cannot be made suitable for all trains using the same track on many railroads of this country, when part of the trains are slow freights and others are fast passenger trains. This would seem to indicate that rail wear problems can only be solved by a railroad for its own locality and conditions, and no universal law applicable to all could ever be obtained where so widely varying conditions exist and where so much depends upon the relative high standard of track maintenance.

Professor Webb's report is based on the consideration of 66-lb. and 72-lb. rail, and this does not conform to the weight of rail on the Baltimore & Ohio Lines. We have had very little experience with these weights of rail since we have been keeping accurate records.



SECTION NO. 1.



SECTION NO. 2.

SECURING RATE OF WEAR BY WEIGHING.

As to the method of determining rate of wear by weighing the rail, it might be possible to do this under traffic conditions which existed in the location in which the tests were made to which Professor Webb refers, but this method of procedure would be entirely out of the question on a railroad carrying frequent and heavy freight and passenger traffic. The cost of such a method would be very high, to say nothing of the danger and possible delay to traffic, and the writer feels that the methods which we are using on our lines are more safe and come nearer obtaining accurate information, which is desired in actual practice. In many cases inconsistencies might creep in when rate of wear is determined by weighing.

EXCESSIVE FLOW OF HEAD.

The head of the rail might be much decreased in height after a considerable period of service, and this decrease might not be entirely due to wear, but to flow of metal to one side of the head, and, of course, this flow of metal decreases the life of the rail, yet when weighed this flow would be included. This point can be more clearly seen by reference to the following photographs and sections of rail. These have been picked out as extreme examples, but they illustrate the point in question.

On section No. 1 there is a very bad flow shown on the low rail at the end of 31 months' wear; at the end of 37 months' wear this flow has been broken off. This same condition is shown in the rail, as seen in photograph No. 1. In section No. 2 there is another case of excessive flow shown, and in photographs Nos. 2 and 3 some flow can be seen on the side of the head of the rail.

VIEW No. 1.

Provided the flow was not too excessive, it could not easily be removed or sheared from the rail and would be included in the weight. This would not give proper conclusions.

ADVANTAGE OF RAIL SECTION MACHINE.

In working out the rate of wear by means of the rail section machine this machine shows the flow as drawn on the above sections, but in calculating the amount of wear this flow is discarded. Also, these sections show to the eye the actual shape and condition of the rail, which weighing would not.

PER CENT. VERSUS SQUARE INCHES OF WEAR.

Our results are kept in the form of square inches of wear, which appears to be more consistent. Some manufacturers and railroads take sections with a rail section machine, calculate the area, and then transfer these calculations into pounds lost per yard. This is not as accurate because it is necessarily based on the theoretical weight per yard of the original rail and slight variations in the dimensions of the section when rolling would vary considerably the actual weight of the rail. On our lines the section is taken with the machine the first day the rail is in track, and it is this section thus produced to which all subsequent sections taken are referred. Again, actual practice would require that the position of the wear on the head of the rail be given. Conditions might arise where the loss of weight in one case would be less than in another, yet the position of the wear in the first case would be such that the rail would have to be taken from track for the sake of safety.

VIEW NO. 2.

VIEW NO. 3.

It is more frequently the practice to express the results of tests in square inches, and it seems to me that this method would be much more satisfactory than expressing them in percentage. It is very often hard to interpret the entire variation in per cent., as a few tenths of one per cent. might mean a large concrete quantity, and unless a careful study is made of the figures the practical value of the actual condition will be lost. The results shown in actual square inches are rather more direct.

GRADE CONDITIONS.

The rails which Professor Webb's report covers were laid under very different grade conditions from those found on the Baltimore & Ohio Railroad where, on some of the curves, the best obtainable quality of Bessemer rail of 85-lb. A. S. C. E. section lasts but seven months and a great deal of the rail does not last over one year, and when such conditions are compared with the five-year life of the rails shown in the table on ten-degree curves, it is readily seen how impossible it would be to deduce a law applicable to both conditions, and under such conditions a final deduction of the increased per cent. of wear on curves over that on tangents would be a very different figure. It would seem, therefore, that the statement that a rail lasts only half as long on a seven-degree curve as on a tangent would come nowhere near being generally applicable to the conditions existing on the Baltimore & Ohio Railroad.

UNIFORMITY OF RAIL WEAR.

It is noted that Professor Webb states that rail wear appears to be least in the third year or pracically during one-half the life of the rail, and he seems to intimate that the inner part of the head contains softer material than the outer part. It has been recently demonstrated and confirmed by several large steel companies, by results of tests, that the inner part of the head contains the harder material. In some of the graphical charts which have been worked up showing rail wear for certain periods of time on the Baltimore & Ohio Lines, there seems to be no decided difference in the rate of wear at the beginning or end of the life of a rail, while in other cases—that of titanium rail, for instance—the rail wear was extremely rapid for the first month or two, but decreased very materially as the outer portion wore away, soon showing far less wear than the ordinary Bessemer rail.

It is appreciated, of course, that the report only suggests a possible method of gaining some light on this question, and Professor Webb deserves a great deal of commendation for the manner in which he has gone into it. The remarks which are given above are not in any way to criticize, but to bring out points which the writer thinks would be helpful along these lines and with a view to getting other railroads to make tests and studies in regard to rail wear. The methods which have been used on the Baltimore & Ohio Railroad for a number of years have been very satisfactory, and the writer is of the opinion that the method of studying rail wear and rail failures as outlined by the American Railway Engineering and Maintenance of Way Association will give valuable information in years to come. Taking the results of these reports, it may be possible in future years to get some average law. This would be applicable to the general studies of the economics of railway location only, and would be of no value in aiding the railroad engineer in the selection of a weight or section of rail or determining the most suitable kind or quality for his own particular conditions.

COMMENTS ON ARTICLE ON RAIL WEAR BY DR. P. H. DUDLEY.

Professor Webb's article is very interesting, but it applies more to local than general conditions. The oxidation of the rails vary so much in different places that weighing the rails from year to year would introduce errors of magnitude in reference to rail wear. Professor Webb's actual weights of rails are surprising in his tables, and a stranger cannot understand them.

REPLY BY PROF. WALTER LORING WEBB, C. E.

I would note the following points in reply to Mr. A. W. Thompson's valued comment:

STATISTICS.

My original statement that statistics were scarce was based on the fact, which Mr. Thompson admits, that very little in that line has been published and they are, therefore, unavailable to the profession at large; and also on the fact that several efforts on the writer's part to obtain such statistics have frequently been met by the definite statement from the railroad official that they had no such statistics. Such scattered figures as were obtainable were seldom accompanied by a sufficient statement of conditions so that they would have much value in attempting to deduce a law for rail wear. If such statistics, having real value, are in existence, let the profession have them. That is the real object of this Association.

DANGER AND DIFFICULTY ON HEAVY TRAFFIC.

Although it would cost more to make this test on a heavy traffic road than on a light traffic road, the danger and difficulty is only that due to a greater frequency of track disturbance. Rails *must* be taken out and renewed on all roads, and especially on heavy traffic roads. If such a test were made on a track which carried trains every few minutes, it would be necessary to temporarily substitute other rails for the ten rails being tested at any one locality while the cleaning and weighing were done, but the work of substitution would be no more dangerous than the substitution of new rails, as regularly done. Of course, this method would be especially costly in situations where the traffic was so great that the rail's total life was very short. In fact, since at least five or six observations should be taken at approximately equal intervals during the life of a rail, it would be necessary to weigh the rails every month or two in order to apply the method to such rapidly wearing rails.

USE OF RAIL SECTION MACHINE.

The weighing method was not advocated to be used to the exclusion of other methods. The rail section machine is certainly very useful as an auxiliary and especially in order to throw light upon the abnormal cases such as those in which the rail is very soft and the rail flow excessive. The objection to the rail-section-machine method as an exclusive method is that a very slight inaccuracy in the machine makes a very appreciable difference in the results obtained.

PER CENT. LOSS VS. SQUARE INCHES OF WEAR.

The method described by Mr. Thompson and the weighing method are practically identical in that each method assumes that the cross-section, whatever it is, is *uniform* throughout the length of the rail. When this assumption is made, it makes but little difference which method is used; the figures are practically interchangeable.

SYSTEMATIC METHODS.

The real object of the article was not so much to advocate some one particular method as to plead for systematic work by all railroad companies by some method which is uniform and yet broad enough to cover all ordinary variations in conditions, in order to furnish to the profession results which can be compiled and from which some laws can be deduced. It is probably true that a very large percentage of the information, published and unpublished, which has been gathered by railroads regarding rail wear gives only the total wear when the rail is practically worn out, and therefore gives no information as to variation in the *rate* of rail wear during the life of the rail.

OXIDATION OF RAIL.

Although the oxidation referred to by Dr. Dudley was not considered, yet it appears to the writer that whenever the effect of oxidation becomes of real importance, the cleaning and weighing of the rail would determine its effect even better than the rail-section-machine method. After all, the real thing to be determined is the rate of total deterioration of the rail from whatever combination of causes; and if the rust is cleaned off, the net weight of the rail shows the total loss from all causes. In cases where the oxidation of the rail is of real importance the rate of oxidation of idle rails of similar chemical competition could be determined in order to learn the individual effect of this one cause.

Although, as Dr. Dudley says, the figures are "surprising," they are as furnished by the Northern Pacific Railroad. The number of rails tested and the uniformity in the results seems to preclude the idea of mere blunders in the weighing.

DISCUSSION.

The President:—The report of the Committee on Economics of Railway Location, Mr. A. K. Shurtleff, chairman, will now be taken up. I will ask Mr. Shurtleff to make a preliminary statement in regard to the work of the Committee.

Mr. A. K. Shurtleff, chairman (Chicago, Rock Island & Pacific):—I do not know that there is any particular preliminary statement to be made, provided the members have read the report. We may be branching out on startling lines to some of you, but we feel that we have good company; for instance, Mr. D. F. Crawford, General Superintendent of Motive Power of the Pennsylvania Lines West, in December, 1901, read a paper before the Western Railway Club, and in that paper he gave a diagram of drawbar pull of a locomotive. This diagram coincides very closely with some of the diagrams in Appendix A. The drawbar pull dropped rapidly from a velocity of about five miles per hour. The Master Mechanics' curve shows a very uniform drawbar pull up to about ten miles per hour. As a matter of fact, we are not able to get this in practice, and the conditions are such in burning our Western coals as to require shortening of cut-off at from five to seven miles per hour with freight locomotives, otherwise we would not be enabled to maintain steam in our boilers. Another thing Mr. Crawford called attention to as early as 1901 was the fact that, after a number of dynamometer tests extending over considerable mileage and period of time, no material increase in resistance within the ordinary range of freight train speeds was noticeable. This is in contradiction to Mr. Wellington's and other formulas with reference to resistance; and in other tests that have been made since, some of which I am personally familiar with, that has been shown to be true.

With reference to our method of determining the drawbar pull of a locomotive, we believe it is logical; we know that it takes certain heat units to make steam, and, therefore, the quality and quantity of fuel required determines the steam-producing capacity of the locomotive, with its heating surface being known. Mr. George R. Henderson's work goes into this quite thoroughly, and it does seem consistent to do away with any arbitrary mean effective pressure curve in trying to determine the power of a locomotive for the purposes of this Association. It would also be true as far as determining the power of a locomotive for tonnage rating. I do not know that there is anything further to be said.

Mr. L. C. Fritch (Chicago Great Western):—I think the Committee have given us a very instructive report. I believe that railroads to-day are wasting a lot of energy because they do not go into the refinements of the hauling capacity of the locomotives. While there are a great many formulas to establish the hauling capacity of the locomotives, yet I think out of all of them we can select some rational formula, and with the large number of tests that have been made in the past few years, I believe the time has come when we can establish a formula that will pretty nearly cover the conditions under which we are operating to-day.

Only recently the American Locomotive Company issued a pamphlet on train resistances, and they show in that pamphlet the remarkable difference in the resistance in lightly-loaded and heavily-loaded cars. For example, as I recall it now, a 50-ton capacity car, empty, or lightly loaded, has a resistance per ton of about 8.5 lbs. If that car is loaded to its capacity, it has a resistance of about 2.6 lbs per ton. In tonnage rating, these conditions are not always taken into account. I do not believe we have taken into consideration, in establishing the hauling capacity of engines, the internal resistance of the engine, or the loss between the cylinder HP. and the HP. at the rim of the wheel. The Committee, on page 17, Table No. 7, state: (a) Cylinder to rim of drivers; total pounds $R = 18.7\ T + 80\ N;\ T =$ Tons weight on drivers; $N =$ Number of driving axles. According to tests published by the American Locomotive Company, that is a trifle low. They give 22.2 lbs. per ton of weight on the drivers, or about 1.11 per cent. of the weight on drivers, so that that would be a little more than what the Committee gives. I would like to ask the Committee if they have taken into consideration these tests of the American Locomotive Company?

Mr. Shurtleff:—The Committee did not take into consideration the tests of the American Locomotive Company. However, they considered the St. Louis tests, and there certainly is a difference in resistance with reference to the weight on drivers, depending on the number of drivers which are carrying the load, the same as it is in the case of freight cars as to the number of wheels that carry the load.

Mr. L. C. Fritch:—The subject of grade reduction on railroads is one that many of us have in hand at the present time, and my view is that many roads in the past have spent a lot of money unnecessarily in the reduction of grades. I believe that in many cases it is possible to use heavy engines where traffic is comparatively light, instead of spending a lot of money on grade reduction. Economy that will result from the investment in heavier locomotives will give a larger return than spending millions in grade reduction. I would suggest the Committee take that feature into consideration in future reports.

There is another point that I have in mind, and that is the question of establishing and rating the capacity of a certain line. The usual method now in establishing the economy of a grade reduction, in spending money for line improvement, has been to determine how many train miles could be saved. The usual custom in the past has been to estimate the economy of grade reduction by the number of train miles saved, and applying some value to the train miles saved, capitalizing that amount with the amount you are justified in spending on grade reduction. That, in my opinion, is only a very rough approximation.

There is another system that has been used and that is to fix the capacity of the line in ton miles per hour, taking as an ideal condition a straight and level road and taking a certain class of power and determining the quantity of traffic which that particular locomotive can handle over that line in ton miles per hour and calling that percentage 100 and then compare with the characteristics of a particular line and determine what the capacity of the line is on that basis, and in that way you obtain a relation between the various capacities that is a direct measure of the efficiency of the line. I believe that is the more accurate method of determining the value of line improvement than to estimate the saving in train miles. By this method of figuring the actual capacity of the line in ton miles per hour, you give a value to each particular part and characteristic of the line. It gives a value for curve elimination, and elimination of rise and fall, and in fact every element that enters into the problem, so that I would suggest that the Committee in the future take up that line of investigation.

The President:—Mr. Fritch's suggestions are valuable, and I am sure the Committee will note them with interest. The Secretary will read the conclusions of the Committee.

(The Secretary read conclusion 1.)

Mr. L. C. Fritch:—I do not quite understand what the Committee means by the last sentence: "In comparing a new line with an existing line, the same percentage of efficiency of drawbar pull should be used in both cases." What is meant by "percentage of efficiency of drawbar pull?"

Mr. Shurtleff:—In existing lines it is very rarely that 100 per cent. total efficiency is realized throughout the year. Therefore, in comparing a new line with an existing line, on the new line we cannot assume 100 per cent. efficiency. We may assume a higher efficiency, possibly, than we secure on the other operated lines, but in comparing two routes we should use the same rate of efficiency.

Mr. L. C. Fritch:—As I understand it, then, if over the old lines the locomotives were handling, say, 85 per cent. of their efficiency, the same per cent. would be used in comparison on the new lines.

Mr. Shurtleff:—Yes; or if you felt that possibly rules could be put into effect to increase the efficiency of the old line to 90 per cent., you would use 90 per cent. in both cases.

Mr. E. R. Lewis (Michigan Central):—Would the Committee consider this suggestion: To end the first sentence with the word "grade" in the third line, eliminating the words "where such drawbar pull is known?" Eliminating also the following sentence, "Where not known, the drawbar pull should be calculated." I should say, if the drawbar pull is not known, that it would naturally be calculated without the necessity of putting that statement in this recommendation.

The President:—I will ask the Committee if they will accept the suggestion made by Mr. Lewis.

Mr. Shurtleff:—The chairman is willing to accept this modification: "Actual drawbar pull of the locomotive at various speeds, when known, should be used in making estimates with reference to economic value of line and grade." That is eliminating the next sentence, "Where not known, the drawbar pull should be calculated."

Mr. J. E. Schwitzer (Canadian Pacific):—The revision which has just been suggested would mean the speeds were known, not the drawbar pull was known.

Mr. L. C. Fritch:—It seems to me the conclusion as drawn covers the point—you must know the drawbar pull before you can make any comparison.

Mr. Shurtleff:—There is no chance for misconstruing the clause as originally written.

Mr. L. C. Fritch:—There is one thing, however, that is uncertain in the minds of some, and that is the actual drawbar pull—what does that mean? Sometimes we take the drawbar pull to mean the tractive power of the locomotive—that is not drawbar pull.

Mr. Shurtleff:—That is not actual drawbar pull or effective drawbar pull.

Mr. L. C. Fritch:—I think we should understand whether we mean tractive power of the locomotive, the cylinder tractive power or the drawbar pull behind the tender, and I suppose it means the latter.

Mr. Shurtleff:—The drawbar pull is at the drawbar.

Mr. L. C. Fritch:—There is a drawbar between the locomotive and the tender.

The President:—I ask the chairman if the members of this Committee are agreed on this modification?

Mr. Shurtleff:—We are not.

Mr. G. D. Brooke (Baltimore & Ohio):—I move that conclusion No. 1 be accepted.

(The motion carried.)

(The Secretary read conclusion 2.)

Mr. L. C. Fritch:—I would suggest that you add there the weight on the drivers also.

Mr. Shurtleff:—Does not the word "adhesion" cover the point?

Mr. L. C. Fritch:—The weight on the drivers is the element of its tractive power.

Mr. Shurtleff:—Adhesion is the point you are trying to cover.

Mr. L. C. Fritch:—I thought adhesion would cover it the first time I read it, but, in thinking about it, it seems to me the weight on the drivers is the more important point. The weight is the governing element of the tractive power of the locomotive.

Mr. Shurtleff:—I think, probably, a good way of looking at adhesion is that it is the weight on the drivers, multiplied by the co-efficient of adhesion, so that the total adhesion is a percentage of the weight of the drivers, and adhesion in that sense, I think, covers what you want.

Mr. L. C. Fritch:—Adhesion may vary in different cases, but the weight on the drivers is constant.

Mr. F. S. Stevens (Philadelphia & Reading):—The conclusion says: "The tractive power of a locomotive depends on its steam-producing capacity, the boiler pressure, the adhesion and the size of the cylinders and drivers." The weight on the drivers is what produces adhesion. Without the weight on drivers we would have no adhesion, and, therefore, there would be no power, and I think the conclusion as drawn is correct.

Mr. Shurtleff:—The weight on the drivers is always constant, while adhesion is not constant. The tractive power would vary as the adhesion varies; and, therefore, I cannot see why we should mention specifically the weight on the drivers.

Mr. L. C. Fritch:—The formula for tractive power is $T = C$ square times D, or whatever it is, divided by the weight of the drivers.

Mr. Shurtleff:—The only place adhesion enters is where a locomotive is over-cylindered, as you might say, and can develop at low speed tractive power or power at the rim of the drivers, which would slip the drivers; therefore, you must consider adhesion at such a time in estimating tractive power.

Mr. George W. Kittredge (New York Central & Hudson River):—I move that conclusion 2 be adopted, although Mr. Lum has suggested that a very important factor has been left out of the conclusion, that is, the man at the throttle.

(The motion carried. The Secretary read conclusion 3.)

Mr. Shurtleff:—Mr. President, I wish to modify conclusion 3. Since this report was compiled some of us have had bees in our bonnets, and we have found a shorter way of reaching the results obtained in Table No. 1 as shown in the Bulletin. We have found that the steam produced per square foot of heating surface is more directly in proportion to the coal burned per square foot of heating surface. Therefore, we have changed Table No. 1 to show the pounds steam per pound of coal, varying with the ratio of coal burned per square foot of heating surface. It simplifies the table very much. Therefore, I would desire to have the last clause struck out of conclusion 3; that is, "and the ratio of heating surface per grate area," and insert the word "and" after the preceding clause, making the conclusion read: "The steam-producing capacity of a locomotive depends mainly upon the quantity and quality of the fuel burned and the amount of heating surface." I think that covers Mr. Lum's point about "the man."

Mr. President:—I understand that is the recommendation of the Committee?

Mr. Shurtleff:—That point has been put up before the Committee and so far as heard from they are unanimous on the point. There are a number of the Committee who have not answered the letter, as they did not several other letters of the chairman.

The President:—The majority recommendation of the Committee, in its amended form, is now before the meeting.

A Member:—Would the Committee accept this suggestion: Instead of saying "amount," say "area of heating surface?"

Mr. Shurtleff:—"Area of heating surface" is good. That is acceptable, I believe, to all.

The President:—If there be no objection, the clause, as amended, will be adopted.

(The Secretary read conclusion 4.)

Mr. Shurtleff:—Here again we want to eliminate, in the first line, the word "grate" and the word "and," and change the word "areas" to the singular—"knowing the area of heating surface."

The President:—If there be no discussion clause 4 will be accepted.

(The Secretary read conclusions 5, 6, 7, 8 and 9, which were adopted as read. The Secretary read conclusion 10.)

Prof. W. D. Pence (University of Wisconsin):—I think these proposed values of 30 and 25 per cent. adhesion, respectively taking the place of the driver adhesion ratio of 25 and 20 per cent. heretofore commonly used, are of interest to the Association, and it would be interesting to know the basis upon which the Committee has derived the new values.

Mr. Shurtleff:—You will note that we place that as a maximum, with sand; 33 per cent. has been realized to my certain knowledge, but we place 30 per cent. as a maximum for sand, 25 per cent. as a maximum for good rail without sand.

Mr. L. C. Fritch:—I think the Committee is safe in establishing those percentages, because the head of the rail is wider and the adhesion is greater than it was formerly when the rail was narrower and conditions were different.

Mr. Chas. S. Churchill (Norfolk & Western):—In taking up the question of changing grades and such matters as that, we do not want to use maximum figures, such as 25 per cent. We should use a figure that has proven to be a safe figure. I would like to have the idea of the Committee on that point. We are using 22½ per cent. ourselves.

Mr. Shurtleff:—I would say 22½ per cent. is the safe figure, but I notice doctors have disagreed very much upon this question.

Mr. Churchill:—You are the doctor just now.

Prof. Pence:—I am very sure that anyone here should hesitate to make a suggestion of any change. I am certainly not one that wishes to do it, but I think the point that Mr. Churchill called attention to is one that should have careful attention. The 22½ per cent. figure he has mentioned has been pretty extensively used as a conservative figure. This is a conservative Committee, and I am sure no one would expect them to recommend a thing that would be dangerous to depend upon in spending money on economic improvements. Would the Committee be disposed to add something that would call attention to the point of danger by the use of extreme maximum?

Mr. Brooke:—Does not No. 1 cover that? It provides that "the same percentage of efficiency of drawbar pull should be used in both cases;" that is, the same on the proposed line as on that with which it is to be compared.

Mr. Shurtleff:—I would say, with reference to the question of adhesion, there was considerable discussion at the November meeting of the Committee on this point, and we decided that no greater adhesion than these figures should be considered. The question as to what might be used will vary with locality. It is certain that in the arid West, where dew or frost on the rail is unknown, adhesion can be considered higher than in the South and in this section of country, therefore I would consider that the 25 per cent. is the maximum that should be considered in any section. I would look at adhesion at a lower figure in a country similar to this. Where we have our heavy dews, where there is a great deal of humidity in the air, and where we have frosts, adhesion would be reduced.

Mr. W. G. Raymond (State University of Iowa):—Does not the Committee, in view of what the chairman has said, want to change the words "not usually" to "never?"

Mr. Shurtleff:—The chairman does.

The President:—The Committee desire to eliminate the word "usually." The particular sentence then reads, "available drawbar pull at starting, with use of sand, should not be considered as greater than," etc. With that amendment this clause will stand. Please turn to page 38. I will ask the Secretary to read the conclusions given thereon in order.

(The Secretary then read the conclusions on page 38 to and including (b).)

Mr. C. E. Lindsay (New York Central and Hudson River):—Does the Committee, under No. 1, include "under condition of track surface," superelevation, or should that be included under "track?"

Mr. R. N. Begien (Baltimore & Ohio):—Do I understand you to say whether track elevation on curves should be included?

Mr. Lindsay:—Yes.

Mr. Begien:—I think that would be desirable.

The President:—Do you wish to put that under a separate letter?

Mr. Begien:—I think it should be added to that paragraph.

The President:—Do I understand from the Committee that that sub-section (d) will then read, "condition of track surface and rail elevation?"

Mr. L. C. Fritch:—Would it be more consistent to put (d) under the conclusion "track," in the second conclusion, or under the classification for "track conditions?" I simply make that as a suggestion.

Mr. Shurtleff:—As I understand it, Mr. Fritch, this first lot of conclusions are requirements with reference to what the mechanical apparatus should give.

The President:—I will ask the chairman of the Committee if it is the wish of the Committee to amend sub-section (d) in order to read "condition of track surface and rail elevation?"

Mr. Shurtleff:—As I understand it, "condition of track surface" will show the relative elevation of rails, mechanically or graphically shown by the apparatus, and I would hardly think we would have to specifically state "and curve elevation."

The President:—The present condition then is that the section (d) stand as it is printed?

(The Secretary then read paragraphs (i), (j), (k), (l) and (m).)

Mr. L. C. Fritch:—I would like to ask the Committee if they would object to inserting under (m), "kind and quantity of ballast?"

The President:—That is acceptable to the Committee.

(The Secretary then read the paragraphs under "Locomotive," "Cars," "Weather," including conclusion 2.)

Mr. W. H. Courtenay (Louisville & Nashville):—I would like to inquire whether that has been conclusively established by experiment?

Mr. Shurtleff:—It is pretty hard to establish conclusively, to the minds of all men, that a thing has been done. I have personally been connected with dynamometer tests where we took particular care to find out the resistance of the train at various maintained speeds, and there was only about three or four hundredths pound per ton of train variation between the speeds of ten miles per hour, twenty-eight miles per hour and thirty-five miles per hour, and that variation was variation that could easily have been caused by track conditions. They were practically the same. Mr. Crawford, as early as 1901, called the attention of the Western Railway Club to this point. He had a hard time trying to make his dynamometer tests fit the established theories with reference to train resistance, and others have found the same thing to be true. I believe Mr. Wickhorst, in his paper before the Western Railway Club, brought this point out, that within the ordinary limits of freight train speeds—I think he mentioned up to thirty-five miles an hour—the resistance is practically the same. In studying the matter with reference to this point, it is hard to conceive that there would not be an increase in resistance. The velocity resistance will increase as speed increases; but it has been established that journal friction will reduce as the temperature of the journals increases, until the temperature reaches about 100 degrees, and this modification in journal resistance will practically offset the head-end resistance. I think that Prof. Goss has established pretty well the fact that the velocity resistance should not be applied to each ton of train; in fact, the velocity resistance at the front end of the train is considerably greater than the velocity resistance at the intermediate portions or cars of the train, and that the end resistance is higher than the intermediate portion. What I have seen has made me believe that resistance is practically the same at thirty-five miles per hour as it is at ten miles per hour, and is lower at ten miles per hour than it is at the start.

Mr. C. Frank Allen (Massachusetts Institute of Technology):—I have considerable sympathy with anybody who instinctively doubts the statement that the resistance does not increase with velocity in every kind of train. Three years ago there was a report on train resistance, in which I had some part, and in helping prepare the report I remember the shock that came to me when I found that one of the members of the Committee had found that resistance did not increase with velocity in the case of heavy freight trains; but while the shock was still on there was received from Mr. Shurtleff a record of his experiments, backing up Mr. Dennis' results, experiments made, as he stated, on two systems of railroads, where he was unable to find an increase on account of velocity. Since then we have records on the Baltimore & Ohio on freight trains which show the same result; and the pamphlet that has been spoken of—of the American Locomotive Company, based on experiments on the Pennsylvania Railroad—comes to the same conclusion. In the compilation that was made three years ago there was only one formula, or set of experiments, quoted for what might be called a heavy freight train. The Daniel experiments were made on a freight train of 1,139 tons, and the formula given by Mr. Daniel did show an increase due to velocity. However, I have recently platted those experiments, and with the exception of one record at a very low velocity which always gives a high resistance, the straight and level line on the diagram fits fully as well as the line that Mr. Daniel suggested, so that at the present time the situation is substantially this: We have five or more authorities in harmony with the proposition that on heavy freight trains the resistance does not increase with velocity, and I know of nothing which clearly points in the other direction; so that I find myself quite unable to resist the conclusion at the present time that the resistance for such trains is substantially independent of velocity. It seems to me that we must now accept that, however much it goes against our prejudices. It was rather hard for me to accept it at first, but after three years of considering it I have come to rather enjoy it.

Mr. L. C. Fritch:—We would naturally ask, if the resistance does not increase with the velocity, why can we not haul maximum freight trains as well at thirty-five miles an hour as we can at ten? But I think it is perfectly clear. It is not due to increase in resistance; it is due to the decrease in the capacity of the locomotive. So I think that makes it quite clear that if a locomotive could maintain its capacity up to the speed of thirty-five miles per hour, if the steam could be made and supplied at that rate, freight trains could be hauled at thirty-five miles per hour as readily as at ten miles per hour. That is one advantage of the electrical locomotive. The electrical locomotive does not lose its hauling capacity in proportion to its speed, and with the use of electrical locomotives you will be able to handle maximum freight trains at thirty miles per hour as well as you can at ten miles per hour.

The President:—Conclusion 2 is accepted.

(The Secretary read conclusion 3.)

Mr. Fritch:—I do not believe that it is quite correct to say that formula should be used. The grade element is not taken into consideration in that formula, "$R = 22T + 121.6C$." There should be an element in there for the grade resistance. If you would say, "rating on different lines, in the same grades," it would be all right.

Prof. Allen:—I think it says "R is the total resistance on the level tangent."

Mr. Shurtleff:—That is covered in that expression.

Mr. L. C. Fritch:—That is clear; but the formula, as it stands, should not be used for comparing ratings on the different lines and grades. You would have to add the grade resistance. Of course, that is clear.

Mr. Shurtleff:—That is just exactly what we would have to do. We would naturally suppose that any man who is authorized to calculate those things would know he should make the corrections for grades and curves.

The President:—Conclusion 3 is accepted.

(The Secretary read conclusion 4.)

Mr. L. C. Fritch:—I am reminded of the remarks Mr. Churchill made a few moments ago, that we do not want to take the maximum conditions, but the average conditions, into consideration. I do not believe .035 is sufficient to allow for curve compensation. While the tests shown in this report indicate that .03 is probably too low, and that at .04 trains gain speed around the curves, that may be true in cases of selected trains or selected conditions, but I believe that the average condition will be such that .04 is a more reasonable amount to use. There are many who have used .05, but if you take a crooked line, where a train would lap over two or three curves, the resistance would be more than even .04. Then, again, there is no distinction made between curves of different radii. The distance is greater on curves of short radii than on curves of long radius. So I believe that ought to be changed to .04.

Mr. Shurtleff:—Besides the results obtained on the Baltimore & Ohio, in making tests with reference to curves and distances, I will call attention to the tabulated statement on page 37, extracts from answers to Committee circular of October 19, 1907. There are some pretty good authorities there on that point. E. H. McHenry, New York, New Haven & Hartford, found 0.03 per cent. compensation too low and 0.04 per cent. too heavy. H. R. Talcott, B. & O., A. V. Kellogg, Southern Pacific (Atlantic System), found the same. Some tests, analyzed by myself for Mr. Berry, we found, with new rail, trains at less than ten miles per hour retarded on 0.03 compensation and accelerated on same curves at higher velocities. Mr. Merriam, of the Grand Trunk-Pacific, found 0.04 per cent, too high for new rail; Mr. Kittredge, New York Central, found 0.03 per cent. made limiting grades on curves; 0.04 per cent. O. K. Perhaps Mr. Kittredge can tell us whether he found any split, what difference it would be, whether there would be a happy medium or not.

Mr. Kittredge:—I wish to vote unhesitatingly for 0.04 to-day.

Mr. Shurtleff:—Mr. Wendt found 0.035 per cent. proved satisfactory. Mr. Stuart found the same—trains accelerated when loaded for 1 per cent. grade on curves compensated at 0.035 per cent. Mr Courtenay, Louisville & Nashville, found 0.03 per cent. too low—somewhat higher necessary. H. T. Douglas, Jr., Wheeling & Lake Erie, used 0.03 per cent., but believes 0.04 per cent. better. Mr. Churchill, Norfolk & Western, found 0.035 per cent. O. K.; finds that trains accelerate on 0.04 per cent. Mr. Schwitzer, Canadian Pacific, found that trains accelerate on 0.04 per cent. compensation. A. C. Dennis, Canadian Pacific, found 0.04 per cent O. K. up to 5 degrees; too high for sharper curves. V. G. Bogue, Western Pacific, found 0.04 per cent. used, but probably is higher than necessary. H. F. Baldwin, Oregon & Washington, found that heavy trains stalled or retarded on 0.04 per cent. and found 0.05 per cent. O. K. W. S. Dawley, Allegheny Improvement Company, found with 0.05 per cent. compensation trains loaded for ten miles per hour on ruling grade tangents retarded on curves, while fifteen miles per hour trains accelerated. So there is a considerable variation in opinion.

Mr. J. B. Jenkins (Baltimore & Ohio):—I think a great deal depends on superelevation. If a line is built exclusively for freight traffic and superelevated for low speed, you will find that 0.03 is even too much. I have observed a train going over such a line, and in every instance the speed would be accelerated on curves and retarded on tangents with only 0.03 compensation; but when a line has mixed traffic (both passenger and freight) and is superelevated for the passenger traffic the increase of pressure on the low rail increase the friction so greatly that 0.035, I think, is about right. On a purely freight line I am of the opinion that 0.025 would be sufficient.

Mr. Shurtleff:—There is another point in reference to the matter. On a worn rail, yet a rail not ready to come out, the resistance would be different. It is difficult to reach the same results unless the trial is made over the same points in track, and it is pretty difficult to reach the exact amount.

Mr. L. C. Fritch:—I think that is the best argument for making this a limit that could be reasonably attained, under all conditions.

If we had ideal conditions perhaps 0.035 would be all right. I would rather be on the safe side than be just at the limit point.

Mr. Lindsay:—On the New York Central line we had a five-degree curve which was elevated for passenger and freight service 2½ or 3 in.; that was the first stalling point that the test trains encountered; the trains uniformly stalled on that curve. We reduced the elevation to one-half inch and eliminated that as the stalling point. The grade was compensated for 0.3. After that elimination we found 0.03 was insufficient and that the trains stalled at other points on the hill. I think you must take into consideration the location of the grade with reference to the engine run. In that particular case the limiting grade was encountered near the end of the engine run, and the engine came there in such condition that although it was given attention at the foot of the grade, still it was not able to haul maximum tonnage up the grade.

The President:—This is all valuable information. Mr. Fritch, have you any resolution to offer in regard to this section?

Mr. L. C. Fritch:—I will make a motion that in conclusion 4, 0.035 be changed to 0.04.

Mr. Begien:—Speaking on that motion, I will call attention to the fact that it is necessary, especially on long-supported grades with very heavy curvature, to hold down the rate of compensation to the lowest possible minimum. On very long grades the loss of elevation, due to compensation of curvature, is expensive. It may lower the summit elevation so much as to lengthen the tunnel quite a number of hundred feet, or if the tunnel is retained at its constant elevation, it may heighten the fills in the sags, making the expense considerable. I think it is a well known fact that curve resistance on light curves is greater per degree than it is on very heavy ones. Of course, at the top of a grade, if we have a heavy curve, it is necessary to compensate more than is necessary at the bottom, where there is a chance of getting a run. I hope Mr. Fritch's resolution will not pass.

Mr. L. C. Fritch:—The difference between .035 per cent. and .04 or .05 per cent. would make a difference of .26 of a foot in the grades between the two points. It seems to me so slight a difference that it would not cut much figure in the cost of construction.

Mr. John G. Sullivan (Canadian Pacific):—In seconding Mr. Fritch's motion I would like to point out the fact that we are dealing with a vital matter, and something you are building which cannot be easily changed. An error in the elevation of the curve can be readily remedied, but a mistake in grades cannot be changed without a very heavy expense, and I am in favor of the limit of .04 rather than .035.
Kittredge.

Mr. Kittredge:—I would offer as an amendment to that motion that the clause be changed to read that the maximum shall be .04 per cent., if that can be brought in. I would suggest: "In order to equalize resistance on curve and tangent, the maximum compensation of curves shall be .04 per cent. per degree of curvature."

Mr. Joseph O. Osgood (Central Railroad of New Jersey):—This is a subject on which we ought to have considerable experience by this time. When the Atchison road was built into the Rocky Mountains the line was compensated for hundreds of miles to the extent of .04 per cent. per degree, part of it .05 and part of .06. Years later the West Shore was constructed with compensation, as I remember, of .03. If any of the gentlemen here are familiar with the operation of the curves on these lines, they should be able to give us some information from practical experience.

The President:—Do you accept the amendment as proposed by Mr. Kittredge?

Mr. L. C. Fritch:—With the consent of the second.

Mr. John G. Sullivan:—I accept it.

The President:—The amendment becomes a substitute motion in effect that paragraph 4 shall read: "In order to equalize resistance on curves and tangent the maximum compensation shall be .04 per cent. per degree of curvature."

Prof. Walter Loring Webb (Consulting Engineer):—I think there is one point that is not considered here. I think the rate of compensation to be used should never be made absolutely constant, because the effect of that compensation on the construction and on the ruling grade should be taken into account. There are places where an excessive compensation can be harmlessly introduced, and in those cases it is perhaps wise to put the rate of compensation up as high as .05, but then, as Mr. Begien pointed out, there are cases where the rate of compensation has a very important influence on the cost of construction, and so we should recommend the best rate that we can for average conditions, rather than for the unfavorable conditions that might sometimes happen, because, if we adopt a compensation that is excessive for average conditions, then it simply means that we will not only waste money but will put in a compensation that does not apply to average conditions. Wherever there is a limitation, as there is in many cases when compensation is put in on a ruling grade, then I think we must use average conditions, and I think the tests that have been made all over the country show that, for average conditions, .035 is more nearly correct, although .04, or even .05, occasionally may be proper and desirable.

Mr. F. M. Patterson (Chicago, Burlington & Quincy):—There are some roads that have conducted compensation tests with dynamometer cars. I have in mind a case of a 7-degree 30-minute curve, turning through 90 degrees, at the foot of a .5 per cent. grade. The maximum compensation on that line was at the rate of .03 per cent. per degree, and it was found in actual practice to be much too low. There was a long tangent before entering the curve—the freight trains could get a good run for it, but they would be stalled or the speed would be reduced to such an extent that they could hardly get around. On the .05 per cent. grade they would pick up speed and go over the hill without any trouble. Mr. Wickhorst, Engineer of Tests, made some experiments on that track with the dynamometer car. If he is here it would be a good idea for him to give us the results of the tests.

Mr. M. H. Wickhorst (Chicago, Burlington & Quincy):—The results of the tests referred to were published in the American Engineer and Railroad Journal for April, 1902, page 111, and showed a curve resistance on a 7½-degree curve of 1.72 lbs. per ton of train. This would require a compensation of over .08 per cent. grade. If experience shows that a train in going up a hill accelerates on the curve, when the steam pressure remains constant and the throttle and reverse lever are left in the same position, then the compensation is too great, while if the train slows down on the curve the compensation is not enough. The statements of engineers as cited by Mr. Shurtleff indicate that curve resistance is much lower than the result obtained in the test cited above. There seems, however, to be but little definite information available, and it is a field open for considerable exact research.

Mr. L. C. Fritch:—The Committee seems to lay a good deal of stress on the increased cost between the two compensations. I think the point Mr. Sullivan raised is very important in that regard. Suppose you have a mile of three-degree curve, and at the summit you have a tunnel; if you give that increased compensation of .04 instead of .035 you only get .79 of a foot increase in elevation. I would rather spend my money in doing that.

Mr. Begien:—A grade a mile long is a short grade. In many line revisions where we reduce grades by cutting down a number of summits, sustained grades fifteen or twenty miles long result. I have personally projected twenty-mile grades in the last few years, and found that the difference in rate of compensation of a line that carries 60 or 70 per cent. curvatures, as they do through the eastern part of the United States and the Alleghany Mountains, amounts to considerable. An average of seven or eight feet distributed over twenty miles of line will result in a very material difference in the cost. I do not think we ought to set a maximum compensation for curvature, for the reason that if we have a curve at a station where every train stops, or at a water station, it is necessary to compensate that curve considerably more than would be necessary on a curve where the running of the trains was constant. I would further call attention to the fact that this .035 compensation was based on some actual data, and I suppose in the absence of any other information that the .04 is based more on guesswork than anything else.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I think this discussion is developing the fact that if you undertake to fix a standard for this amount you will fix it so that it cannot be used in a great many instances. I think, therefore, that this matter should be given further consideration by the Committee, and that they should enlarge their conclusion with some description as to the conditions under which this per cent. should be varied from. I do not think that this convention should undertake to alter the conclusion of the Committee, and if their conclusion is not satisfactory they should be asked to give it further consideration.

Mr. Shurtleff:—With reference to the question for further consideration, we have in our Bulletin recommended these conclusions for present adoption, with a view to future study on all of these points. We do not expect to cover this field in one year, two years or five years—we will do what we can.

With reference to the matter of curvature, we thought we had pretty good authority for recommending .035 compensation. I know where .03 has been used on mountain lines, and the curves have become the controlling points. I know where .04 has been used, and the curves have become the accelerating points. I had in one case been guilty of compensating at .03 1-3, or .1 per cent. for three-degree curve, and found that it worked satisfactorily. I believe that this thing is somewhat in the nature of a local question, depending on conditions and the maintenance of the grade and elevation, and that it is a very wide one. I do not think that we are too high in this figure; at the same time I see no serious objection, as far as I am concerned, to changing this as Mr. Kittredge has suggested. I think that a medicine which is good for Sue is not always good for John, and we should have some leeway.

Prof. S. S. Roberts (University of Illinois):—I move as an amendment that the recommendation of the Committee be adopted, with the request that, if they see fit within the next year to change their recommendation, they then do so.

Mr. L. C. Fritch:—I would like to see Mr. McDonald's suggestion carried out, for the reason if we adopt .035 now, and change to a higher compensation later, then we would be put to an additional expense for changing what we have done. I think it would be better for Mr. McDonald's suggestion to be carried out.

Mr. McDonald:—If I understand it, the Committee desires that this convention should give some expression as to the percentage desired, in order that the Committee may base its future work on such an expression. Am I correct?

Mr. Shurtleff:—That is my understanding.

Mr. McDonald:—If that is correct, after you take the vote and get the sentiment of this convention, I would suggest that the Committee in its next report bring in a conclusion as to the conditions under which this percentage should be varied from. The chairman has stated there are such conditions and it would be well to describe them for the benefit of those using the table who do not understand the matter as well as the chairman.

Mr. Osgood:—It seems to me the principal objection to the .035 per cent. is that it is too fixed. The report says "curves shall be compensated .035 per cent. per degree of curvature." So far as I can see, there is a general agreement that the compensation should be somewhere between .03 and .04. Would it not be better for the present purposes to put in the word "ordinarily," so that it will read "shall be ordinarily compensated," etc.? I believe that would overcome those objections to the paragraph. I think .035 is about right; at the same time it is too arbitrary to fix definitely.

(Mr. Kittredge's motion was lost.)

Prof. Pence:—Mr. Osgood's suggestion of the use of the word "ordinarily" may be accepted by the Committee as defining what they really mean.

Mr. Shurtleff:—That will be acceptable to the Committee.

Mr. L. C. Fritch:—I offer a motion that conclusion 4 be referred back to the Committee for further report at the next convention.

The President:—Will you state in what way you wish it considered?

Mr. L. C. Fritch:—The question should be referred back to the Committee to investigate the subject further and report at the next convention if they have any further suggestions to make in reference to the matter.

Mr. Shurtleff:—Since this matter of referring the clause back to the Committee has been brought up, I will call to the attention of Mr. Fritch that it is very hard to make the railways connected with this Association give up the information. We have dug very hard this year for information, and we have got some. I do not know whether this Committee wants to do any more strenuous work on this subject or not. I know the chairman does not feel inclined that way. We will take what is cheerfully given us on that point and digest it, and be honest with the Association, even though it may not coincide with our views; but it is pretty hard to send a matter back to a Committee for further report when we cannot get the railroads represented in the Association to furnish the information.

Mr. Churchill:—I understand the Committee has accepted Mr. Osgood's suggestion to put the word "ordinarily" before compensation. I think that puts the matter in good shape. It allows the compensation to be anywhere between the limits given in this report, which is .035 and between .03 and .04. We have all that variation and we can even go above .04 in case trains stop at stations of any kind. I believe we have all the information we want with the modified article as it now stands, and I move that it be accepted.

Mr. L. C. Fritch:—In view of the remarks made by the chairman, and with the consent of the second, I withdraw my motion.

Mr. Patterson:—I withdraw my second.

The President:—The motion is that paragraph 4 be adopted, with the word "ordinarily" inserted before "compensated."

(The motion was carried.)

(The Secretary read conclusion 5.)

Mr. Brooke:—In the discussion of conclusion 4, no mention has been made of the exact gage on curves. That is evidently a feature which will affect the resistance. I would suggest that, in connection with dynamometer tests, in section (d), "Condition of track surface," provision be made that the exact gage on all curves be accurately given.

Mr. Shurtleff:—How would it do, under section (d), describing the things to be given graphically, to make it read, "Condition of track surface and gage"?

Mr. Brooke:—That will be acceptable.

Mr. Lindsay:—I ask how far the superelevation and depression, as provided in paragraph 5, is observed by the railroads? From our point of view it is undesirable to depress the low rail below the grade line.

Mr. Shurtleff:—That practice existed on the Union Pacific, to my knowledge, and on the Chicago, Rock Island & Pacific, to my knowledge. It was put into effect on the Union Pacific for the purpose of reducing the entrance resistance to curves, the curve run-offs—by the way, as an explanation, curves two degrees and under are not spiral, and the run-off is carried off in the tangent. Unless the grade be compensated on the run-off the entrance resistance to these curves was increased. We know that the entrance resistance to curves is pretty heavy anyway, because of the skewing of the trucks in succession, and we desire to bring that entrance resistance down to the minimum, and the method of depressing the inner and raising the outer rail equally, in effect, compensated the grade of the run-off.

Mr. Lindsay:—I appreciate the theory, but desire to know the extent to which it is put into practice. If there are any representatives of the two roads mentioned here, I would like to hear from them as to how they maintain the curves.

Mr. L. C. Fritch:—There is another point that has not been brought out, as indicating an advantage in the use of the method prescribed by the Committee, and that is, on curves on limiting grades with the elevation all on the outer rail, it is well known that you must raise the center of gravity of your load past the elevation. If you are using momentum grades and come to a curve that is elevated 7 in. you must raise the entire weight of the train 3.5 in., which will have a great effect in retarding the momentum of that train. That is a point in its favor in addition to the one which the Committee has given.

Mr. Edwin F. Wendt (Pittsburg & Lake Erie):—The Committee on Track has heretofore considered the superelevation of curves, and on page 62 of the Manual you will find that it is recommended that the inner rail should be retained at grade. Conclusion 5 is a slight departure from the former deliverance of this convention and attention should be directed to this matter.

Mr. Begien:—This subject is given consideration with a view to train resistance and not especially with reference to track maintenance. Personally, I do not see why it would be any harder to maintain the track with the inner rail slightly depressed than it would be to hold it at grade.

Mr. Kittredge:—I would move as an amendment to this conclusion that the superelevation of curves should be obtained by the elevation of the outer rail, if it is necessary to put it in here at all. The convention being on record, as cited by Mr. Wendt, might make it unnecessary to mention that fact here, but if it is decided right and proper to introduce it here, I would offer my amendment.

Mr. Shurtleff:—I think Mr. Begien has just covered the point. The reason it is brought in here is that it must be considered in train resistances. If you are going to make the superelevation by maintaining the inner rail at grade, you have increased your grade resistance or the entering of curves, particularly on supporting grades. Mr. Fritch brought up the same thing. We have increased the grade resistances, and if there is anything to be changed, the chairman of this Committee would desire that the Track Committee change their conclusion which has been adopted in the past.

Mr. Jenkins:—I think the best way to arrive at the proper result in maintaining a uniform resistance would be to drop the grade line so as to keep the center of gravity of the train at proper elevation If you establish the grade line with just the compensation required for curves, and then depress the low rail, you will not have sufficient ballast under the low rail. It is better to depress the subgrade line to allow for the expected superelevation and keep the low rail, as in present practice, as fixing the grade line for top of rail.

There is another factor—the superelevation of track is frequently changed with changes in schedule of speed. If the grade line is a mean between the two rails, then when the superelevation is changed there will be a different relation between the subgrade line and the top of the low rail because of such change, and it will have considerable effect on bridges and trestles. You will either have to raise the grade line on tangents when you increase the superelevation or else you will have to drop the bridge floor.

Mr. W. M. Camp (Railway and Engineering Review):—I think I recall that this question was pretty thoroughly threshed out when it came before the Track Committee. There is a difficulty in maintaining track surface on curves where the lower rail is depressed to give part of the elevation. It works all right when one has the engineer's stakes to go by, when the track is first put up, but subsequently, in maintenance, it does not. If there comes to be a low place in the vicinity of the run-off for the depression, the foreman has nothing to go by in sighting his rail to bring it to surface, whereas if the low rail is carried to grade, all around, he has the tangent on either side to guide him in keeping that rail in surface;

and, of course, he uses his level board in checking the upper rail to keep it in proper elevation. I have seen that question come up a good many times in practical work and, considering that section men do not have grade stakes to go by at all times, I think it is better to keep the lower rail at grade and elevate the outer rail.

Mr. Lindsay:—I would like to know if there are any gentlemen who maintain the track by depressing the lower rail half of the elevation and raising the outer rail the other half.

Mr. D. W. Lum (Southern):—I would like to ask how the gentlemen accomplish it, how they get the lower rail down? I do not believe it is possible. I think after a few months one would find the section masters, in spite of one's orders, surfacing the low rail and making the superelevation conform. I have never heard of their cutting the inside rail down, and we would, therefore, have to assume that the adjustment of the inside rail always required raising. It does generally require raising, especially where one has very slow speed in one direction and high speed in the other. I would like to hear someone describe how they attained their superelevation by lowering the inside rail.

Mr. Shurtleff:—One of the members who used this method on the Union Pacific is the chairman of the Committee. On the reconstruction of the Union Pacific through Wyoming we did not find any difficulty in doing this. We did not find any difficulty in making our embankments or our excavations in line with this, but I cannot say as to their difficulty since then in maintenance. I know personally, from having to handle track in my experience, that a track foreman who can carry a gradient for several hundred feet around a curve is a dandy. If you do not find 3 in. difference in your gradient on your inner rail, where you have no stakes, I am very much mistaken. The matter of carrying it into effect is no trouble whatever. We are speaking of building new lines. In such cases this can be carried into effect, and in many cases can be carried into effect on constructed lines.

Mr. Courtenay:—A number of years ago there was a wreck on the Old Colony road, due to jacks being placed between the rails. On the Louisville & Nashville we have a rule prohibiting jacks from being used between the rails. Since it has been enforced it was found our section foremen could not reasonably put the lower rail to surface, for the jacks outside of the rail, toward the center of the curve, interfere with their line of sight. Our foremen have almost universally adopted the method of surfacing the outer rail by lifting the outer rail to proper surface with jacks, and then bringing the lower rail to surface with the level board. We some time ago adopted a rule requiring that the outer rail follow the profile, and the lower rail be depressed. In practice for a number of years with this method, which has prevailed on the Louisville & Nashville, we do not find any serious difficulty about it. Our experience is that the lower rail goes down a great deal more than the upper rail. Our curves are elevated for passenger train speed and, therefore, the lower rail gets excessive weight and requires more lifting and attention than the upper rail.

Mr. Lum:—Mr. Shurtleff states that he has given such orders, but does not know how it is accomplished. I do not think it can be done as a practical proposition.

Mr. Camp:—The practice which Mr. Courtenay described is not what the Committee recommends. Mr. Courtenay states that in his practice he keeps the outer rail at grade. That is easily enough done because he has the rail on the tangent on either side to sight by, but where the outer rail is lifted half the elevation above the grade of the tangent, on one side, and the inner rail is depressed half the elevation on the other side, there is where the difficulty comes in. It is easily enough done if one has grade stakes, as when the track is first rebuilt, but I do not think it will be found that the trackmen will keep it in surface as well as they will a curve elevated by keeping one rail on the straight grade and elevating or depressing the other rail sufficiently to make the elevation. Of the two ways (elevating or depressing) I think the method of putting the inner rail to grade and elevating the outer one is the preferable.

Another consideration is the decreasing amount of knowledge and skill to be found with section foremen. Men of mechanical instincts do not seek track labor as they once did, and of late years railroad companies have in cases been obliged to employ for or promote to the position of section foremen men hardly able to speak or comprehend the English of ordinary terms. It is therefore important that, other considerations not conflicting, track work should be reduced to simplicity wherever possible.

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—It has been my experience that we have to change the elevation a good many times. The speed of trains increases and it is necessary to change the elevation. I do not see how that could be accomplished in this case unless you dig the track down or raise the profile of the whole line.

Mr. Begien:—I do not think it is a function of this Committee to describe methods of maintaining the track. If we recommend what should be done, that is all that is in our province. On the other hand, I do not believe that it would be a very hard matter to maintain the track under these circumstances. It is not an unusual thing to take the track down in case of change of the superelevation. It is merely a matter of taking down the lower side and raising the higher side. If it is necessary to do that, however, and no doubt it is something to be accomplished in view of train resistances, I do not see why we should not keep stakes for the section men to surface by.

Mr. H. T. Porter (Bessemer & Lake Erie):—I have endeavored to place the vertical curves so they will come on the tangents. I am aware this cannot be done all the time, but as a rule it can be done. This places the curve on a straight line, so that all the foreman has to take care of is the horizontal curve. You give him stakes set to straight grade for his inner rail, and he gets his track up in good, solid condition. As a rule, he can keep the lower rail very close to the grade. The engineer can set the stakes exactly, but as a rule the foreman, by experience, can follow the grade closer than the engineer could if he undertakes to do it; I mean with the section gang, not with the instruments. Now, you could either follow the straight grade with your inner rail or your outer rail. I have always followed the straight grade with the inner rail. That simply leaves to the foreman to put in the elevation called for, which he determines with his level board so that it makes his proposition a simple one. If you have to lower the inner rail and raise the outer rail, you have four vertical curves in the inner rail and four vertical curves in the outer rail, and the foreman has nothing to guide him unless you furnish exact stakes. You must furnish stakes by which to surface the track the first time, but we are well aware that it is not desirable to maintain stakes alongside the track at all times on account of danger to the trainmen. Besides, a permanent set of monuments from 25 to 50 feet apart would be very expensive, and this would be necessary in order to have the foreman do good work with four vertical curves in both rails, as he can now with stakes for the inner rail set at the time he gets his track in good, solid condition.

I believe that the elevation of the outer rail does increase the resistance, but it only affects it on a short length of the train and the momentum readily takes care of this. It may produce a slight reduction of speed on entering the curve, but it is compensated for as you leave the curve so that in the end there is practically no loss of speed.

Mr. Churchill:—In view of the fact that item No. 6 refers to general track maintenance, and in view of the fact that the Committee have already presented us a rule for elevating rails on curves, and that this section 5 affects the other, I move that it be stricken out.

(The motion carried.)

(The Secretary then read clauses 6 and 7, which were adopted, with the addition of the words "and design in clause 6," making it read "condition and design of equipment has a great effect on train resistance.")

(The Secretary then read conclusion 8.)

Mr. C. H. Ewing (Philadelphia & Reading):—This is quite an important table. I have had to refer to it within the last few weeks, in making a comparison of actual practice, in adjusting for winter tonnage, and I was very much surprised to find so great a variance in actual practice with the results obtained, from the table prepared by the Committee. It appears to me that the table is entirely too conservative. I have talked to some motive power men who have made a number of experiments in this line and they stated that the reduction should not start above 35 degrees. I have found by starting at 45 and then going down to winter weather, say 20 degrees, the reduction is very much greater than is usual in actual practice. If we would

eliminate (a) and start the reduction at 35 degrees, with percentages under (b), it would approach more nearly the actual condition.
Thompson

Mr. L. C. Fritch:—I agree with what Mr. Ewing has said. The changes are too slight. I think they should be reduced in (a) to 35; the limits for (b) for 35 to 45 are too narrow.

Mr. W. S. Thompson (Pennsylvania Railroad):—My experience is different from the last two speakers. The reduction is not enough. If it is calculated for double track and trains moving constantly after starting, that is one proposition; but if the train gets in on the side track and waits ten, fifteen or twenty minutes, or an hour, you cannot start at zero degrees with the reduction you have in this table. I would like to ask what experiments are made on which this table is based.

Mr. Begien:—This table represents the practice of the Baltimore & Ohio. This practice varies on the different divisions. I have known of cases where the temperature was about freezing, where according to the sheet it would call for 90 per cent. of rating where we were pulling 30. This is not a basis of tonnage rating, and is not intended to be such. It is a basis for comparing one line with another. If you can get the average temperature in any given locality on your line, we merely offer this table to show what per cent. of the calculated rating you can have the year around. We do not recommend this as a basis of tonnage rating. That is my understanding.

Mr. L. C. Fritch:—I would suggest to the Committee changing the last three or four words in the conclusion and make it read, "is submitted as information."

Mr. Ewing:—In view of what the member of the Committee has just said, if they would add to this conclusion that it is only intended for theoretical comparison between lines and not intended to apply to tonnage rating of locomotives, I think that would cover the whole matter. It is confusing the way it is placed now.

Mr. Shurtleff:—I believe the Committee would consent to adding the words: "Is recommended for use in making comparisons of the economical value of locations or lines."

Mr. Ewing:—I think the Committee should make it a little more definite and say, "It is not intended to be made use of for tonnage ratings." A great many of us will fall into that error unless we are very careful.

Mr. L. C. Fritch:—I do not see how it would be useful in comparing various lines, because you cannot estimate what your temperature conditions will be in making comparisons. It is very valuable matter, as far as information goes, but it will not fit the country generally.

The President:—I understand that the Committee will accept the suggestions which have been made.

(Clause 8, as amended, was adopted.)

Mr. McDonald:—I would like a division on the last vote. I will move to reconsider the vote. My reason for a reconsideration is that if we receive this part of the report as information we cannot put it in our Manual, and I think if we amended it at all we should amend it as we want it, and then adopt it. I favor the idea of Mr. Ewing that we add to conclusion 8 that it be used as a method of working on new lines and not for tonnage rating.

Mr. Lindsay:—Mr. McDonald voted against the original motion and, therefore, his motion to reconsider is out of order.

The President:—Is there anyone who voted in the affirmative who desires to have the vote reconsidered?

Mr. Kittredge:—I want to say here that I believe this Committee has done better work on this subject than has been done in any meeting before, and while at times it looks as if we were riding rough shod over the Committee, I do not think that is the intention at all. In this case I do not think it fair to the Committee to cut that out; I think it should go in I voted in the affirmative, and I move that the clause be reconsidered.

(The motion carried.)

Mr. Begien:—Perhaps some substitute can be offered. It is very difficult, in a recommendation of this character, to get something to suit everyone. I think you will all agree that it is absolutely necessary to have some figures of this sort in comparing revisions, especially those extending over whole divisions. It we can have something to substitute I do not think that the Committee is at all anxious to use these particular figures. They certainly have worked out well in some cases.

Mr. McDonald:—I move that conclusion 8 be amended by adding the words to the conclusion, "in comparing new lines and not for tonnage rating." I think the Committee has already expressed the fact that it is almost a necessity to have such a table in this report, and if you put it in in this way I think it will be acceptable to the Committee.

Mr. L. C. Fritch:—I cannot understand how you are going to assume your temperature under conditions where you are going to compare one line with another. You must assume some conditions. I do not see how it will be useful to you in making a comparison between various lines. It is, as Mr. Begien stated, almost impossible to make up a table of this kind that will be acceptable to everyone Every railroad will make this a study, to suit their own conditions, governed by their location and the climatic conditions. It is a useful table, but I do not see how people in different sections of the country could use the table with safety.

(The motion of Mr. McDonald was carried.)

(The Secretary read conclusions 9 and 10, which were adopted. The Secretary then read the conclusions on page 41.)

Mr. Lindsay:—I think there is danger in the use of the word "safest." I think it would be better to use "preferable."

Mr. C. P. Howard (Lake Shore & Michigan Southern):—I think the word "safest" is the best, because we cannot deny the fact that straight lines are safer than curves. There is always an element of danger which we can never get rid of.

Mr. J. A. Atwood (Pittsburg & Lake Erie):—I suggest the substitution of the word "preferable."

Mr. Begien:—Why not leave it, "A straight line is the best alinement?"

Mr. Courtenay:—I suggest as an amendment that it read, "A straight line is the best alinement."

Mr. Shurtleff:—This Committee has been studying many things about curvature, and we were trying to lead up to the value of curvature. The chairman and several other members vigorously fought some conclusions that were presented to the Committee, and if these conclusions had gone in you would understand why we are putting in this word "safest." We are leading up to something which will appear in the future—we are trying to establish values of curvature.

Mr. G. A. Mountain (Canadian Railway Commission):—I agree with the speakers who move the amendment. I do not think the word "safe" or the word "dangerous" should be used in any clause in the Manual whatever. It might be construed in a lawsuit, where an accident occurred on a curve, to mean that the curve was dangerous.

Mr. L. C. Fritch:—I object to the last amendment because that is axiomatic—a straight line is the best alinement. I would prefer to have the word "preferable" used in place of "safest."

Mr. Porter:—I suggest this: "A straight line is the best alinement, and with the possible exception of very light curves, other things being equal, it is the safest."

Mr. Kittredge:—I want to protest against the use of the word "safest." I agree with what Mr. Mountain said. Neither "safest" nor "dangerous" are good words for us to use. "Preferable" is better if you use the long clause, but I think it might be better to curtail it in accordance with Mr. Courtenay's amendment.

Mr. Shurtleff:—The Committee realizes the reasons for limiting the word "safest." It brings up a point that I got a little excited about awhile ago. That is, in establishing values for curvature we have got to consider the question of safety, and we notice that the railroads are very diffident about giving out even to committees of this kind information with reference to the matter. After these conclusions have been considered this Committee would like to have suggestions from such operating or executive officers as are in the convention room as to how we can get information that is necessary to establish these values, in fact, establish all values that we must establish for our work.

Mr. Lindsay:—I do not want to prolong the discussion, but as much odium attaches to the comparative terms "safe," "safer" and "safest" as to the word "unclean." There is nothing in that resolution proposed by Mr. Courtenay to prevent the Committee considering the safety of the alinement and giving proper value to it, but there is a strong objection to the use of the word "safest."

Mr. Camp:—It seems to me that it might be pertinent to inquire what the standpoint of the Committee is in giving this recommendation. Is it from the standpoint of economy of the operation of trains or from the standpoint of safety in the operation of trains? The chairman intimates that he has something "up his sleeve."

Mr. Shurtleff:—No; he is looking for something to put into his sleeve.

Prof. Allen:—Although I have not specially fathered this, I have had some correspondence connected with it. The element of safety is, of course, a part of the economical consideration, and I can properly state, from the correspondence I have had in connection with it, that the element of safety entered into it from that consideration. I am not either defending or otherwise the desirability of using the word "safety."

Mr. Camp:—Is it necessary that the Committee should say that all curves are dangerous or are not as safe as tangents? If that is axiomatic, why not leave it out, so as to avoid misunderstandings and possible exaggeration on the part of those who have not practical views of an engineering question of this character.

Mr. Shurtleff:—It will be necessary either to state it or imply it very plainly before we are through with the work of this Committee.

Mr. Camp:—Why can't you give us some intimation of what is coming?

Mr. Shurtleff:—We are trying to do that.

The President:—Mr. Courtenay's motion, duly seconded, is that conclusion 1 read, "A straight line is the best alinement."

(The motion was carried.)

(The Secretary read conclusions 2, 3 and 4, which were adopted.)

The President:—The Committee will be relieved, with the thanks of the Association for the excellent report they have presented, and we trust that the Committee on Economics of Railway Location will have a report every year.

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PART I.