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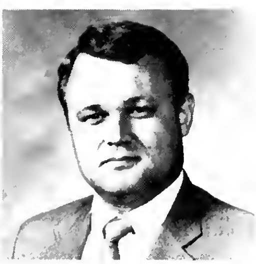

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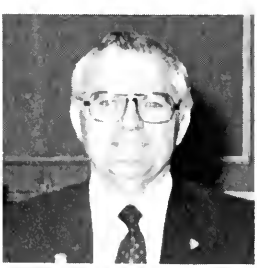

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Numerical Index to Committee Reports

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American Railway Engineering Association

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Front Cover Photo - Mexican railways freight heads east out of Tepic, in the state of Nayarit.

Rear Cover Photo - Passenger train crosses the Salisipuedes Viaduct on the line between Guadalajara and Tepic in Mexico (See article on Page 1 for details).

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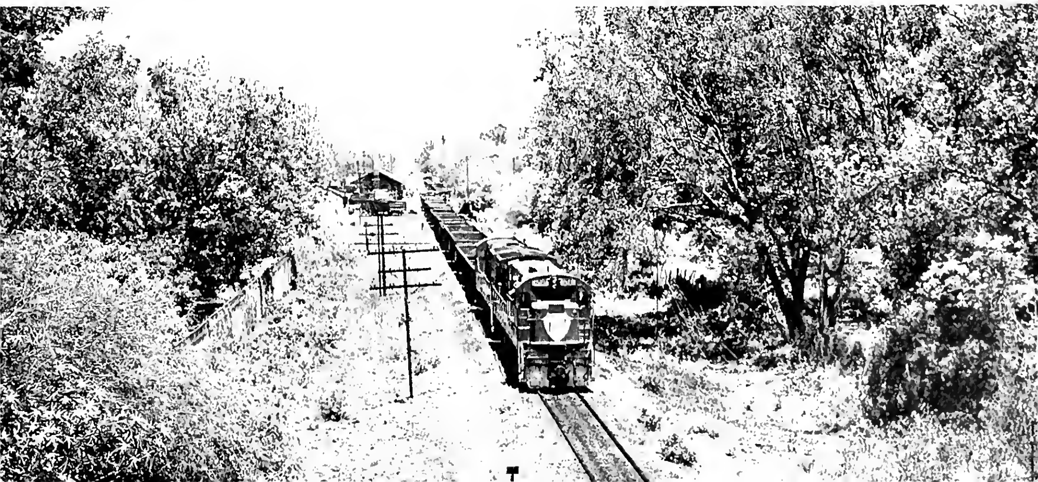
In the Tropics

While many Railroaders on the North American continent are enduring the rigors of winter, some of them work in areas free of snow and freezing weather. No matter what the weather where we are on the contiguous rail system of the North American continent, the rails we are looking at are part of a continuous engineered structure able to support the load of rail cars and locomotives from the Northwest territories of Canada to the Guatemalan border of tropical Mexico. Tropical scenes from the National Railways of Mexico were selected for this wintertime issue, so that those involved with snow and freezing weather can, at least in spirit, join their fellow railroaders that are working on that same continuous structure while enjoying warm weather. The scenes above and below are on lines heading west and south, respectively, from the city of Guadalajara. The rear cover shows the famous Salsipuedes viaduct in the Barrancas region between Guadalajara and Tepic. It was at this 240 ft high bridge that the final spike was driven on April 15, 1927 to complete a through railway from Mexico City to the U.S. along the Pacific Coast of Mexico.



1987
ANNUAL REPORTS
OF
TECHNICAL COMMITTEES

Excerpts From Annual Report of A.R.E.A Committee 1 - Roadway and Ballast

H.C. Archdeacon, Chairman

Brief status of each subcommittee assignment:

Subcommittee 1. Roadbed

(a) "Report on criteria including subgrade conditions: depth, type, size and condition of ballast; condition of track superstructure; tonnage and need for installing geotextiles, justifying the use of undercutters."

The subcommittee has been preparing a report on this assignment. Expect it to be presented at the October meeting. If satisfactory, this assignment will be complete.

(b) "Update the Manual text on maintenance of roadbed."

This assignment has been completed and submitted to the Board for approval.

(c) "Investigate and report on railway use of prefabricated concrete units for retaining embankments."

Anticipate that the subcommittee will present a draft report at the October meeting.

Subcommittee 2. Ballast

(a) "Finalize the plan of study for the correlation of the field performance of ballast types with laboratory testing".

A report has been submitted. Wish to discuss this with the Board members at the chairmen's meeting.

(b) "Progress the study of elements of the plan until an economic analysis can be made of various ballasts."

This relates to assignment 2(a). Also wish to discuss this at the chairmen's meeting.

(c) and (d) "Furnish input and act as a steering committee for the AAR ballast research program. Review and monitor the AAR program and the interpretation of all ballast test data prior to dissemination." and, "Report on results of AAR and other appropriate ballast research programs. Utilize suitable elements as part of AREA plan of study."

These assignments are ongoing in nature. They have a relationship to assignments 2(a) and 2(b). They should be included in the discussion.

(e) "Complete the revision of the Manual section on ballast."

This assignment has been completed and submitted to the Board for approval.

Subcommittee 3. Natural Waterways

(a) "Develop recommendations for the prediction of scour and update the present recommended practice for protection against scour damage."

This assignment is being actively pursued by the subcommittee. Expect them to present a progress report at the October meeting.

Subcommittee 4. Culverts and Drainage Pipe

(a) "Develop design criteria for hydraulic factors affecting the size of culverts for railway applications."

A letter ballot is currently in circulation on this assignment. If approved, the Manual revisions will be submitted to the Board for approval and the assignment will be complete.

Subcommittee 5. Pipelines

(a) "Develop specifications for use of casing pipe larger than 42 inches in diameter."

(b) "Study use of plastic carrier pipes."

These assignments have been a problem because of limited qualified personnel. There has been some improvement in this situation, and this subcommittee is actively at work. This is an area where we should have more help. If the Board members have qualified pipeline specialists on their staffs, recommend that they be encouraged to join the committee and participate in this work.

Subcommittee 6. Fences

(a) "Develop manual recommendations for security fencing."

(b) "Review and update manual recommendations for snow fencing."

These are new assignments. They are being actively pursued. Do not anticipate completion this year.

Subcommittee 8. Tunnels

(a) "Review and update manual recommendations for tunnels."

This is a new assignment. The subcommittee is actively working on it. Anticipate that it will take at least one more year to complete.

(b) "Report on the design and construction of the Roger's Pass tunnel."

This is a new assignment. It was intended to be a two year assignment as the project will not be complete until 1988.

Subcommittee 9. Vegetation Control

(a) "Revise the vegetation control glossary."

(b) "Develop recommended practices for roadbed spray patterns."

Both of these assignments have been completed and submitted to the Board for Manual approval.

Subcommittee 10. Geosynthetics

(a) "Develop recommended practices for the use of geotextiles in erosion control applications."

(b) "Develop recommended practices for the use of geotextiles in drainage applications."

Proposed additions to the Manual are expected to be submitted by the subcommittee at the October meeting. If satisfactory, a vote will be taken on each assignment to authorize a letter ballot.

Excerpts From Annual Report Of A.R.E.A. Committee 2 - Track Measuring Systems

W.M. Worthington, Chairman

Subcommittee activities:

Subcommittee 1 - Rail Planimetry

A paper on rail corrugation was presented at Chicago in March. The Subcommittee is now defining new objectives including obtaining more data and in developing new processing methods.

Subcommittee 2 - Track Surveying

The subcommittee has worked with the results of the survey of track data bases and is continuing to evaluate how the data can be used and how it can be collected, preferably using an automatic method.

Subcommittee 3 - New Technologies

The subcommittee is continuing to evaluate the results of the questionaire regarding interest in new track measurement technology. They will direct their interest towards potentially useful devices based on survey results.

Subcommittee 4 - Track Geometry Car Development

A glossary of standard track geometry definition was prepared and voted on by committee members. This will be submitted to the 1987 Manual when the final results are documented. A new assignment to subcommittee is developing, is to propose standards for track geometry cars.

Subcommittee 5 - Track Geometry Analysis

The subcommittee is working on defining the elements included in a Track Quality Index. They are also evaluating the pros and cons of different track rating techniques.

Subcommittee 6 - Rail Flaw Detection

The subcommittee produced a draft statement of performance requirements for rail flaw detection systems. It is currently under review by the Committee.

Excerpts From Annual Report Of A.R.E.A. Committee 3 - Ties and Wood Preservation

C.L. Hardy, Chairman

Status of Subcommittee Assignments:

Sub-Committees A&B

No change recommended for these sub-committees. Subjects for further study and research is always welcome. I have asked Sub-Committee A to furnish any information they can gain on imported timber for use as cross ties. We need to keep alert as to needed revisions to the manual.

Sub-Committee No. 1 - Cross Ties and Switch Ties

The assignment dates are unknown. We are in the process of reviewing all the Sub-Committee assignments. But at the June 2, 1987 meeting the committee unanimously voted on the need to drop assignment (b). We feel that while field inspections can be beneficial to the committee as well as the operator, the time spent on these inspections is insufficient to draw a fair conclusion as to adherence to specifications. Also, most plants operate under the specifications of the Railroad or Railroads they supply.

Sub-Committee No. 2 - Wood Preservatives and Preservative Treatment of Forest Products

The assignment dates are unknown for (a), (b), (d), (e) and (f). Item (c) was assigned in 1983. As in the other Sub-Committees there is, possibly the opportunity of consolidating some of these assignments. While there has not been too much published activity in this field for some time, the possibility of new products and changes in this field is very real, particularly in view of environmental pressures. With the exception of some consolidation and rewording, the scope of this assignment should remain as listed with the continued monitoring of developments.

Sub-Committee 3 - Service Records of Forest Products

We have no dates available for any of the assignments. Both (a) and (c) are ongoing activities and we continue to monitor and gather information on these subjects. Assignment (b) has had little or no activity over the past few years and it is doubtful we will see any in the near future, therefore, we suggest this assignment be dropped. Item (d) while having little activity in the past few years, seems to be drawing a lot of attention lately. We plan to closely watch developments in this area.

Sub-Committee 4 - Collaborate with A.A.R. Research Departments and Other Organizations in Research and Other Matters of Mutual Interest

The assignment dates are unknown. We continue to have activity in assignments (a), (b), (e) and (f) and recommend these to be ongoing. Assignments (c) - one step seasoning and treating method developed by AAR-NLMA and (d) - feasibility of using atomic energy to retard decay in forest products continue with no activity, therefore, we recommend these two be dropped.

Excerpts From Annual Report Of A.R.E.A. Committee 4 - Rail

B.D. Sorrels, Chairman

Brief Status Of Each Subcommittee Assignment:

Subcommittee A

Subcommittee A is assigned with the recommendations for further study and research.

This committee has assigned all recommended subjects for study to the appropriate subcommittees.

Subcommittee B - Revision of Manual

All of the requested manual revisions have been assigned to the appropriate subcommittees.

Subcommittee 1 - Collaborate with technical representatives of rail suppliers, welding contractors, suppliers of field welding, rail grinding and rail testing contractors on matters of mutual interest.

Ad Hoc Committee on Profile Grinding

This assignment was made some 4 or 5 years ago and progress has been made since that date. An interim report was presented at our Spring Meeting in Toms River, New Jersey and this study is ongoing.

Qualification Testing

The work continues on the evaluation of flash butt welds. The 132-lb. rail welds have been made and slow bend tested and the 115-lb. rail welds are being completed for slow bend testing. More physical testing is planned, and the metallurgical microstructure analytical work is in progress.

High Strength Rail Welding

This Ad Hoc Committee is presently about one year old, and has been assigned to study the significant problems associated with the hardened rail end batter at welds. This Ad Hoc Committee has collected and presented field experience and test data. Further work is required by this committee and its work will continue.

Subcommittee 2 - Collaborate with technical representatives of rail and joint bar suppliers in research and other matters of mutual interest.

The rail suppliers have furnished the rail committee with survey results of rail symmetry, rail heights, base width and flange thickness of rail producing mills. These statistics, are being utilized by our Subcommittee 5, in preparing revisions to our rail specifications. Other important work being performed by this subcommittee, includes the ongoing research work on ultrasonic testing, stamping, side sweep, long rail lengths and tolerances.

The work of an Ad Hoc Committee, on microwave standards, have completed their work, and have presented this specification to Subcommittee 5 for inclusion in our upcoming revision to our rail specifications.

Subcommittee 3 - Rail Statistics

Rail statistics is an ongoing study of quantities of welded rail laid on various railroads in the United States as well as failure data covering various types of rail failures occuring. During the past year, we have corresponded with our headquarters relating to the possibility of eliminating several of these reports. Approval has been granted, and this committee is proceeding with the collection of data to provide our rail statistics.

Subcommittee 4 - Update data on methods and equipment for making welding repairs to rail and turnouts including thermit welding.

This committee has established a liaison with the AWS, which has again become active in the field of trackwork welding. We feel that this particular subcommittee can produce some worthwhile information relating to this subject, which will be of benefit to AREA, as well as the industry.

Subcommittee 5 - Rail specifications research and development.

This is a very important subcommittee and has been most active during the past several years. The subject is continuing, and currently the committee is working on some very important matters, including a major revision to Chapter 4, relating to a specification for rail. The new specification will include microetch standards as well as numerous alterations to the specifications for ultrasonic testing as well as dimensional tolerances. The new revision should be prepared within the next several months for circulation and approval by letter ballot.

The assignment of this committee is ongoing and we feel that this subcommittee is quite important to the functioning of Committee 4.

Subcommittee 6 - Joint bars, design specifications, service tests including insulated joints and compromise joints.

Currently this committee is developing specifications for the fabrication of bonded insulated rail joints. Committee members were solicited for current railroad specifications and test data for inclusion in this assignment. This data is currently being evaluated for applicability.

Subcommittee 7 - Effects of heavy wheel loads on rail.

Subcommittee 7 has an ongoing study relating to the effects of heavier cars upon the fatigue life of rail steel. This committee has presented several interim reports, and its study its continuing.

Subcommittee 8 - Recommendations for interval of non-destructive testing for internal defects of rail and track.

This committee has worked on this assignment for several years and has presented a paper for inclusion into the AREA manual. The AREA Board discovered some possible improvements to this report and this committee is now in the process of rewriting this particular paper. A liaison with CORT, has been accomplished and hopefully between the two organizations an improved paper will be produced.

Excerpts From Annual Report Of A.R.E.A. Committee 5 - Track

W.B. Dwinnell III, Chairman

Subcommittee Assignments:

A. Recommendations for Further Study and Research

a. Subcommittee B has submitted to AREA Board a questionnaire on "Recommended Practices for Anchor Application and Maintenance."

b. Subcommittee B has submitted to AREA Board a questionnaire on "Recommended Practiees for Preservation of Track Fixtures."

c. Recommended to AREA that tests be made to determine the most desired width of ballast shoulder for improving track geometry horizontally.

B. Revision of Manual

a. Review anchor pattern for bolted rail and CWR.
This subject is in its final stages of completion.

b. Review current anchor application and maintenance procedures in collaboration with Subcommittee 7, Track Maintenance.
Questionnaire has been submitted to AREA Board for distribution.

c. Review rail laying temperatures for CWR in collaboration with Subcommittee 7.
Letter ballot on laying temperatures was passed as indicated by Subcommittee 7.

2. Track Tools

a. Review inclusion of new and additional track tools.
Letter ballot on insulated track tools was submitted to full Committee and is currently outstanding.

4. Track Design

a. Elastic rail fasteners - wood ties
Evaluate elastic fastener system design and establish minimal recommended performanee standards.
Letter ballot of full Committee was taken and proposal did not pass. Subcommittee is reevaluating parameters after input from last meeting.

b. Hold down fastenings - wood ties.
This is being reviewed in conjunction with 4 (a) although it is moving slowly.

c. Tie Plates - wood ties.
This is a standing assignment and no recent progress on same.

5. Turnout and Crossing Design

a. Review of guard rails protecting turnout frogs.
Letter ballot is being prepared and will be submitted to full Committee.

b. Investigate use of fastening agents for track work.
Subject is presently under discussion by Subcommittee and they have not made a proposed recommendation.

c. Investigate use of gage plates on turnouts to maintain gauge.
Letter ballot is being prepared and will be submitted to full Committee.

d. Develop specifications for explosion hardening of track work castings.
Subcommittee has worked on this subject and they are ready to present it to full Committee 5 for approval.

e. Study the use of Direct Fixation Fasteners on turnouts.
This subject is currently under review by the Subcommittee.

6. Track Construction

a. The Subcommittee Chairman recommended, and the full Committee 5 agreed, that this Subcommittee should be placed on an inactive status. The Committee feels that interest in this subject matter is low at this time, and the membership resource should be used on more active subjects.

7. Track Maintenance

a. Study rail lubrication collaborating as necessary as desirable with Committee 4.
This subject continues under review at the present time.

b. Maintenance parameters for frogs and switches.
This is a new subject and the Subcommittee is reviewing same.

c. Review current anchor application and maintenance procedures.
Subcommittee 7 submitted for letter ballot to full Committee 5 a proposed change in the anchoring temperatures. The proposal passed and will be forwarded to AREA headquarters for this action.

8. Criteria for Track Geometry

a, b, and c - Responses to questionnaire were reviewed from 17 railroads and the Subcommittee is evaluating the results.

Excerpts From Annual Report Of A.R.E.A. Committee 6 - Buildings

D.V. Fraser, Chairman

Subcommittee Assignments:

Subcommittee A - New Subjects

No progress currently. John Smith is over extended due to his work role, and we intend to identify a new chairman for this subcommittee in January.

Subcommittee B - Manual Material

At our June meeting the current section of Chapter 6 on Loco Sanding Facilities was distributed for comment. The illustrations are extremely old and need revision. Also, many railroads have abandoned the purchase of green sand. Several experts in the field of sanding were identified and these will be provided to John Smith to solicit outside opinion and comment.

1. Design Critera for CTC Centers

Mr. Barrett has been unable to attend meetings in 1987. At our June meeting Jack Kushner of Union Pacific brought plans of recent UP installations and concept drawings of a center currently under planning. John Comeau told us that the CSX Center in Jacksonville was using similar rear view projection technology. Nick English of NS will help prepare some of the material on power and ventilation criteria. We plan to review the work to date on this report in Denver.

2. Design Criteria For Car Shops

At our June meeting we discarded the idea of incorporating Heavy Repair into our report since such activities are decreasing in importance in the industry with the advent of unit trains and private ownership of rolling stock. We decided Preventive Maintenance features such as found in unit train service facilities should be incorporated into the report. Chairman Wally Sturm plans to contact several CMO's to seek their opinions on what items should be included in the report. John Comeau will also obtain plans of the CSX Corbin facility. Ernie Rewucki said he would obtain plans of the CP Rail facilities at Golden, BC to aid in this report. The idea of sponsoring a design workshop on Car Repair Facilities was discussed at our Toronto meeting. It was generally felt that the Committee did not have the time or number of members to sponsor such an undertaking at this time. The revised Design Criteria for Car Repair Shops is intended to serve as the basis for the program when it is completed.

3. Design Criteria for Office Buildings

Jay Steerman was assigned this report in January 1987. It is planned that this report will be ready for initial reading and review in January 1988.

4. Design Criteria for Wheel and Bearing Shops

John Smith of ICG volunteered to head this subcommittee. Gerard LaVoie of CN also offered to help on this topic. Other members are needed to serve on this project. It was also suggested that equipment manufacturers be asked to submit general information and possibly make a presentation at a future meeting.

5. Architectural Education

Don Bessey was not present. Tom Smithberger reported that the Student Affiliate Program of AREA is being re-established with Don Hanna of Committee 24 heading the effort. We plan to table the work of this subcommittee pending an approval at the combined Committee level.

6. Energy Conservation and Audits

This extremely well conceived and well written report has now cleared legal review by the AREA pending its being published as Manual material. The final revision of this report is being edited for submission in September 1987.

Excepts From Annual Report Of A.R.E.A. Committee 7 - Timber Structures

D.C. Meisner, Chairman

Subcommittee Status:

Assignment A

Recommendations for further study and research - No new projects until some existing ones are closed out. New chairman elected to take over for retired member.

Assignment B

Revison of Manual - Revised manual sent to AREA for printing, however this will be some time in the future due to graphs, prints and charts which will have to be reproduced. The committee will do this on their own.

Major changes in the manual are:

1. New tables for Working Unit Stresses for Structural Lumber Subject to Railway Loading.
2. Using ASTM Specs for timber piles.
3. Addition of glue lam tables and specs.

Sub-Committee 2

Grading Rules and Classifications of lumber for railroad use - Voted to drop this committee pending approval of AREA Board.

Sub-Committee 3

Specifications for design of wood bridges and trestles - Two ballots currently out for sub-committee approval.

Sub-Committee 5

Design of Structural glued laminated wood bridges and trestles - Voted to drop this committee pending approval of AREA Board.

Sub-Committee 6

Effect of unit trains on timber trestle components - New chairman was elected and in process of securing information from previous chairman.

Sub-Committee 7

Effect of dapping and end overhang on allowable stresses in bridge ties - New chairman was elected. Information is not in his hands as of yet. Results of survey need to be clarified and additional survey may be needed to show what the results are on the effect of dapping.

Sub-Committee 8

Protection of pile cut-offs; protection of piling against marine organisms by means other than preservatives - Rough draft made on part concerning marine organisms. Chairman hopes to complete in one year.

Sub-Committee 9

Study of in-place preservative treatment of timber trestles - A report is complete and will be submitted to be published as information only and a request to drop this committee will be made.

Excerpts From Annual Report Of A.R.E.A. Committee 8 - Concrete Structures and Foundations

H.R. Sandberg, Chairman

Subcommittee Activities:

A. Recommendations for Further Study and Research

In cooperation with Committees 7 and 15 the possibilities of research in railway bridges was pursued. On February 10 a meeting was held with Mr. George Way and Mr. Roy Allen of AAR and Prof. Barenberg of the University of Illinois. A second meeting with representatives of 7 and 15 was held at the AREA Conference in March. It was decided that AAR would seek National Science Foundation support for a program of bridge research. This was developed and presented to Committees 7, 8, and 15 at Colorado Springs. The first phase of this program will be a Bridge Research Workshop which will be held at the University of Illinois, Urbana on October 28 and 29, 1987.

B. Revision of Manual

This subcommittee is actively reviewing Chapter 8 to make the presentation consistent with the "official" AREA format. All ballot material will be reviewed by this subcommittee prior to the full committee vote.

1. Design of Concrete Structures

a. Work on the segmental bridge specification is being coordinated with the Post-Tensioning Institute's recommendations. It is expected to be sent to full Committee in 1988.

b. The task of developing recommendations for inspection and repair of prestressed concrete beams was reassigned to Subcommittee 4.

c. A revised Part 19, Rating of Existing Bridges, was successfully balloted, but due to the concerns of some members it is being reviewed and may be reballoted.

d. Part 13, Precast Box Culverts, has been completed and will be submitted for inclusion in the Manual.

e. The criteria for design of railroad bridges in seismic zones is being held in abeyance. AREA is considering a translation of the Japanese Railways' publication on Seismic Design.

f. Applicable impact factors are a continuing concern. S. Skaberna has written a paper entitled, "A Review of Studies of Impact on Concrete Railway Bridges." This will be submitted for publication.

Study is also being made of the American Concrete Institute's changes regarding development lengths for epoxy coated bars and AASHTO's requirements for minimum reinforcements in column.

2. Foundations and Earth Pressures

a. Revision of Part 3, Footing Foundations, will be sent to the full committee for ballot this fall.

b. Revision of Part 4, Pile Foundations, is expected to be ready early in 1988.

c. Revision of Part 10, Reinforced Concrete Pipe, is delayed pending resolution of inconsistencies of loads on the different types of materials.

d. Revision of Part 22, Specifications for Subsurface Investigation, is continuing.

Study is also being made on the inconsistencies discovered in surcharge requirements of Part 5.

3. Waterproofing for Railway Structures

General assignments of this committee has been broadened from strictly "Waterproofing for Railway Structures" to "Durability of Concrete."

a. Revisions to Chapter 29 were successfully balloted and will be submitted for inclusion in the Manual.

b. A questionnaire to be sent to all members of Committee 8 soliciting their experience in protecting and maintaining concrete is being developed.

4. Strengthening Existing Concrete of Masonry Structures and Restoration of Existing Structures to Restore Original Structural Capacity and Durability

a. New Part 25, Slurry Walls, has been completed and will be submitted for inclusion in the Manual.

b. A questionnaire regarding protection of piers adjacent to railway tracks was sent to the Chief Engineer of all major railroads, as well as to all members of Committee 8. The responses are being evaluated and a report will be made in 1988.

c. Part 11, Tunnel Linings, has been completed and will be submitted for inclusion in the Manual.

d. The completion of the study of possible bridge research to be done at FAST depends on the results of the Bridge Research Workshop to be held on October 28 and 29, 1987.

e. The reassigned subject of inspection and repair of prestressed concrete will be addressed in 1988.

Excerpts From Annual Report Of A.R.E.A. Committee 9 - Highway-Railway Crossings

A.D. Moore, Chairman

Status of Subcommittee Assignments:

Subcommittee A - Recommendations for Future Study and Research

This subcommittee is a standing committee under the Information and Rules for Guidance of Technical Committees. With the reorganization, this committee will be responsible for the development of studies and research projects which are directed toward recommended practice for engineering highway-railway grade crossing improvements. The development of procedures for testing and reporting of results of testing on grade crossing surface materials is a high priority for the committee.

Committee 9 again requests a research item. We are requesting the conducting of tests on various grade crossing surface materials. Some of the possible tests would be failure by load, failure by fatigue, coefficient of friction, flammability, etc. It is requested that the Board of Directions of AREA consider this request for research. It is felt that there is no common place in this country to obtain information such as the above for the railroads. We feel it is important that such data be obtained and put out to AREA members so that logical engineering decision on material usage can be made.

Subcommittee B - Revision of Manual

This subcommittee is a standing committee under the Information and Rules for Guidance of Technical Committees. The committee is looking at progressing several revisions to be included in future manual revision. Subcommittee B will continue to coordinate with other subcommittees for manual revision.

Subcommittee 1-87 Foundations for Highway-Railway Grade Crossings

This subcommittee was assigned in 1987 and completion is expected in about 3 years. It has been determined that the foundation is very critical to grade crossing stability. There has been some discussion that the requirements for engineering fabric under a grade crossing is different than under general track locations. At the first meeting of the new subcommittee, the organization was discussed and then a poll was going to be sent out to all subcommittee members for comments and subjects to get organized.

Subcommittee 2-87 Grade Crossing Surfaces

This subcommittee was assigned in 1987 and completion is expected in about 5 to 6 years. This assignment is going to be difficult as the surface material area is a sensitive issue due to the many materials now on the market. The first meeting was organizational in nature with the organization being discussed along with that subjects need to be discussed and what information needs to be developed. There is future contacts planned with leaders and interested parties to determine the scope of the assignment and there is also another meeting in the works prior to the next full committee meeting.

Subcommittee 3-87 Approaches to Highway-Railway Grade Crossing

This subcommittee was assigned in 1987 and completion is expected in about 2 years. This subcommittee will focus on guidelines for highway-railway intersection construction and problems associated with geometrics of long vehicles and sight distance problems. In the initial meeting the organization was discussed along with the scope of the subject and how to approach it. There is planning for another meeting to continue the discussion of the subject.

Subcommittee 4-87 Grade Crossing and Separation Elimination

This subcommittee was assigned in 1987 and completion is expected in about 2 years. The initial efforts of this committee will focus on the development of guidelines for determining the removal of an existing grade separation structure. This committee set up short and long term goals with assignments to be carried out by the next meeting which is to be scheduled in October to continue this progress.

Excerpts From Annual Report Of A.R.E.A. Committee 10 - Concrete Ties

S.P. Heath, Chairman

Subcommittee Activities:

Subcommittee - Assignment (A) - "Recommendations for Future Study and Research"

Do not have any recommendations for future research at this time.

Subcommittee - Assignment (B) - "Revision of Manual"

Do not have any recommendations for manual revisions at this time other than the revisions that are presently assigned to other subcommittees.

Subcommittee - Assignment (1) - "Flexural Strength"

(a) Review of Table I in Section 1.4.1, Monoblock ties.

(b) Review of Table II in Section 1.5.1, two block ties.

(c) Investigate the effect of axle loads and tie spacing on tie requirements.

(d) Monitor developments in prestressed and reinforced concrete technology which may affect concrete tie requirements.

A complete revision to Table I will be presented at the next meeting of Committee 10 and will be ready for a letter ballot. These revisions have been discussed at several Committee 10 meetings but have been unable to get consensus of full committee. We should have this resolved soon and be able to revise Tables I and II next year.

Subcommittee - Assignment (2) - "Investigate Requirements for Concrete Switch Ties, Bridge Ties and Grade Crossing Ties."

While a few more concrete tie turnouts are being installed in various rail lines, there is still very little data available. This subcommittee is continuing to develop recommendations but is limited in being able to develop final manual material until more data is available. Recommend this assignment continue as it will take considerable time.

Subcommittee - Assignment (3) - "Fastenings"

(a) Revise current test requirements.

(b) Investigate the effects of axle loads and tie spacing on fastening requirements.

We are working on the first phase of revising the test requirements. Due to the number of variables involved this is a taking a great deal of time. We hope to greatly simplify the manual's fastener requirements.

Subcommittee - Assignment (4) - "Test Requirements"

(a) Review and recommend revisions of the load magnitude specified for the fastening repeated load test.

(b) Review and recommend revisions of the rail seat overload and ultimate load test for two block ties.

(c) Evaluate acceptance criteria for repeated load test.

Due to the relation of the test requirements to the work of several other subcommittees, work on this assignment has been slow. We hope to make better progress as the issues under flexural strength and fasteners are resolved.

Subcommittee - Assignment (5) - "Review manual and make recommendations to include Post Tensioned Concrete Cross Ties"

This assignment has been completed and manual revisions have been submitted.

Subcommittee - Assignment (6) - "Maintenance requirements of concrete ties, including pads and insulation."

As the number of concrete ties in service continue to increase, we hope to develop more information on maintenance requirements. Due to the increase in concrete tie usage we feel this is an important assignment which will be ongoing.

Subcommittee - Assignment (7) - "Collaborate with Committee 1 on concrete tie ballast requirements."

A representative from Committee 10 attended the last meeting of Committee 1 and also attended the meeting of the ballast subcommittee. We will continue to furnish data and recommendations to this committee concerning concrete tie ballast requirements. Although we have now started this much needed liaison. Committee 10 will retain the ballast requirements for concrete ties in Chapter 10 until adequate requirements are included in Chapter 1.

Excerpts From Annual Report Of A.R.E.A. Committee 11 - Engineering Records & Property Accounting

G.L. Fisher, Chairman

Subcommittee Assignments:

Subcommittee "A" Recommendations for Further Research and Study

Chairman Davis, who will become committee chairman in 1988, spent much of his time assisting other subcommittee chairmen in the revision of the Technical Manual during the year. At the same time, consideration was given to further study on the issue of salvage under Track Depreciation and the affect of the 1986 Federal tax legislation on transportation companies.

Subcommittee "B": Revision of Manual

The existing Technical Chapter (11) of the Committee was completely rewritten during 1987. The new chapter material is currently under review by members of the committee and we anticipate making a recommendation to the AREA that the new chapter material be officially printed for the comment of AREA membership in January of 1988.

Chairman Wagner is to be complimented along with committee members M. J. Buinickas, S. R. Forczek, M. L. Kent, A. R. Ranuio and W. D. Munz for their effort expended in the Manual revision. The revision is the first exercise of its type within Committee 11 in approximately the last twenty years. All committee members who contributed to the revision have helped make the new chapter material a very useful tool for AREA membership.

Subcommittee "1": Accounting

Much of the effort of this subcommittee was spent during the year in the rewrite of the committee's chapter in the Technical Manual. Members of this subcommittee were also involved in the format of the presentation given to the entire Committee on Track Depreciation by a representative of the Interstate Commerce Commission during this year's Technical Conference in Chicago.

Subcommittee "2": Office and Drafting Practices

The chairman and Subcommittee 2 members spent much of the year compiling the information necessary to complete this subcommittee's portion of the Technical Manual. As a result of their effort, section 2 of Chapter 11 now contains current state-of-the-art information on automated design and drafting systems.

Subcommittee "3": Taxes

Much of the year was spent gathering tax related materials for inclusion in the Technical Manual revision. Since the 1986 Federal tax legislation was the first major change in corporate taxation in many years, subcommittee 3 members will have the ongoing responsibility of disseminating a great deal of information on tax issues to Committee 11 membership.

Once the major ramifications of the federal tax legislation are analyzed, it will be Committee 11's intent to make a presentation on the impact of this legislation at a future AREA Technical Conference.

Subcommittee "4": Planning, Budgeting and Controls

Subcommittee 4 membership put a considerable effort into creating a completely new section of Chapter 11 in the Technical Manual. The input from all subcommittee members in this task was significant.

It is important to note that Subcommittee 4 is one of the few, if not the only, professional group within the industry that is currently studying and/or reporting on the subject matters of Planning, Budgeting and Controls as one concept. These new areas of study have provided a great deal of interest and vitality to Committee 11 membership.

Excerpts From Annual Report Of A.R.E.A. Committee 12 - Rail Transit

D.W. Reagan, Chairman

Committee 12 was organized approximately two years ago. Consequently, the following subcommittee assignments are relatively new and will continue.

Subcommittee Assignments:

Subcommittee 1 - Rail Corridor Evaluation

1. Outline and define - Rapid Transit corridors, routes and alignments.

Subcommittee 2 - Special Trackwork and Roadway Considerations

1. Track Design, Construction and Maintenance
2. Track and Vehicle Interface
3. Equipment

Subcommittee 3 - Special Bridge and Structural Considerations

1. Basis for Structural Design
2. Special Track Considerations on Aerial Structure.

Above mentioned assignments are ongoing and will be coordinated with other AREA Committees where applicable.

Excerpts From Annual Report Of A.R.E.A. Committee 13 - Environmental Engineering

R.J. Spence, Chairman

Progress on the following five Sub-Committee's assignments are as follows:

1. Water Pollution Control

The situation with regard to EPA publications of final regulations pertaining to "Leaking Underground Storage Tanks" is being monitored. The eventual goal is to publish the summary of the regulations in the Manual. A 1985 assignment to report on storm water run-off regulations, is similarly being held up through regulations not being published. A study called "Report on Remediation of Contaminated Groundwater" was assigned in 1986. It has been decided to use much of the information from a report published as information in Bulletin 686, January - February 1982 in this current assignment. Chapters have recently been assigned to Sub-Committee Members, with the objective of having a preliminary draft for the fall meeting.

2. Air Pollution Control

Work proceeds on the 1985 assignment of revising Part 2 of the Manual material. Assignments of sections to various Sub-Committee Members have been given and a preliminary draft of some sections are anticipated for upcoming fall meeting.

3. Land Pollution and Solid Waste Management

A revised draft of some sections of Part 3 in the Manual were submitted to the Committee for comment. The sections of this 1985 assignment submitted dealt with hazardous waste management. Early circulation of the revised draft, to the Committee under ballot is intended, with the aim of Manual publication. Coverage of nonhazardous waste management will follow in a like manner in 1988 or beyond.

4. Noise Pollution Control

The report on "Employee Exposure To Noise In The Railroad Work Place" was published in the January Bulletin as a proposed 1987 Manual revision. The report on "Noise Barrier Technology" was also circulated under ballot for submission as a Manual revision. The prognosis is favourable that this latter report will be progressed for Manual publication.

5. Plant Utilities

Sections of the revised draft, Part 5 of the Manual, have been assigned to various personnel on the Sub-Committee. As the subject material may be somewhat specialized, participants have been urged to solicit outside assistance or advice where necessary. Every attempt will be made to publish each section as it is completed, rather than wait for the completed Part 5.

Excerpts From Annual Report Of A.R.E.A. Committee 14 - Yards And Terminals

W.A. Schoelwer, Chairman

Status of Subcommittee Assignments:

Subcommittee A - Recommendations For Further Research

One new subject will be submitted for approval:
Revision - Part 3 of Chapter 14 of the manual.

Subcommittee B - Revision of Manual

One item has been approved as manual material, it is presently being voted upon:
Local Yards.

Subcommittee I - Bulk Material Handling Systems

Assigned - about 1973
Progress to date - complete and submitted for publication as information in August 1987.

Subcommittee 2 - Designed TOFC/COFC Facilities (continuing assignment)

Assigned 1987
Progress to date - Committee is being reassembled after completion of manual material to update progress in this field.

Subcommittee 3 - Local Yard

Assigned 1984
Work complete and voting in progress. Expect to submit to Board in October, 1987.

Subcommittee 4 - Run Through Trains, Effect on Yards

Assigned 1983
The third Chairman is now working on the project. The first Chairman prepared a brief outline and the third Chairman expects to have a draft at the October meeting.

Benefits will be the assembling of information on how the large increase in run through trains and those who swap blocks affect yard design. It is recommended that this subcommittee continue and the work should be completed in 1988.

Subcommittee 5 - Control of Contaminated Wheels in Hump Yards

Began in 1985. Chairman appointed in 1986, new Chairman appointed in 1987.
Information is being assembled and a discussion of the data is expected at this October meeting. Completion is expected in 1989. The work should continue.

Subcommittee 6 - Design of Automobile Loading/Unloading Facilities

Began in 1985 with Chairman appointed in 1986.
Progress to date is a draft report which will be discussed at the October meeting. Completion is expected in 1988 with the report published as information and in 1989 as manual material.

Subcommittee 7 - Collaboration with the Transportation Research Board Committee on Intermodal Terminal Design

Began in 1983 and ongoing
Benefits include coordinating work shops and reports with the TRB. The TRB committees are vitally concerned with Intermodal design. Joint meetings have been held and there is a cross flow of information. Another conference has been scheduled and possible joint participation will be discussed at the October meeting.

Subcommittee 8 - Design of Reclamation Plants

Began in 1987
Chairman has not attended a meeting since his appointment, but he is expected at the October meeting. Little progress has been made, but information is being gathered. A report is expected in 1989.

Subcommittee 9 - Yard Control Systems

Began in 1978

Chairman has not attended a meeting since his appointment. It is hoped he will attend the October meeting and the report work can begin. The committee is to update the types of yard control systems. The work should be completed by 1989 and should continue.

Excerpts From Annual Report Of A.R.E.A. Committee 15 - Steel Structures

E. Bond, Chairman

Status of Subcommittee Assignments:

Subcommittee A - Further Study and Research

The Committee hopes to participate with Committees 7 and 8 in joint AAR-National Science Foundation bridge research to begin with a Bridge Research Workshop to be held at the University of Illinois, Urbana on October 28 and 29, 1987.

Subcommittee B - Revision of Manual

The committee has been working on clarifying the definition of "S" in the impact formula. An approved letter ballot has been taken on the changes and the committee is working on text to be inserted in Part 9 to further clarify "S"

Subcommittee 1 - Develop Specifications for the Design of Elastomeric Bearings in Collaboration with Committee 8.

Another draft of the specifications is being prepared for letter ballot.

Subcommittee 2 - Obtain Data From which the Frequency of Occurrence of Maximum Stress in Steel Railway Bridges may be Determined Under Service Loading.

John Fisher of Lehigh University is having a student summarize the results of the study to date.

Subcommittee 3 - Steel Fabrication - Materials, Methods, Quality Control Procedures and Qualifications of Fabricators

The committee is working on the development of specifications for loading details for fabricated members.

Subcommittee 4. - Develop Specifications for the Earthquake Design of Steel Railway Bridges.

The subcommittee is awaiting the completion of some work in this area by Committee 8. It is contemplating some work independent of Committee 8.

Subcommittee 5 - Establish Criteria for Determining Serviceability of Steel Structures which Have Been Exposed to Fire.

This subcommittee has completed its assignment.

Subcommittee 7 - Bibliography and Technical Explanation of Various Requirements in AREA Specification Relating to Iron and Steel Structures.

There is a continual need for this committee to update and add to their area of responsibility.

Subcommittee 8 - Fracture Control Plan

This subcommittee continues to develop specification changes to keep current with changes in its area of assignment. They are currently awaiting the results of their latest letter ballot.

Subcommittee 9 - Methods for Repairing Damaged Steel Bridge Members

This is a new committee. Work should begin at the October 1987 meeting.

Welded Steel Bridges

Continuing review and updating of the welding specifications is underway by this subcommittee. As there is continuing new information being developed in this area, this subcommittee should be continued.

Movable Bridges

The subcommittee continues to review Part 6, Chapter 15 to update and improve on the moveable bridge specifications.

The subcommittee has reviewed and commented on Committee 8's pending revision of Chapter 8, Part 19, Rules of Rating. The subcommittee continues to review the rating specifications and upon receipt of test results on riveted joints by John Fisher, will review fatigue values for rivet connections.

High Strength Bolts

This subcommittee continues to monitor ASTM and Research Council on Structural Connections and has submitted specification changes for letter ballot to keep specifications current.

Excerpt From Annual Report Of A.R.E.A. Committee 16 - Economics of Plant, Equipment and Operations

C. Bach, Chairman

Status of Subcommittee Assignments:

Subcommittee B - Revision of Manual

The committee is planning to review Committee 16 manual material to determine which parts should be updated. Many parts of this manual material has not been updated for a number of years.

Subcommittee 1 - Economics of New Railway

Terminal location and Operation in Cooperation with Committee 4.

This assignment was completed and the results were published in the recent AREA bulletin. The assignment can now be terminated.

Subcommittee 2 - Engineering Economics as an Element in Railway Decision Support Systems

At the Committee 16 meeting held on June 4, 1987, it was recommended that this assignment be dropped because of lack of data to progress the study and lack of interest of members to work on this assignment.

Subcommittee 3 - Economics of Train Speed

A draft of this report has been prepared and was reviewed on Jan. 29. Minor changes to the report were suggested. It is expected that the report will be completed for the next meeting on Sept. 24. Committee approval should be obtained by the end of 1987, and publication for information should be available for early 1988.

Subcommittee 4 - Economics of Automatic Train Inspection Equipment and Location, Including Consideration of Unattended Rear of Trains

The response of the survey for the "End of Train" devices has been limited and is not sufficient to make any conclusions of economics. Another approach is being formulated in order to complete this phase of the assignment. After this is completed, other inspection devices will be examined.

Subcommittee 5 - Economic Comparison of Track and Right-of-Way Inspection Methods and Equipment

A survey form was prepared but has to be modified to make it acceptable to AREA Headquarters before issuing. Changes to the survey form are expected to be made for the September 24, 1987 meeting.

Subcommittee 6 - Application of Industrial Engineering to the Railway Industry

(a) Applications of Robotics in the Railway Industry

A draft report of the results of the railway industry survey, and M.I.T. work at a railway main shop is ready for the committee to review at the September 24, 1987 meeting. A final report for publication is expected to be ready early in 1988.

(b) Railway Application of Artificial Intelligence

Considerable data has been gathered on actual and possible applications. This data is being reviewed by the committee. Inspection of applications of A.I. at two railways is being planned for May 27, 1988.

Subcommittee 7 - Economics of Railway Operations Without Institutional Restrictions

To begin this new assignment, a planning meeting was held at the committee meeting on June 4, 1987. The assignment was divided into 4 major segments for which separate groups will be assigned to gather information and prepare suitable reports.

Subcommittee 8 - Factors to be Considered on Evaluating Advanced Train Control System

There is also a new assignment. The subcommittee is collecting material to begin developing a series of progress reports. The first such report will be a check list of factors to be considered and later reports will discuss these factors. Much of the material will be abstracted from existing reports by various task forces now working on ATCS. The draft of the first report is planned for May 1988.

Excerpt From Annual Report Of A.R.E.A. Committee 22 - Economics Of Railway Construction & Maintenance

W.C. Thompson, Chairman

Status of Subcommittee Assignments:

Subcommittee A - Recommendations for further study and research

Progress - New subjects approved by board
1. Economics of Various Vegetation Control Methods
2. Economics of Rail Profile Grinding

Completion date-Reports at every committee meeting
Benefits-Provide effective assignments
Problem area-None
Recommendations-Continue

Subcommittee B - Revision of Manual

Progress-Chapter 22, Part 3 to Letter Ballot
Completion date-Various
Benefits-Improve quality of information in Manual
Problem areas-Increasing importance
Recommendations-Continue

Subcommittee 1 - Analysis of operations of railways that have substantially reduced the cost of construction and maintenance-of way work

Assigned-unknown
Progress-Reported on 1986 field trip
Completion date-Continuing Assignment
Benefits-unknown
Problem areas-Not effective
Recommendations-Drop

Subcommittee 2 - Develop economics of methods to dispose of scrap and obsolete materials

Assigned-1/26/87
Progress-5%
Completion date-6/88
Benefits-Addresses an important and expensive topic
Problem areas-Slow start
Recommendations-continue

Subcommittee 3 - Economics of various surfacing gang consists used by railroads in North America

Assigned-1/14/86
Progress-15%
Completion date-1/89
Benefits-Information
Problem areas-Slow start but in progress
Recommendations-Continue

Subcommittee 4 - Economics of ballast cleaning

Assigned-1/84
Progress-Complete, for publication
Completion date-6/87
Benefits-Good economic information, a first
Problem areas-None
Recommendations-Study complete

Subcommittee 6 - Economics of standardization of turnout material

Assigned-1/87
Progress-20%, Questionnaire for approval 9/4/87
Completion date-6/88
Benefits-Can have impact on the industry
Problem areas-None
Recommendations-Continue

Subcommittee 8 - Economics of standardization of track stabilization upon high speed surfacing operations

Assigned-6/85
Progress-Complete
Completion date-6/87
Benefits-Reviewed track stabilization
Problem areas-Report not published
Recommendations-Complete

Subcommittee 9 - Economics of various fixations of rail to wood ties

Assigned-1/86
Progress-60%, Questionnaire being returned
Completion date-1/88
Benefits-Review and analyze impact of other fasteners
Problem areas-None
Recommendations-Continue

Subcommittee 10 - Economics of AREA Standard Carbon vs Premium Rail

Assigned-6/87
Progress-New
Completion date-1/89
Benefits-Develop rail usage priority and economics
Problem areas-None
Recommendations-Continue

Excerpts From Annual Report Of A.R.E.A. Committee 24 - Engineering Education

C.E. Ekberg, Chairman

Status of Subcommittee Assignments:

Subcommittee A - Research and Recommendation for Further Study

Assigned: Prior to 1983.

Progress: A proposal has been drafted for an AREA Undergraduate Research Fellowship Program. The purpose is to provide small grants to partially support undergraduate research fellows who would be supervised by engineering professors actively participating in research programs of importance to AREA. The grants would be awarded on the basis of proposals submitted to AREA by interested professors.

Completion: Should be continuous.

Benefits: Develop meaningful new assignments.

Problems: None.

Recommendations: Continue.

Sub-Committee 1 - Recruiting and Speakers

Assigned: Prior to 1983.

Progress: Publish an annual survey of college graduate hiring by railroad engineering and maintenance departments. Advice schools of availability of railroad speakers for student groups.

Completion: Should be continuous.

Benefits: Provide starting salary information to the railroads. Inform top students of career opportunities in railroading.

Recommendations: Continue.

Subcommittee 2 - Faculty Support

Assigned: 1983.

Progress: Offer to obtain railroad data for engineering schools who might need such material as teaching aids. Seek information from railroads and consultants as to the availability of the needed material.

Completion: Possibly by 1988, assuming AREA Headquarters would then assume the responsibility of handling the distribution of materials to engineering schools upon request.

Subcommittee 3 - Curriculum Development

Assigned: 1985.

Progress: Only preliminary planning has been undertaken. The two chairman who undertook this assignment both resigned after short terms in office.

Completion: Probably 1989. Will discuss future plans at next meeting of Committee 24.

Benefits: Provide opportunity for the railroad industry to assist in developing engineering curricula which might relate to railroad needs.

Problems: Slow start due to loss of leadership.

Recommendations: Continue.

Subcommittee 4 - Student Relations

Assigned: Prior to 1983.

Progress: Successfully handled 1987 student scholarship program through which five engineering students received awards.

Completion: Should be continuous.

Benefits: Increase student and faculty awareness of AREA and the railroad industry.

Problems: Interesting students as to the benefits of student membership in AREA.

Recommendation: Continue.

Subcommittee 5 - Continuing Education

Assigned: Prior to 1983.

Progress: Successfully handled the 1987 Track and Roadbed Seminar in conjunction with the AREA Annual Technical Conference in Chicago.

Completion: Should be continuous.

Benefits: Provides ample opportunity for AREA members to update their knowledge in subjects which are relevant to the railroad industry.

Problems: None.

Recommendations: Continue.

Excerpts From Annual Report Of A.R.E.A. Committee 27 - Maintenance Of Way Work Equipment

S.F. Mills, Chairman

Status of Subcommittee Assignments:

Subcommittee A - Recommendation for Further Study and Research

It was decided by the committee and approved by the Board of Directors to combine this Sub-Committee with Sub-Committee 8, Future Needs of Machinery.

Subcommittee B - Revision of Manual

The specifications for On-Track Roadway Machines are now in the revision process and it is expected that they will be sent to the board for approval in 1988. As well the Sub-Committee will start to clean up the redundant items now in the Committee 27 segment of the manual.

Subcommittee 1 - Reliability Engineering, as Applicable to Work Equipment

A questionnaire was developed and approved by the Board. This questionnaire is now out and will be tabulated. Future direction will be established from the results of the survey.

Subcommittee 2 - Preventive Maintenance of Maintenance of Way Equipment

A new chairman has been appointed to this committee and he will be discussing this sub-committees direction in Kansas City.

Subcommittee 3 - Computer Applications As Applicable to Work Equipment.

In November of 1986, the computer assisted work equipment maintenance facility of Amtrak at Bear Delaware, was host to the meeting of Committee 27. Handouts of the system were given to the committee members and a good discussion of the system followed. This committee is currently looking at other systems available and will report on some of them at the Kansas City meeting.

Subcommittee 4 - Maintenance of Way Equipment Safety

The board recently approved the merger of this sub-committee and Sub-Committee 9, study noise reduction on equipment, the board also recommended that this sub-committee and Committee 13, Environmental Engineering, work closely together on noise reduction.

Subcommittee 5 - Training Programs for Machine Operators and Maintainers.

Following the questionnaire sent out by this committee in 1986 a meeting was held with various railroad training personnel in attendance. The results of this meeting will be discussed in Kansas City.

Subcommittee 6 - Rationalization of the Work Equipment Function.

The chairman of this sub-committee resigned from his railroad this year and a new chairman will be appointed shortly. Following this the sub-committee direction will be established and sent to the board for ratification.

Subcommittee 8 - Future Needs of Machinery

Survey results will be discussed and approved at the Kansas City meeting, it is expected that the survey will be sent to the board for approval and then published. Following the Kansas City meeting this sub-committee will be dissolved and incorporated into Sub-Committee A.

Subcommittee 9 - Study Noise Reduction on Equipment

This sub-committee will be dissolved and incorporated into Sub-Committee 4.

Excerpts From Annual Report Of A.R.E.A. Committee 28 - Clearances

C.C. Smoot, Chairman

Status of Subcommittee Assignments:

Subcommittee "A"

Latest reviews were on manual graphics, recommendations for further study and research on double stack equipment. Recommended reorganization on subcommittee's to involve greater participation.

Subcommittee "B"

Has submitted several items for change and addition to manual including change to published clearance outline and an additional method of measuring railway line clearances.

Subcommittee 1-85

This subcommittee is actively working with the publishers of "Railway Line Clearances" in development of a proposed format suitable for computerized format for updating published clearances. Submissions have been made to National Railway Publication Company and Committee 28 for consideration. Recommendations include publication entries for multi-level and double stack equipment. It will be several years before completion of this assignment. Benefits expected are more timely and accurate updating of present material and expansion of information relating to new equipment types.

Subcommittee 2-62

This permanent assignment on state legal clearances and regulations has in the past year solicited changes from states, updated and presented revisions to the chart of standards.

Subcommittee 3-81

This assignment is complete awaiting publication in the bulletin and Board action. When this is complete, publication will be made through AREA of the booklet developed.

Subcommittee 4-85

Conversion of the heavy capacity special type flat car section of the Official Railway Equipment Register to Umler Capability Format is entering its final stages. This committee working with an AAR Umler Ad Hoc Subcommittee has developed the formatting and specifications necessary for conversion. It is estimated completion of this assignment will require about one additional year.

Subcommittee 5-80

Progress continues toward publication of heavy duty car diagrams and rating. At our last meeting this subcommittee presented diagrams and ratings for 6 axle equipment. With other Committee 28 assignments nearing completion, members will be assigned to assist in preparing diagrams, ratings and specifications on the remaining equipment. We anticipate several more years will be required to complete all equipment publications.

Subcommittee 6-76

This assignment has been limited to monitoring and tabulating the types of high CCG loads presently being handled over member lines. The goal to study the effects of such shipments in a controlled test environment (Pueblo) does not seem likely to occur in the near future. With this in mind the subcommittee chairman has recommended, and Committee 28 has voted to approve, termination of this assignment until such time as testing can be accomplished. Members will continue to report to the Committee on CCG Loads and Changes in their individual handling procedures.

Subcommittee 7-85

Earlier in the year this assignment was terminated as complete. National Railways Publication Co. will keep the committee advised on items of interest occuring.

Subcommittee 8-86

The subcommittee chairman has presented to the committee two drafts on procedure for review. Questions have been raised from several members on items relating to legal issues. The latest draft of September 24, 1987 is now under study by members and their comments and incorporation of changes will be presented at the March 1988 Committee Meeting. It appears that at least one additional year will be required to complete this assignment.

Subcommittee 9-86

This recent assignment has been delayed in starting. Its first chairman left due to early retirement/force reduction and the replacement chairman, a short line carrier management employee, has been temporarily diverted due to Labor/Management negotiations and work suspensions. We would anticipate a start up in 1988 with completion in about 1 1/2 years.

Subcommittee 11-85

The Glossary of Technical Terms published in the Railway Line Clearances Issue has been updated by additional terms and modification of previous items. The additional assignment of technical literature is updated continually. The Committee feels that this assignment will require continual updating and maintenance and should be continued for the present with review next year as to requesting permanent status.

Subcommittee 12-84

Assignment is complete and has met the required committee votes and ballots. This subcommittee chairman has recently retired and is in the process of presenting the finished assignment "Recommend Procedure To Insure Reporting To Clearance Engineer" To the Director of Engineering, AREA.

Excerpts From Annual Report Of A.R.E.A. Committee 32 - Systems Engineering

A.R. Hermann, Chairman

Subcommittee Status/Activity:

1. Engineering Management Systems (Established 1/86)

The sub-committee is working on the development of a paper on the stages involved in the development of computer systems including the emphasis that users take strong roles in the development to insure the desired product. It is proposed that this document be completed by early 1989 for possible bulletin publication. The smaller railroads are targeted as the benefactor of this work as it will provide guidance in the development of technologically advanced management systems that are most likely already in place on the major roads.

2. Gathering and Coordinating Information for the Management of the Engineering Function (Established 1/86)

The sub-committee is examining the type, sources and uses of information that are available to support the management systems of the various Railroad Engineering Departments that are being visited. A paper will be prepared by the fall of 1988 which will attempt to summarize the information obtained. It is the groups expectation that it will step back from the basic data and look at the concepts behind data collection methods, data base structures and management report designs that were chosen.

3. Systems Engineering Education (Date Established Unknown)

The sub-committee is currently reviewing the information returned on the questionnaires given to the participants at the 3/87 symposium and will be developing the theme for an 8/89 symposium based on the topic interest and other feedback information. Also, the sub-committee is examining other media to employ exchange of information in addition to the symposia technique which has proven very successful in the past.

4. Engineering Graphic Systems and Interchange Standards (Established 1/86)

Members of this sub-committee represent the only Railroad CADD (Computer Aided Drafting and Design) User Group that is available to help increase the performance and productivity of their systems. The sub-committee expects to complete a rough draft of a paper for an AREA Bulletin article that will summarize the types, equipment, utilization pro and cons of the various systems that exist on the responding railroads that offered information on a questionnaire that was distributed in 1986. Project completion in 1988.

Excerpts From Annual Report Of A.R.E.A. Committee 33 - Electrical Energy Utilization

A.J. Peters, Chairman

Subcommittee Activities:

Subcommittee 1 - Electrification Economics

No activity due to serious illness of the chairman.

Subcommittee 4 - Catenary Pantograph Systems

Significant progress had been made in the compiling of data on the alternative types of footings now available for catenary support structures. Particular attention had been given to the pile drive footing used by BC Rail on the Tumbler Ridge construction, and by a number of European railway administrations. Guidelines for the selection of a design, and the procedures that should be followed for the design of catenary footings will be drafted as part of this assignment. However, it was concluded that local codes would take precedence over AREA guidelines.

Subcommittee 5 - Signal and Communication Protection in Electrified Territory

No activity to report due to the retirement of the chairman from active employment. He is being contacted to determine his willingness to continue as chairman.

Subcommittee 6 - Power Supply and Distribution

No active assignments at this time.

Subcommittee 7 - Equipment Generated Electrical Noise

No progress to report due to resignation of the previous chairman due to relocation. K. M. Watkins has volunteered to chair this subcommittee.

Much work is needed to restore this committee to the level of activity of one or two years ago. To accomplish this dormant members, of which there are many, must be reactivated. Active subcommittee chairmen, the lifeblood of the committee, are needed to meet this objective. The present economic climate dictating the need for travel restrictions on the membership is likely to be a major obstacle to this end. Every attempt will be made to return this committee to full vigor during the coming year.

Excerpts From Annual Report Of A.R.E.A Committee 34 - Scales

C.T. Picton, Chairman

Subcommittee Activities:

Subcommittee "A"-Recommendations For Further Study and Research

Recommendations For Further Study and Research is an ongoing committee.

They investigate all new innovations connected to Railroad Weighing and determine if they comply with the A.A.R. Handbook.

F.J. Loyd reported that a Kilowate Scale has been installed on the CSX System in an industry and that they are monitoring the weights between this coupled-in-motion scale and a static scale.

C.T. Picton has been invited to witness the testing of a newly designed Kaman Corporation coupled-in-motion scale on a Conrail connecting railroad in September, 1987.

Subcommittee "B"-Revision of A.A.R. Scale Handbook

Revision of A.A.R. Scale Handbook is an ongoing committee.

This subcommittee will remain one of the most important for Federal and State Laws must be carefully monitored for changes so the handbook can be quickly supplemented to reflect these changes. Also, innovations in scales and weighing are taking place at a faster pace and it is necessary that the handbook reflect any changes needed to accomodate the new systems.

Subcommittee 1-Preparations of Subject For Publication

Preparations of Subject For Publication is an ongoing committee. This subcommittee had no articles for publication.

Subcommittee 2-Statistical Data For Coupled-In-Motion Weighing and Testing

At the Committee 34 Meeting on October 7, 1986 in Chicago, Ill. it was voted on by the members to disband this subcommittee due to the fact we have our members of the advisory group to the National Bureau of Standards. This group is to present new testing procedures for coupled-in-motion weighing to the Specification and Tolerance Committee of the Bureau of Standards at their interim meeting in January, 1988.

Subcommittee 3-Innovations In Scales Used In Connection With Operations Of Railroads

Innovations In Scales Used In Connection With Operations Of Railroads is an ongoing committee that investigates all new designs and types of scales used in railroading.

Subcommittee 4-Criteria For The Location Of Coupled-In-Motion Track Scales

The efforts of this subcommittee are directed towards writing a set of procedures to be followed by railroads or others who are comtemplating the installation of a coupled-in-motion scale.

The National Bureau of Standards advisory group is also helping this subcommittee with their test data.

Subcommittee 5-Investigate Stenciling Of Cars Using Coupled-In-Motion Weights

Data is still being collected by this subcommittee.

Your Committee continues to keep abreast of all proposed legislation which will affect railroad scales and weighing and will keep the A.A.R. Scale Handbook up to date with the latest proven innovation in weighing and weighing systems.

Proposed Manual Revisions

The following proposed Revisions of the A.R.E.A *Manual for Railway Engineering* have been recommended to the association by the technical committee responsible for each chapter after a letter ballot is approved by: (1) a two-thirds majority of the eligible members voting, and (2) by at least fifty percent of the total eligible voting members on the committee. They are being published here for comment of the general A.R.E.A. membership and any other interested parties. Comments should be sent to A.R.E.A. headquarters by March 1, 1988. These comments will be considered by the A.R.E.A. Board of Direction in deciding whether to give final approval for inclusion of the proposed changes in the Manual Revisions which go into effect August 1, 1988.

Proposed 1988 Manual Revisions To Chapter 1 - Roadway and Ballast

The following Parts of Chapter 1 are proposed to be revised as follows:

Part 1 - Roadbed:

It is proposed to replace Article 1.4.1, Maintenance of Roadbed with paragraphs 1.4.1.1 through 1.4.1.6. The existing paragraph 1.4.1.4, Frost Heaving will be retained and renumbered paragraph 1.4.1.7. These revisions include the addition of discussions on the consistency of roadbeds and roadbed instability, with substantially amplified explanation on recommended corrective procedures.

Part 2 - Ballast:

A glossary of ballast terms are proposed to be added at the beginning of Part 2.

It is proposed to replace with a complete rewrite the specifications on subballast. Significant new information includes the identification of materials commonly used, recommended ASTM tests and specifications for a subballast section.

Part 4 - Culverts:

Proposed Part 4 changes involve a total reorganizing and renumbering. Section 4.2, Specifications for Ductile Iron Pipe and Section 4.3, Specifications for Cast Iron Culvert Pipe will be deleted. A new Section 4.8. Hydraulics of Culverts, is proposed to be added. (A copy of Section 4.8 is not being printed here, but is available by writing A.R.E.A. Headquarters and enclosing $2.00.)

Part 9 - Railroad Vegetation Control:

Proposed changes include revision and deletion of terms in the glossary, addition of Article 9.1, Rationale and Scope of Work and revision of Article 9.2, Preparing a Vegetation Control Program. A substantive change to Article 9.2 includes the addition of Recommended Roadbed Spraying Patterns.

1.4 MAINTENANCE

1.4.1 MAINTENANCE OF ROADBED

1.4.1.1 General

The roadbed is that portion of the track structure beneath the ballast section and within the major zone of influence of live traffic loads. The performance of the roadbed is greatly influenced by the following factors:

(1) The presence of excess moisture in the roadbed and the site specific drainage characteristics of the roadbed and ballast section.

(2) The engineering properties, thicknesses, in place densities, and degree of confinement of the various materials.

(3) The effect upon the roadbed of environmental factors; especially, precipitation, temperature, and the presence of groundwater.

(4) The magnitude and repetition of the rail traffic loads.

(5) The characteristics of the track super-structure (rail and ties) and ballast; especially, the thickness of the ballast section.

Of all the factors affecting roadbed performance, the presence of excess moisture in combination with one or more other factors is the root cause for most roadbed maintenance problems. Therefore, the design and maintenance of drainage is of primary concern and paramount to the success of most corrective measures.

The roadbed consists of the zone of native rock and soil and imported soils and granular materials extending downward from the bottom of the ballast section that is within the major zone of influence of live traffic loads. In new construction and in some existing tracks, the roadbed is separated from the ballast and sometimes sub-ballast by distinct boundaries. However, in most cases, there are no distinct boundaries between layers of the ballast, sub-ballast, and roadbed.

The roadbed can be considered to extend to an approximate depth of six feet beneath the ballast section. Beneath this level, the stresses from live traffic loads are relatively low and the adverse effects of climate, precipitation and groundwater on the roadbed are minimal.

The roadbed can be composed of a wide variety of materials. The most predominant material is local native soils and soils imported from nearby sources. In the upper layers of the roadbed, imported materials including cinders, chat, sands, and pit run gravels may be found intermixed with the ballast materials that have been placed during track surfacing cycles.

The composition and thickness of the materials and the drainage conditions existing in the upper two feet of the roadbed are extremely important because of the high stresses from track loads and exposure to environmental factors. Roadbed induced track problems such as loss of line, surface, gage, mud pumping and ballast fouling in most cases can be traced to one or a combination of deficiencies in the material properties, thickness, or drainage characteristic within the upper two feet of the roadbed. Therefore, most roadbed corrective measures should be concentrated at making improvements to the upper two feet of the roadbed and especially to the interface between the ballast (or sub-ballast) and the roadbed soils in addition to making improvements to the drainage.

1.4.1.2 Existing Roadbeds

The great majority of railroad roadbeds in service today were originally constructed many years ago and without the benefit of modern methods and equipment. In many instances the track was built directly on top of the native loose soils or on nearby borrow soils that were loosely dumped and spread in place to form narrow shallow fills with steep side slopes. Little attention, if any, was given to selecting soils with more favorable roadbed properties or compacting the roadbed soils before constructing track. However, over the years, these roadbeds have tended to become firm and stable from the compaction and consolidation effects of rail traffic and from the numerous surfacing cycles that have contributed granular materials and ballast to the roadbed. Often these old gravel and ballast layers seem to form natural filters that prevent migration of roadbed soils into the more recently placed crushed ballast section. Subsurface exploration of existing roadbeds will often reveal several layers of soil, imported granular materials, and old ballast of varying thicknesses and depths. An example of a typical cross section of an existing roadbed is shown in Figure 1.4.1.

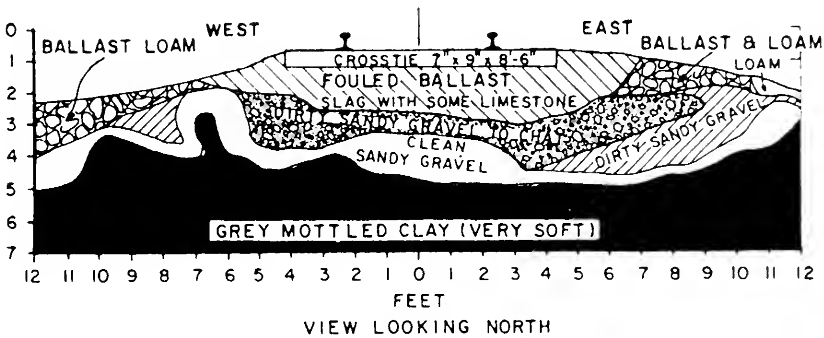


FIG. 1.4.1

TYPICAL CROSS SECTION OF EXISTING TRACK

There are many instances of a continual loss of line and surface accompanied by mud pumping, often referred to as "chronic spots" or "soft spots". Subsurface explorations of these chronic problem areas will often reveal unsuitable materials at great depths mixed with ballast sometimes referred to as "ballast pockets". A cross section of a typical ballast pocket is shown in Figure 1.4.2

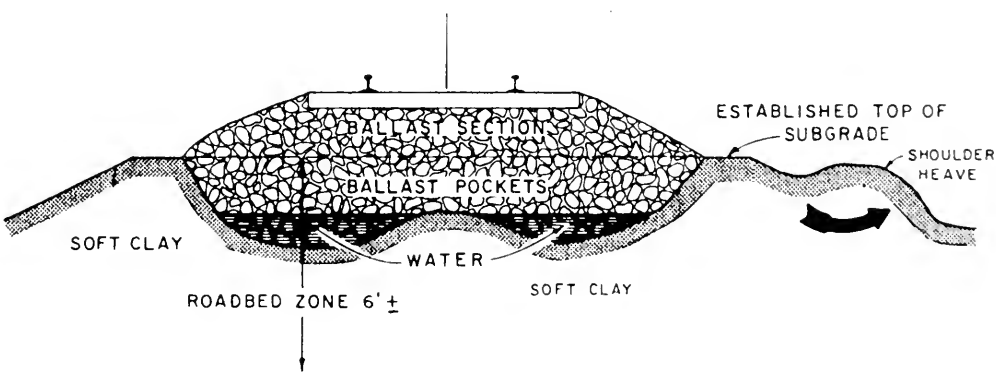


FIG. 1.4.2 TYPICAL SECTION OF DISPLACED ROADBED AND BALLAST POCKET

1.4.1.3 Identifying Roadbed Instability

Initial evidence of roadbed instability is a continual loss of line and surface despite satisfactory rail and tie condition and an assumed adequate ballast section. Loss of line and surface may continue even after several ballast applications followed by lining and surfacing operations. A muddy, fouled ballast section and heaved track are other indications of roadbed instability. Excess moisture and poor drainage conditions are so closely related that evidence of either can almost be considered as an indicator of roadbed instability. However, caution should be used before identifying a muddy fouled ballast section as roadbed instability. In some cases internal abrasion and weathering of the ballast or windblown dirt and car droppings will cause a fouled ballast section and give the appearance of roadbed instability. If any doubt exists as to the cause or extent of roadbed instability; subsurface explorations, sampling and geotechnical testing of the roadbed materials should be performed. The technique of excavating a trench several feet deep across the width of the ballast section for the purpose of exposing the layers, thicknesses, and relative positions of the roadbed materials is strongly recommended as an aid in the planning any roadbed corrective measures.

Vertical and laterial displacements of the roadbed as evidenced by loss of track line and surface may actually originate beneath the roadbed zone. The possibility that embankment, slope, or foundation stability problems exist and are contributing to roadbed displacements should be investigated and analyzed before attempting roadbed corrective measures. Refer to Articles 1.2.3 and 1.4.3, this chapter for further information of fill and slope design, and maintenance.

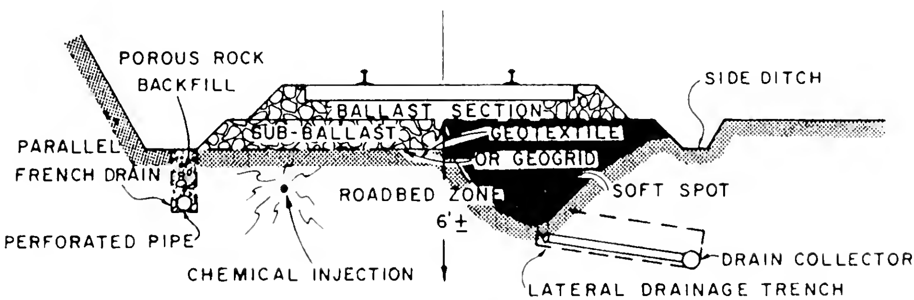


FIG. 1.4.3 TYPICAL SECTION INDICATING VARIOUS ROADBED TERMINOLOGY

1.4.1.4 Types of Roadbed Instability

Possible indications of unstable track include the loss of surface, line and gage, and fouled ballast. These may be caused by the following roadbed conditions:

(1) Migration and pumping of the subgrade and roadbed materials into the ballast section. The ballast section becomes contaminated with fine materials resulting in a dramatic decrease in the overall strength of the ballast system and resulting in a loss of surface and line.

(2) The vertical and lateral displacement of the roadbed soils and roadbed materials as reflected in surface and line of the track.

(3) Frost heaving of subgrade soils and roadbed materials.

The presence of excess moisture in the roadbed is the single most important factor contributing to the first two roadbed instability problems. Also the first two conditions often combine to create roadbed displacement, pumping and contaminated ballast. An increase in the weight and frequency of traffic will contribute to the first two conditions by overstressing the subgrade and roadbed material and pumping fines upward into the ballst. The third condition, frost heaving, is heavily dependent on unfavorable environmental and roadbed material conditions, and to a lesser extent is dependent on traffic.

1.4.1.5 Migration and Pumping of Roadbed Soils and Materials

Subgrade and roadbed soils may be pumped up into the ballast voids by the action of repetitive wheel loads. Fine sands, silts, clays, and clayey silts are highly susceptible to pumping when excess moisture is present in the roadbed. Subgrade and roadbed soils also will tend to migrate into and eventually foul the ballast section if the roadbed is composed of loose, fine materials that deform under traffic loading or permit the ballast materials to penetrate into the roadbed.

In new construction, or major reconstruction projects, pumping and migration of roadbed soils can be prevented by the design and construction methods presented in Article 1.2.5.3 of this chapter.

Pumping and migration of roadbed soils can be controlled or eliminated in existing track by the methods listed below:

(1) Improving the drainage to keep the roadbed dry. Both surface and subsurface drainage improvements will reduce pore water pressure build up and will increase the strength of the roadbed. Surface drainage of the roadway is described in Article 1.2.4 of this chapter. Improvements to subsurface drainage are described in Article 1.2.4.2 of this chapter. Before considering subsurface drainage, an adequate field investigation and drainage system design should be performed. Lateral and longitudinal subdrains consisting of perforated pipes, geotextiles, and free draining backfill materials can be used in combintion to improve the roadbed drainage.

(2) Removing the track and fouled ballast and reconstructing the roadbed by adding a compacted granular sub-ballast layer of sufficient thickness that will function as a firm, unyielding, load bearing layer and as a filter against the intrusion and migration of roadbed and subgrade fines. It is recommended that the sub-ballast consist of a well graded crushed rock with not more than 8 percent passing the #200 sieve and with gradation conforming to the base mixture gradation in ASTM D-2940. Other sub-ballast materials as described in Article 1.2.11.1 of this chapter may be used. It is recommended that the sub-ballast layer be at least 12 inches thick and should be compacted to a minimum of 95 percent relative density as determined by ASTM D-1557.

(3) Removing the track and fouled ballast and reconstructing the roadbed with a layer of high strength, flexible or rigid stabilized material. Hot-mix asphalt concretes have been used with success as a flexible stabilized roadbed. Lime treated soils, soil-cements, cement treated bases, and Portland Cement concretes have been used as rigid stabilized materials. The stabilized materials should be of adequate thickness and include provisions for drainage and prevention of pumping. It is highly recommended that a free draining material resistant to pumping and migration of fines be placed beneath rigid stabilized layers.

(4) Placing a geotextile (combined with removal of fouled ballast) at least 8 inches and preferably 12 inches beneath the bottom of tie. The application and physical requirements for geotextiles are given in Part 10 of this chapter. With careful planning, the geotextile may be effectively placed during an undercutting or sledding operation that avoids total removal or shifting of the track. The primary purpose of the geotextile is to function as a filter and to separate the ballast and sub-ballast from the fine roadbed soils. The geotextile may also function to reinforce the roadbed and reduce ballast penetration into the roadbed section.

(5) Injecting chemicals into the roadbed. Lime, lime/fly ash, and cement slurrys injected at relatively shallow depths and close spacing have been used with some success to reduce pumping and prevent migration of fines into the ballast section. Use of chemical injection should be preceded by a program of subsurface exploration, sampling, and laboratory testing to determine if the chemical will react with and improve the roadbed material and soil.

(6) Increasing the thickness of the ballast section by track raise.

(7) Applying and compacting a layer of sand utilizing large on-track equipment similar to an undercutter. This equipment is capable of lifting the track as a unit, removing fouled ballast, laying and compacting a sand layer and replacing the track. This technique and equipment has been used with success in Europe.

1.4.1.6 Vertical And Lateral Displacement of Roadbed Soils and Materials

Areas where track settles repeatedly under traffic requiring frequent surfacing and lining can be caused by deformation of weak and plastic subgrades and roadbed materials. The deformation may be accompanied by the roadbed squeezing up between the ties or out at the track shoulders, or bulging on the upper roadbed side slopes. These track areas that require frequent surfacing are often called "soft spots", "chronic spots" or unstable roadbed.

Soft spots usually ocur where there are low strength and/or saturated subgrade soils and roadbed materials that permanently deform under traffic causing a local depression in the roadbed beneath the track.

Soft spots or unstable roadbed are believed to develop as follows:

(1) An existing track or recently constructed track is located over low strength, plastic subgrade or roadbed materials. In most cases there is no sub-ballast layer and the roadbed is loose and not compacted. Traffic loads transmitted through the rail, tie and ballast structures overstress the roadbed and subgrade resulting in permanent deformation and the creation of a depression that traps water.

(2) The water trapped in the depressions saturates and lowers the strength of the roadbed materials and soils.

(3) The continual cycle of repetitive wheel loads combined with saturation results in the roadbed becoming plastic and displacing or squeezing laterally beyond the ends of the ties to the track shoulder. Frequent additions of ballast combined with surfacing and tamping supplies material permitting the deformation and displacement to continue.

(4) A ridge of displaced roadbed materials and soils is raised around each depression and forms a ballast pocket capable of holding large amounts of water. Roadbed materials and soils at the base of the pocket continue to be saturated and deform, creating a worsening self-perpetuating condition.

Corrective techniques for soft spots and unstable roadbed can be divided into those that can be performed by removing the track and those that must be performed without removing the track.

When the track can be removed, displaced and deformed roadbeds, soft spots and ballast pockets can be corrected by one of the following methods:

(1) Improvements to the surface and subsurface drainage conditions as described in Article 1.4.1.5 (1), combined with excavation and wasting of the fouled ballast and roadbed material and replacement with well compacted suitable soils and a sub-ballast layer as described in Article 1.4.1.5 (2) or replacement with a high strength stabilized layer as described in Article 1.4.1.5 (3).

(2) Improvements to the surface and subsurface drainage combined with excavation and wasting of the fouled ballast and roadbed materials and replacement with a well compacted suitable soil.

(3) Excavation of the ballast and roadbed materials and the placement of a geotextile and/or geogrid at the ballast/roadbed interface or the sub-ballast/roadbed interface. The geotextile will separate and filter the fine roadbed and soil materials from the ballast section and geotextiles and geogrids may provide reinforcement to the ballast/roadbed system. Improvements to the surface and subsurface drainage conditions should also be considered.

(4) Relatively deep chemical injection of the roadbed with lime, lime/fly ash, or cement followed by combinations of corrective methods listed above. Use of chemical injection should be preceded by a program of subsurface exploration, sampling and laboratory testing to determine if the chemical will react with and improve the roadbed material and soil.

When the track cannot be removed, displaced and deformed roadbeds, soft spots, and ballast pockets may be corrected by one of the following methods:

(1) Improvements to the surface and subsurface drainage. The surface drainage can be improved by constructing a system of ditches parallel to the roadbed with catch basins, culverts and other surface drainage facilities that will quickly dispose of surface water without accumulation or damaging effects. However, caution should be used when constructing parallel side ditches that are too deep and affect the lateral stability of the roadbed materials. Subsurface drainage improvements should be preceded by a thorough field investigation including subsurface explorations, trenches to expose the roadbed, laboratory testing and an analysis and design of the subsurface drainage system. This careful and thorough attention to detail for the use of subsurface drainage systems to correct roadbed instability is required for three reasons. First, subsurface drainage works best where it is least needed. Soils and roadbed materials that respond the best to subsurface drainage include sands, gravels and granular roadbed materials; materials that are inherently stable. Low strength fine grained materials including silts, clays and contaminated granular materials have very low permeabilities and are extremely difficult to drain. Second, effective subsurface drainage often requires a system of parallel and lateral trenches, pipes, connections, porous backfill materials, graded filter materials, geotextiles, etc., all of which must be carefully installed and diligently maintained to provide a drainage system that functions properly. Third, the installation and maintenance costs associated with effective subsurface drains can be very high.

In many cases improvements to the drainage will be combined with one or more of the corrective techniques included below:

(2) Geotextiles, geogrids and other reinforcing materials may be installed in combination with undercutting, sledding or other track raise techniques that avoids the total removal or shifting of the track. The geotextile and geogrid used in this manner must possess the strength and other material properties necessary to act as a reinforcement capable of bridging over the unstable area or soft spot. The geotextile and/or geogrid should at least be 8 inches and preferably 12 inches beneath the bottom of the tie.

(3) Stabilization of the roadbed by lime or lime/fly ash injection. Use of lime or lime/fly ash injection should be preceded by a program of subsurface exploration, sampling and laboratory testing to determine if the lime or lime/fly ash will react with and improve the roadbed soils and materials. The injection of lime and lime/fly ash slurry into unstable roadbeds, soft spots and ballast pockets has been most successful with certain reactive clays and silts. Ballast pockets can be made impermeable by the saturation and injection of lime/fly ash slurry. Lime slurry chemically improves reactive soils and increases the strength at depths to 40 feet. Double lime injection is often required to improve shallow soil problems in areas where stresses are highest.

(4) Stabilization of the roadbed materials and soils with cement grout according to the procedure given in AREA proceeding, Volume 53, 1952, pages 736-742.

(5) Railroad roadbeds constructed on shallow narrow embankments often become unstable due to a combination of poor roadbed materials and a lack of lateral confinement extending beyond the end of the ties. This condition can be corrected by the addition of small berms to the roadbed side slopes. The effect of the berm construction on the roadbed drainage should be carefully analyzed prior to building any berms. Stabilization berms should always be kept below the level of the ballast and the upper portion of the granular roadbed. The berms should have good cross slope to promote drainage.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Part 2

Ballast

1988

GLOSSARY

MINERAL AGGREGATES AND RELATED TERMS

AGGREGATE

The mineral material, such as sand, gravel, shells, slag or broken stone, or combinations thereof, with which cement or bituminous materials is mixed to form a mortar or concrete. "Fine Aggregate" may be considered as the material that will pass a 1/4-inch screen. "Coarse Aggregate" is the material that will not pass a 1/4-inch screen.

BANK GRAVEL

Gravel found in natural deposits, usually more or less intermixed with fine materials, such as sand or clay, or combinations thereof, gravely clay, gravely sand, clayey gravel and sandy gravel, indicate the varying proportions of the materials in the mixture.

BANK SANDS

Sand pits containing sand with little or no gravel. This sand contains from 0 - 12% clay and silt and has a gradation suitable for sand asphalt, a bituminous mix.

BASALT

A word of ancient but uncertain etymology. It is employed as a rock name in its restricted sense for porphyritic and felsitic rocks consisting of augite, olivine, and plagioclase with varying amounts of glassy base which may entirely disappear. In a broader sense the basalt or basaltic group is used to include all the dark, basic, volcanic rocks, such as the true basalts; the nepheline, leucite, and melilite-basalts; the augites and limburgites; the diabases, and melaphyres.

BOULDER

A rock fragment with an average dimension of 12 inches (305mm) or greater.

C.B.R. (California Bearing Ratio)

A measurement of strength and support value of base materials or subgrade soils (ASTM 01883 or AASHTO T-193).

CALCITE

Calcite (calcium carbonate, $CaCO_3$), is the important mineral in limestone and is, therefore, one of the most common minerals and contains 56 percent lime, CaO. Generally, it is white or colorless but it may be tinted gray, red, green or blue. It occurs in many varieties of crystal forms (more than 300 have been described). Calcite can be scratched by a knife, but not by the fingernail, and it fizzes freely in cold hydrochloric acid. If a large crystal of calcite is shattered with a hammer, it breaks into smaller rhomb-shaped blocks because it has perfect cleavage in three directions.

CHATS

(Northumb) Small pieces of stone with ore. (Emg.) A low grade of lead ore. Also middlings which are to be crushed and subjected to further treatment. The mineral and rocks mixed together which must be crushed and cleaned before sold as a mineral. Chats are not the same as tailings, as the latter are not thrown aside to keep for future milling.

CHERT

A compact, siliceous rock formed of chalcedonic or opaline silica, one or both, and of organic or precipitated origin. Chert occurs distributed through limestone, affording cherty limestones. Flint is a variety of chert.

CHIPS

100 percent fractured stone usually passing 1/2-inch square mesh sieve but retained on No. 8 sieve. Applied over seal coats, broomed and rolled to provide a skidproof surface and to prevent bleeding on bituminous roads.

CLAY

A fine grained soil (finer than 0.002mm - 0.005mm) that has plastic properties within a range of moisture contents and exhibits considerable strength when air dried.

CLAY SIZE

Soil with a particle size finer than 0.005mm (in some cases, finer than 0.002mm).

CLOSED CYCLE SYSTEM

A series of conveyors and/or elevating devices which return oversize material back to a crusher for further reduction.

COBBLE

A rock fragment with an average size between 12 inches (305mm) and 3 inches (76mm).

COMPACTION

The artificial densification of a soil, generally by mechanical means.

COMPACTION TEST PROCEDURE

The general procedure is to specify the size, weight, height of drop and number of blows to be delivered by a tamper to a confined soil sample, and then to measure the resulting density both wet and dry. The process is repeated, varying the water content, until the highest density is recorded for the method. The moisture content of the wet sample corresponding to the highest density of the dry sample is the optimum. Some special variations in method may exist but the most common prescribed are the AASHO T-99 or T-180 or corresponding ASTM D698 or D1557. The method does not apply to ballast.

CONGLOMERATE

A coarse grained clastic sedimentary rock composed generally of pebbles, cobbles and boulders set in a fine-grained matrix of sand or silt and commonly cemented by calcium carbonate, silica or hardened clay. The consolidated equivalent of gravel.

CONSOLIDATION

The reduction in soil volume due to increase in compressive stress.

CONVEYORS

A device consisting of a steel frame equipped with rollers and pulleys over which a continuous rubber belt travels and used for delivery of material from one portion of a plant to another. NOTE: Conveyors are further described by a word describing their use; i.e., a "feed" conveyor usually feeds material into a plant, crusher or on to a screen. A "delivery" conveyor usually delivers material from any of components to another component, or to a truck or stockpile.

COVERAGE

One complete application of a compactive effort over the entire area being compacted.

DEFLECTION

The amount of downward vertical movement of a surface due to the application of a load to the surface.

DENSE GRADED AGGREGATE

A continuous grading from a designated top size to dust to provide maximum density after compaction.

DENSITY

Mass per unit volume. Can be expressed as unit weight per cubic foot (excluding water) as a measure of the degree of compaction.

DIABASE

A basic igneous rock usually occuring in dikes or intrusive sheets, and composed essentially of labradorite and pyroxene with small quantities of magnetite and apatite. The plagioclase forms lathshaped crystals lying in all directions among the dark irregular augite grains, giving rise to the peculiar diabasic or ophitic texture, which is a distinctive feature in the coarser-grained occurrences.

DIORITE

A granitoid rock composed essentially of hornblende and feldspar which is mostly or wholly plagioclase, with accessory biotite and (or) augite. Minute grains of magnetic and titanite may be visible. Quartz may be present in considerable amount, in which case the rock is called quartz diorite.

DOLOMITE

Dolomites are fine to coarse grained carbonate sedimentary rocks having a magnesium carbonate value above 36%. Dolomite occurs in crystalline and non-crystalline forms, and is clearly associated and often interbedded with limestone.

The mineral dolomite is composed of calcium magnesium carbonate ($CaMg(CO_3)_3$) and is closely related to calcite. In large masses, the mineral forms the rock called dolomite. It may be white, gray, greenish gray, brown or pink, and has a glassy to pearly luster. It occurs in coarse to fine grained granular masses and in crystals. Most dolomite crystals are rhomb-shaped like calcite cleavage blocks, but unlike most other minerals, the crystal faces are typically curved. Dolomite is slightly harder than calcite, although it can be easily scratched by a knife. It will not fizz in cold hydrochloric acid unless first ground to a powder or the acid heated.

FEEDER

A device placed under a hopper which conveys material into a plant, crusher or onto a conveyor at a uniform rate. The types most commonly used are reciprocating (back and forth motion), continuous steel apron type, rubber belt conveyor and vibrating pan.

FELDSPAR

A general name for a group of abundant rock-forming minerals, the names and compositions of which are as follows: Orthoclase, Microcline, Anorthoclase, Plagioclase, Oligoclase, Andesine, Labradorite, Bytownite, Celsian, and Hyalophane. The name of the mineral is often prefixed to the names of those rocks that contain it such as feldspar-porphyry, feldspar-basalt, etc. The term feldspar applies not merely to one but to all members of a group of minerals composed of aluminum silicates carrying principally sodium, calcium, or potassium. The feldspars are light in color (pink, green, white and gray), have a glassy or satiny luster and have a good cleavage in two directions, almost at right angles to each other. They cannot be scratched by a knife. Most feldspars occur in igneous rocks. Feldspar pebbles may be distinguished from quartz pebble by the good cleavage.

FINE GRADED AGGREGATES

Mineral aggregates which will pass a No. 4 mesh screen and be retained on No. 200 screen.

FINE SCREENINGS

Materials below No. 4 mesh screen.

FINISHED PRODUCT

The resultant material after it has been processed (crushed, screened, sometimes washed) to the desired size and specifications.

GABBRO

A finely to coarsely crystalline igneous rock composed mainly of lime-soda feldspar (labradorite or anorthite), pyroxene and frequently olivine. Magnetite or ilmenite, or both, and apatite are accessory minerals. It is generally dark colored. Gabbros composed largely or wholly of feldspar are called anorthosites, and those containing orthorhombic pyroxene are often called norites.

GNEISS

A foliated rock formed by regional metamorphism in bands of lenticles of granular minerals alternating with bands or lenticles in which minerals having flaky or elongate habits predominate.

GRADED AGGREGATE

A term describing a mineral aggregate in which there is a continuous grading in the sizes of mineral fragments from coarse to fine, the coarser sizes being many times the diameter of the finer sizes.

GRANITE

A plutonic rock having an even texture and consisting chiefly of feldspar and quartz.

GRAVEL

A rock fragment with an average dimension between 3 inches (76mm) and 3/16 of an inch (4.75mm). Gravel deposits vary greatly in mineral composition, size, shape, and color. There are gravels which consist mainly of just one mineral, as chert or flint weathered from the Pennsylvanian and Permian Rocks, or feldspar, agate, clear transparent quartz, native copper, granite, basalt (a fine grained rock) and other igneous rocks.

GRAVEL PIT SANDS

Produced by separating sand (material passing No. 4 sieve) from gravel with a mechanical screen. This type of sand sometimes contains quantities of clay and has a fairly complete gradation ranging from coarse to very fine.

GUMBO

A name current in Western and Southern states for those soils that yield a sticky mud when wet. A putty-like clay associated with lead and zinc deposits. A clay encountered in drilling for oil and sulphur.

HORNBLENDITE

A granitoid, igneous rock, consisting essentially of hornblende and analogous to pyroxenite.

HORNSTONE

An impure flint or chalcedony with splintery fracture, more brittle than flint. Also, a general term for a tough silicious rock having a splintery fracture.

JAW CRUSHER

A crusher which breaks material by squeezing it between two jaw plates, one movable and one stationary.

LAVA

A general term for a molten extrusive and for the rock that is solidified from it. It is dark fine-grained rock. Boulders and pebbles of lava rock occur in stream deposits and in boulder clay and related deposits of some glaciated regions.

LIME

An alkaline earth consisting of the oxide of calcium. Artificially made by calcining or burning limestone or marble.

LIME ROCK

A term used in Southeastern U.S. for an unconsolidated or partly consolidated form of limestone usually containing shells or shell fragments with a varying percentage of silica.

LIMESTONE

A sedimentary carbonate rock composed chiefly of calcium carbonate and small percentages of magnesium carbonate. Carbonate materials indicating magnesium carbonate values below 28% are defined as limestones.

LIQUID LIMIT

The moisture content at which a soil changes from a plastic state to a liquid state.

MAGNESITE

Native magnesium carbonate, $MgCO_3$. Purities range from 82 to 96 percent MgO.

MATERIALS HANDLING

Methods of transporting broken or crushed material from one point to another.

MICA

A group of complex phyllosilicates that are characterized by low hardness and by perfect basal cleavage, readily splitting into thin, tough, somewhat elastic plates with a pearl luster and color that ranges from colorless to white to dark green or black. Micas are prominent rock-forming constituents of igneous and metamorphic rocks and occur as flakes or scales. Muscovite or "white mica" is transparent and colorless. Biotite or "black mica" is dark green or black in color.

HARDNESS OF MINERALS

A scale of hardness used as an aid in identifying minerals and based on a scale of one to ten with talc having a value of one and diamond a value of ten. Diamonds are harder than quartz and will, therefore, scratch quartz; quartz will scratch calcite; calcite will scratch gypsum and so on. An easy way of estimating the hardness of a mineral in the field is by trying to scratch it with such common objects as a fingernail, a copper penny, a pocket knife blade, and a piece of window glass. Glass, the hardest of the four, will scratch the most minerals, the knife is next in hardness, then in order comes the copper cent and the fingernail.

MINERAL CLEAVAGE AND FRACTURE

Some minerals when struck a sharp blow, break only along certain lines, while other minerals break just as easily in one direction as in another. When a mineral has a tendency to break along certain planes, it is said to have cleavage, which is the result of arrangement of the molecules and atoms. Minerals may have only one plane of weakness or cleavage, or they may have two, three or more. The second type of breaking, that which is not determined by an arrangement of molecules, is called fracture and this also varies among different minerals. Various types of fractures are described as smooth, uneven, ragged, and shell like.

MOISTURE CONTENT (Water Content)

The ratio, expressed as a percentage, of the weight of water in a given soil mass to the weight of solid particles.

NEPHELINE SYENITE

A quartz-free crystalline rock consisting mostly of nephelite, albite and microline feldspar. Rare minerals are frequently found as accessory minerals.

OLIVINE

A mineral group consisting of fayalite, olivine and forsterite and forming the isomorphous system. Olivine also is an olive-green and a common rock forming mineral of basic and low silica rocks.

OOLITE

A sedimentary rock consisting of small round grains, usually carbonate of lime, cemented together.

OPEN GRADED AGGREGATE

Aggregate graded to a narrow size range with few, if any, fines designed to provide rapid internal discharge.

OPTIMUM MOISTURE

Percentage by weight of water at which the maximum dry density can be obtained on a sample by a prescribed compaction procedure. It will, therefore, vary with the method used.

OVERBURDEN

Soil or decomposed rock which overlies unweathered rock in a quarry.

OVERSIZE

Material which will not pass a desired size of square opening screen wire and, therefore, must be crushed or recrushed.

PARTICLE

An individual piece of rock, gravel or other material in the screen feed.

PASS

A pass refers to one passage (one way) of compacting equipment over the area being compacted.

PEA GRAVEL

Any clean gravel, whether bank or river gravel, having a gradation of from 1/4-inch to 1/2-inch or which approximates a pea in grain size.

PERIDOTITE

A granular igneous rock composed essentially of olivine, generally with some form of pyroxene, and with or without hornblende, biotite, chromite, garnet, etc.

PHOSPHATE ROCK

A rock consisting of calcium phosphate, usually together with calcium carbonate and other minerals, used in making fertilizers.

PLASTIC LIMIT

The moisture content at which a soil changes from a semisolid state to a plastic state.

PLASTICITY

The property of a soil or rock which allows it to be deformed beyond the point of recovery.

PLASTICITY INDEX

The numerical difference between the liquid limit and plastic limit.

QUARTZ

Quartz, the most common of all minerals, is composed of silicon and oxygen (SiO_2) and is found in many different varieties. When pure, it is colorless but it also assumes various shades of yellow, pink, purple, brown, green, blue or gray. One of the hardest of minerals, it will easily scratch window glass. It has no good cleavage and has a glassy to greasy luster.

There are two main types of quartz, the coarsely crystalline and the fine or cryptocrystalline forms. The crystals of the first type are six-sided prisms with pyramids capping one or both ends.

The second main type of quartz is called cryptocrystalline because the crystals are so small that they cannot be seen without a microscope. The best known varieties in this group are flint and chert.

QUARTZITE

Quartzite is a granoblastic metamorphic rock consisting mainly of quartz and formed by recrystallization of sandstone or chert by either regional or thermal metamorphism. Quartzite may also be a very hard but unmetamorphosed sandstone consisting chiefly of quartz grains with secondary silica, that the rock breaks across or through the grains rather than around them.

RIVER GRAVEL

Found in almost any stream or river and consists of partly rounded and smooth fragments of rock from sand to boulder size and is usually free from clay and silt.

RIVER SAND

Due to action of water and the rolling of one particle of sand over another, does not have a high percentage of sharp angular grains and is usually free from clay and very fine sizes.

RHYOLITE

A group of extrusive igneous rocks, typically porphyritic and commonly exhibiting flow texture with phenocrysts of quartz and alkali feldspar in a glassy groundmass. Rhyolite is the extrusive equivalent of granite.

ROLL CRUSHER (Double)

A crusher which breaks material by squeezing it between two revolving metal cylinders, with axes parallel to each other and separated by a space equal to the desired size of finished product.

SAND

Material with a particle size between 4.75mm (No. 4 sieve) and 0.075mm (No. 200 sieve).

SANDSTONE

An indurated sedimentary rock formed of coherent or cemented sand. The sand usually consists of quartz, may vary in color, and may be deposited by wind or water.

SCALPING SCREEN

A vibrating or revolving screen which separates various sizes of materials for delivery to one or more crushers and by-passes small sizes around the crushers.

SCHIST

A strongly foliated crystalline rock, formed by dynamic metamorphism, that can be readily split into thin flakes or slabs due to well developed parallelism of more than 50% of the minerals present. Mineral composition is not an essential factor in the definition.

SCREENING

The separation of crushed or natural aggregate materials of different sizes by causing one size to be retained on a screen surface.

SCREENINGS

Material, most always undersize, that will pass through the smallest production mesh screen.

SCREENING EFFICIENCY

Ratio of screen undersize actually passing the screen openings to the total undersize in the feed.

SERPENTINE

1. In mineralogy, a hydrous magnesium silicate ($H_4MgSi_2O_8$), commonly green, greenish-yellow, or greenish-gray, and massive, fibrous, lamellar, or occurring as pseudomorphs. It is an important constituent of some metamorphic rocks and is everywhere secondary, after olivine, amphibole, pyroxene, etc. 2. In petrology, a metamorphic rock composed chiefly or wholly of the mineral serpentine.

SHALE

A fine grained detrital sedimentary rock, formed by consolidation of clay, silt or mud. It is characterized by finely laminated structure, which imparts a fissility approximately parallel to bedding, along which the rock breaks into thin layers. Shale is generally soft and may have a variety of colors.

SHELL

The term "Shell Aggregate" applies to oyster, clam shells, etc., used for road surfacing material. These shells are crushed in an ordinary stone crusher. It is difficult to crush this material to a given specification, and it does not produce a strong pavement unless a suitable gradation is produced through the introduction of other aggregates, such as sand and stone.

SILICA

An oxide of silicon (SiO_2). Occurs in nature as a mineral of economic importance in quartz, chalcedony, chert, flint, opal, diatomaceous earth and sandstone. The most abundant constituent of the earth's crust.

SILT

A fine grained soil (passing the No. 200 sieve) of low plasticity which exhibits little or no strength upon air drying.

SILT SIZE

Soil with a particle size between 0.075mm (No. 200 sieve) and 0.005mm (in some cases, size range is 0.002mm to 0.005mm - 0.075mm).

SILTSTONE

Consolidated or compacted silt is known as siltstone. This rock may be found as thin, slabby beds. Many siltstones and fine sandstones contain layers rich in tiny flakes of mica, which glitter in the sun. The mica is concentrated along the bedding planes where the rock breaks easily.

SIZING SCREEN

A vibrating or revolving screen which separates various sizes of materials for delivery as finished products into hoppers, trucks, or onto conveyors.

SLAG

Materials formed during the metal making process by the fusion of fluxstones, coke and other metallic particles and are generally of two types; iron blast furnace slag and steel furnace slag. Iron blast furnace slag is produced during the blast furnace operation and is essentially a composition of silicates and alumino silicates of lime and other bases. Steel furnace slag is a by-product of the open hearth, electric or oxygen steel furnace and is composed primarily of oxides and silicates.

SLATE

A dense, fine-grained metamorphic rock whose separate minerals are indistinguishable to the unaided eye, and which has an excellent parallel cleavage, so that it breaks into thin plates or pencil-like shapes.

STABILIZATION

Modification of soils or aggregates by incorporating materials that will increase load bearing capacity, firmness and resistance to deterioration or displacement.

STONE

A generic term for a particle of rock between the sizes of 3 inches (776mm) and 3/16 of an inch (4.74mm).

STONE-SAND

Refers to the product (usually less than 1/4-inch in dia.) produced by the crushing of rock. This material is usually highly processed, and should not be confused with screenings. Also known as mechanical or manufactured sand.

STRIPPING

Removing of overburden to provide access to usable rock deposit.

SUB-SOIL

1. Broadly and loosely, the part of the regolith (earth mantle) which lies beneath the true soil and which contains almost no organic matter. 2. More precisely, a layer of the regolith, grading into the soil above and into unmodified rock waste below, which is less oxidized and hydrated than the soil proper and contains almost no organic matter, but is somewhat charged with and indurated by iron oxides and clay that has been leached down from the overyling soil.

SYENITE

Any granular igneous rock composed essentially of orthoclase, with or without micraline, albite, hornblende, biotite, augite or corundum. In mica syenites hornblende is replaced by biotite and in augite syenites it is replaced by quartz syenite. In nephelline syenite the feldspar is partly replaced by nephelline.

TAILINGS

The waste material remaining after crushing and processing which has little or no value. Most generally, tailings are produced from mineral ore processes.

TRAP

Is any dark colored fine-grained non-granitic hypabyssal or extrusive rock. Hypabyssal pertains to an igneous intrusion at intermediate depth.

TRIPPER

A mobile mechanical device for continuously discharging and distributing aggregate from a belt conveyor into a line of bins or stockpiles.

UNIT WEIGHT

Weight (force) per unit volume.

VOLCANIC ASH

Volcanic ash or volcanic dust (in some places called "silica" although this name is not exactly accurate) consists of tiny glass or congealed lava fragments which have been blown into the atmosphere during the eruptions of volcanoes. Volcanic ash is sometimes referred to as a type extrusive rock that has been forced out or extruded onto the earth's surface. Under a microscope or a hand lens, ash is seen to contain small curved pieces of glass which are the broken walls of bubbles of the lava rock which burst from the volcano.

SUB-BALLAST SPECIFICATIONS

This part of the specifications shall cover the materials and construction of the sub-ballast section, the section of small sized, usually granular material, laying between the ballast and the subgrade and as defined in Article 2.0.2.4.

2.11 GENERAL

For over fifty years general railroad construction and maintenance practices have utilized a roadway structure composed of a ballast section of two feet in depth, including both the track ballast and sub-ballast. Experience has indicated that a substantial portion of this ballast depth may be successfully composed of a sub-ballast material which is less expensive than track ballast provided that proper engineering designs and standards are observed for selection and installation of the sub-ballast.

The use of sub-ballast is primarily confined to the construction of new tracks or the total rebuilding of an existing roadbed.

2.11.1 MATERIALS

A variety of materials may be used as sub-ballast provided they exhibit suitable mechanical, permeability, chemical and environmental characteristics as defined by this specification or as may be defined by the individual railway company.

Materials used as sub-ballast and most commonly available are those materials used in highway construction including crushed stone, natural or crushed gravels, natural or manufactured sand, crushed slag or a homogeneous mixture of some of these materials. Other natural materials such as sand-clay-gravels and clay-gravels or on site materials may be used provided proper engineering standards and specifications are defined by the individual railway companies.

2.11.2 DESIGN

Due to the great variety of materials that may be used for sub-ballast and the varying conditions under which they may be applied, it is not feasible to present in this specification detailed design programs. Materials preferred as sub-ballast should not be limited to the type material but rather should be selected on the basis of subgrade and track ballast compatibility as well as drainage and climatic conditions. Each location for sub-ballast installation should be examined to determine the appropriate type of sub-ballast for the subgrade encountered. Applicable specifications may then be developed by the individual railway companies.

2.11.3 TESTING

Some of the most frequently used tests for sub-ballast material are given in Table 2.11.1 which state properties, test methods and comments on limiting values.

2.11.4 CONSTRUCTION OF SUB-BALLAST SECTION

The sub-ballast material shall be transported and delivered to the site in a manner that will prevent segregation or loss of material. Before placing the sub-ballast material, the subgrade or previous layer shall be wetted as directed by the Engineer.

The sub-ballast shall be placed on the prepared subgrade, shaped and compacted by power equipment in layers of not less than three inches and not exceeding six inches in depth when compacted. The sub-ballast material shall be placed to specified lines, grades and depth without segregation. Water shall be added as required to facilitate compaction.

Each layer of sub-ballast after shaping to required lines, grades and cross section shall be compacted to the design density.

It is recommended that vehicular traffic be kept off the prepared sub-ballast surface. In any event, the contractor should be required to maintain a true and smooth surface until track ballast is placed on the sub-ballast.

2.11.5 PRODUCTION AND HANDLING

Production and handling shall conform to Article 2.5 of this chapter.

2.11.6 INSPECTION

Inspection of material shall be as provided in article 2.7 of this chapter.

2.11.7 MEASUREMENT AND PAYMENT

The pay item for furnishing, placing and maintaining the sub-ballast until acceptance by the railway company shall be "Sub-ballast" and the pay unit shall be by the ton.

Measurement and payment for water used to moisten subgrade prior to placing the sub-ballast, in mixing sub-ballast material to maintain optimum moisture during compaction and maintenance of the surface during construction shall not be measured for separate payment but shall be considered incidental to the sub-ballast placement.

TABLE 2.11.1

SUB-BALLAST
PROPERTIES AND TEST METHODS

PROPERTY	TEST METHOD	COMMENTS
Particle Size Analysis	ASTM D 422	See Section 2.11.2
Moisture Density Relation	ASTM D 1557	Maximum Dry Density and Optimum Moisture Content
Liquid & Plastic Limits Minus No. 40 Sieve	ASTM D 423 D 424	See Design Section
Degradation - Los Angeles Abrasion	ASTM C 131	Variable*
Sodium Sulphate Soundness	ASTM C 88	Variable*
Percent Material Passing No. 200 Sieve	ASTM C 117	Variable*
Permeability	ASTM D 2434	Variable*
Specific Gravity	ASTM C 127	Variable*

* The numerical value of these tests will depend upon the physical and chemical characteristics of both the ballast and subgrade as well as the material used for sub-ballast and values as may be defined by the individual railway companies

COMMENTARY

Sub-ballast exists under most of all railroad tracks as a result of degradation of track ballast material. Most of our rail lines are over a century old and during that period weathering and mechnical forces from traffic have reduced the size of the earlier ballasts to much smaller particles.

Sub-ballast is used in new construction and rehabilitation of the track substructure when the entire track superstructure has been removed to rebuild the subgrade. The sub-ballast performs several important functions:

(1) The sub-ballast must be sufficiently impervious to divert most of the water falling into the track to the side ditches to prevent saturation of the subgrade which would weaken the subgrade and contribute to failure under load.

(2) The sub-ballast must be sufficiently pervious to permit release of the capillary water or seepage of water to prevent the accumulation of water below the sub-ballast. This condition could cause failure of the subgrade. If the sub-ballast material is not sufficiently pervious, a layer of sand or other suitable material meeting engineering standards as outlined in this specification should be constructed between the subgrade and sub-ballast sections of the roadway structure.

(3) The sub-ballast must possess sufficient strength to support the load applied by the ballast section and transfer the load to the subgrade.

(4) A sufficient thickness of non-frost susceptible sub-ballast should be provided in those installations where extreme environmental conditions (freezing and thawing) are encountered.

(5) The finished surface of the sub-ballast section should be stable to provide a construction platform for placing the track ballast and superstructure without rutting or other surface irregularities which could pocket water.

As defined, there are many preferred characteristics which will determine the performance of a suitable sub-ballast material. Therefore, it is imperative for the engineer to follow established engineering principles and select those materials meeting performance criterion commensurate with roadway stability requirements. The Engineer may also define other tests of a proposed sub-ballast material in addition to the tests outlined in Table 2.11.1 to define other properties of the track ballast and subgrade where unusual subgrade or ballast conditions exist.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Part 9

Railroad Vegetation Control

1988

(Rewritten 1988)

GLOSSARY

Absorption

Pesticide entrance into plant, animal or soil.

Acre

Along the railroad right-of-way, 8'3'' wide by 1 mile long, or 43,560 square feet.

Active Ingredient

The chemical in a product that is responsible for the herbicidal effects.

Acute Oral Toxicity (LD 50)

The dosage required to kill 50% of the test animals administered a single dosage by mouth. The dose is represented by the weight of the chemical per unit of body weight (see Table Two).

Adjuvant

Product combined with sprayed materials to act as wetting or a spreading agent, sticker, penetrant, emulsifier, etc., aiding in the action of the active material.

Adsorption

The adhesion by dissolved or suspended material to the surface of a solid (the soil micelle or organic matter).

Agitation

The process of stirring or mixing in a sprayer.

Amine

An organic compound derived from ammonia by replacement of hydrogen by as many hydrocarbon radicals. Normally water soluble and nonvolatile.

Amine salt

An amine salt is prepared by the neutralization of 2,4-D or similar acidic compounds with an amine. These are usually liquid formulations.

Annual

A plant that completes its life cycle from seed in one year. Examples: foxtail, kochia, crabgrass, sandbur, common ragweed.

Basal Treatment

An application to the stems of plants at and just above the ground line and including application to root collar and exposed roots.

Biennial

A plant that completes its life cycle in two years. The first year, it produces leaves and stores food; the second year it produces flowers and seeds. Examples: wild carrot, common mullein, poison hemlock and henbit.

Broad Leaf Weeds

A subdivision of flowering plants generally having broad, netveined leaves, with a distinct blade and petiole, and which sprout two embryonic leaves at germination, as contrasted with narrow leaved grassy plants.

Broadcast Application

An application of spray over an entire area, such as the roadbed or right-of-way for brush control.

Brush

Woody shrubs and trees.

Carcinogen

A substance that causes cancer.

Carrier

The liquid or solid material added to a chemical compound to facilitate its application.

Chlorosis

A yellowing or whitening of the foliage due to the absence of chlorophyll.

Chronic Toxicity

Illness caused by prolonged exposure to a toxin; it may be mild or eventually fatal, depending on amount of material absorbed. Note: chronic toxicity may be caused by a single dose, or by repeated doses.

Common Chemical Name

A well-known, simple name of a herbicide accepted by the Pesticide Regulations Division of the Environmental Protection Agency.

Concentration

The amount of active ingredient, or acid equivalent in a given volume or liquid, or in a given weight of dry material.

Contact Herbicide

A herbicide that kills primarily by contact with plant tissues, rather than as a result of translocation.

Deciduous

Having leaves which fall off seasonally, usually in autumn.

Defoliant

A compound which causes the leaves or foliage to drop from the plant.

Degradation

The process by which a substance is decomposed.

Dermal Toxicity

Ability of a chemical to cause injury when absorbed by the skin.

Dilute

To make a pesticide thinner or weaker by adding a diluent, such as water, oil or other materials; to "water down".

Dormant Application

Applied while vegetation is not actively growing.

Drift

Airborne movement of small particles of spray solution to areas outside of the spray pattern during application.

Emulsifiable Concentrate (EC)

A formulation produced by dissolving the active ingredient with an emulsifying agent in an inorganic solvent such as water or oil.

Emulsifying Agent

A surface active material which facilitates the suspension of one liquid in another.

Emulsion

The suspension of one liquid as minute globules in another. For example, oil dispersed in water.

EPA

Environmental Protection Agency.

Ester

An organic compound formed from an acid and alcohol, usually insoluble in water, scented and volatile. Volatile herbicide formulations may injure off-property crops.

Foliar Application

Herbicidal treatment to the stems, leaves, blades or needles of a plant.

Granule (G)

A pesticide formulation in which the active ingredient is impregnated into grain-sized particles of clay or other carrier. May be applied dry to the soil or mixed with water to spray.

Grassy Weeds

Plants characterized by narrow leaves with parallel veins, by leaves composed of blade, sheath and ligule, and by jointed stems and fibrous roots. At germination only one leaf emerges, as compared with broad leaf weeds.

Herbaceous Plant

A vascular plant that does not develop wood tissue.

Herbicide

A chemical for control of undesired vegetation.

Label

All written printed or graphic matter on or attached to the pesticide or the immediate container.

LC_{50}

The concentration of an active ingredient in the surrounding air (or water in the case of aquatic organisms) so as to cause death to 50% of test animals.

LD_{50}

See "Acute Oral Toxicity".

Leaching

Movement of a substance downward, or out of the soil as a result of water movement.

Necrosis

Localized death of living tissue such as death of a certain area of leaf.

Nonselective Herbicide

One that is active on such a wide variety of species that few, if any species will remain.

Oral Toxicity

The degree of toxicity of a compound when it is ingested through the mouth. See "Acute Oral Toxicity".

Orifice

An opening or hole in a spray nozzle.

Pellet (P)

A pesticide formulation in which the active ingredient is incorporated into larger than granule sized chunks of inert material, and applied dry to the soil.

Perennial

A plant that continues to live from year to year.

Photosynthesis

A process by which carbohydrates are formed in the chlorophyll containing tissues of plants exposed to light.

Postemergence Treatment

Treatment after plants emerge in the spring.

Pre-emergence Treatment

Treatment before plants emerge.

Residual

To have a continued killing effect over a period of time.

Selective Herbicide

A herbicide that will kill some plant species when applied to a mixed population without serious injury to other species.

Soil Application

Application of a chemical to the soil surface rather than to vegetation.

Soil Persistence

Refers to length of time that a herbicide remains active in the soil.

Solution

A preparation made by dissolving a material in another substance, usually water. Once solutions are formed they tend to be stable, as compared to emulsions, which will settle-out.

Species

A population of organisms having common attributes and capable of interbreeding; a subdivision of a genus.

Suckering

Sprouts arising from roots or underground stems.

Surfactant

Surface active agent used for more uniform coverage of the herbicide on the plant and to increase absorption.

Systemic Herbicide

See "Translocated Herbicide".

Toxicity

Degree to which a substance is injurous to organisms, most generally people or animals.

Translocated

One which is moved within the plant from point of entry, to another part where it has lethal effect.

Vines

Any plant which climbs by tendrils, or which trails along the ground. Stems may be woody or nonwoody.

Volatility

The tendency of a substance to evaporate.

Weed

A plant growing where it is not desired.

Wettable Power (WP)

Dry preparation which is mixed with water to form a suspension. NOTE: a suspension will settle-out unless regularly agitated.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

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Railroad Vegetation Control

1988

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9.1 RATIONALE AND SCOPE OF WORK

It is obvious that undisturbed land will return to its preindustrial variety and density of vegetation. It is less obvious which methods of neutralizing this tendency are best. In order to understand these methods one should consider the scope of the work and the reasons why control is necessary in each case.

Reasons to Control Vegetation on Railroad Rights-of-Way

In Ballast Sections:

a. Keep ballast draining properly.
b. Permit proper inspection of track structure.
c. Prevent wheel slippage or sliding.

Shoulders and Ditches:

a. Maintain drainage.
b. Provide safe walkway.
c. Inspection of trains.
d. Reduce fire hazard.

Around Bridges, Buildings and Other Structures:

a. Fire prevention.
b. Permit proper inspection of structure.
c. Facilitate maintenance of structure.

Yards:

a. Safety.
b. Improve efficiency of yard operations.
c. Permit proper inspection of track.
d. Facilitate track maintenance.
e. Fire prevention.

Noxious Woods:

a. Health and safety of employees.
b. Compy with legal requirements.
c. Reduce spread to neighboring properties.

Signal Appurtenances:

a. To maintain visibility of signals, switch position indicators and derails.
b. To permit safe, efficient operation of switch stands and telephones.

Wayside Signs:

To maintain visibility of speed limit signs, whistle signs, mile posts, etc.

Signal, Communication and Power Lines:

To prevent service interruptions.

Brush Adjacent to Track:

a. To permit inspection of moving trains.
b. To prevent close clearance hazards.

Highway Grade Crossings:

a. Sight distance for highway and rail traffic.
b. Comply with legal requirements.

9.2 PREPARING A VEGETATION CONTROL PROGRAM

9.2.1 Vegetation Control Methods

The methods employed to control vegetation on railroad rights-of-way may be grouped into three general categories: controlled burning, mechanical control and chemical control. In the course of developing a program, a determination must be made of the method to be used. If the program is extensive, a combination of methods may be desirable. The principal advantages and disadvantages of each method are:

9.2.1.1 Controlled Burning

This method is the least important in terms of total usage. It is used principally to remove dry vegetation from areas when fire hazards exist due to sparks from locomotive exhausts or braking of trains. This removal of dry vegetation is required by law in some states regardless of the hazards presented. A major objection is atmospheric pollution. Chemical or mechanical control can usually be substituted. But soil erosion may result if the soil is denuded.

9.2.1.2 Mechanical Control

Included in this category are methods involving the use of hand tools, such as brush hooks, axes, and scythes, as well as all types of power equipment since the results obtained are similar. The determination of where to use these mechanical methods should be based on the degree of control desired and existing conditions.

Lawn maintenance by mowing in the vicinity of stations, offices, and other facilities is part of the vegetation control program. Mowing may also be performed on the rights-of-way where terrain permits and particularly in the area beyond drainage ditches to the right-of-way line. It is in this area that ground cover is usually desired. Reasons are:

a. Visibility adjacent to grade crossings.
b. Preventing the spread of weed seed onto adjacent farmlands.
c. Appearance.

The establishment of a permanent, maintenance-free ground cover may be justified. Mowing weeds and grasses in the track and shoulder areas is also useful, principally to cut down uncontrolled vegetation which interferes with the efficient performance of duty by operating and maintenance personnel. The use of this practice in ballasted areas will further contribute to the fouling of ballast.

Recent developments in mechanical control have been largely directed toward brush cutting. Equipment is available to perform this work operating either on-track, off-track, or with the flexibility of rail-highway equipment. On-track equipment has the advantage of not having to operate over rough terrain. The area which can be worked is limited by the lateral reach of the cutting equipment from the track. Productive time may be limited with such equipment, depending upon the density of rail traffic. Off-track equipment can work independently of train movements and is not restricted by the distance from the track. This may be of particular value in working under communication and signal lines. Frequently, the area covered per working hour may be less than with on-track equipment as the equipment has to traverse rough terrain. While rail-highway equipment may be more flexible in many cases by combining advantages of the other two types, its construction is such that it generally cannot cover terrain as rugged as equipment designed exclusively for off-track usage.

The cost of controlling brush by mechanical methods is usually greater than the cost of chemical brush control. Mechanical brush control is appropriate for situations where removal of all standing vegetation is required such as interference with communication lines, clearances, or visibility. Once a knock-down of the brush is accomplished, it will usually be more economical to control regrowth by chemical than by mechanical means. Mechanical control may also be used where the use of herbicides is restricted due to adjacent crops or ornamental vegetation.

9.2.1.3 Chemical Control

The predominate method of controlling vegetation on railroad rights-of-way is with herbicides. Factors which contribute to this widespread usage include:

a. Economy.
b. Ease of application.
c. Ability to regulate degree of control, including percentage of kill, duration of control period, and selectivity.
d. Productivity, which results in less demands on available labor and track occupancy.

9.2.2 Degree Of Control

Where controlled burning or mechanical control methods are used, the degree of control obtained is usually a fixed characteristic of the method used. With chemical methods the desired degree of control can be regulated with the area requirements and available funds. It is important to determine the degree of control required by segments in the early stages of planning and develop the program in accordance with these requirements. Degrees of control attainable are described as follows:

9.2.2.1 Bare Ground

Complete elimination of vegetation is the most expensive degree of control. Initial high rates of long residual chemicals followed by reduced rates are required. This is usually desired around timber bridges, switch stands, fuel storage tanks, and other structures and/or areas.

9.2.2.2 Short-Term Weed Control

This term denotes a high degree of vegetation control, but not to the extent that bare ground is obtained. It involves the use of a herbicide or combination of herbicides which produce a quick knock-down plus residual control for less than a growing season. One or two treatments may be necessary per growing season, depending on the chemicals used, the problems, and length of the growing season. It may vary as to percent of kill or control desired. This is usually desired in yards and terminals, at highway grade crossings, on passing tracks and sidings, and such main-track areas as ballast sections and shoulders.

9.2.2.3 Chemical Mowing

Non-residual herbicides are used to chemically burn down vegetation. One to four treatments per year may be necessary, depending on rainfall and length of growing season.

9.2.2.4 Selective Weeding

This item denotes the removal of some species of vegetation without damaging the desired species. It has had a limited use on railroad right-of-way, concerning the control of such noxious species as johnson grass, kudzu, various thistles and brush. More recently midwest railroads have sprayed wide on the right-of-way annually to allow low growing grasses to replace brush and broadleaf weeds. This involves not only the use of selective herbicides, but also the dispersal of grass seeds.

9.2.3 Quantitative Considerations

9.2.3.1 Patterns and Acreage

Railroads generally exercise the option of specifying not only the total acreage to be treated, but the treatment shape, or pattern. By using the center of track as reference point it is possible to define a simple pattern, as in a yard program pattern. Main and branch line patterns may be specified in terms of an inner, or "tie" area (which may not require out-of-face treatment), and an outer or "berm" area. Below are figures frequently specified.

Program	Track Centers	Tie Pattern		Berm Pattern	Total Pattern Width	Acres/Mile if treated out-of-face
		From	To	To	(Tie & Berm)	
Yard	14′	Center	7′	—	14′	1.75
Branch	—	"	5′	9′	10 + 8 = 18′	1.25 + 1 = 2.25
Main or Br.	—	"	6′	12′	12 + 12 = 24′	1.5 + 1.5 = 3.0
Siding	20′	12′	—	28′	16′	2.0
Crossing	—	12′	—	28′	32′	0.32/crossing when 200′
		(both sides of track)				both sides of road*
Brush						
Pole-line	—	12′	—	52′	40′	5.0
Opposite side	—	12′	—	20′	8′	1.0

An estimate of acres per track mile may be gotten by dividing the pattern width in feet by eight. This figure times treated miles yields total program acreage if treated out-of-face. Actual acres treated may be less if the inner or tie area pattern has been "spot treated", that is, sprayed only when emerged weeds are evident. Similary, brush acres may be spot sprayed as needed, which will cause the actual average to be less, or in some cases more than that shown above.

*Note: Many states require a minimum distance of several hundred feet further than that indicated here.

9.2.3.2 Contract Costs

For railroads that do not use their own personnel for the application of herbicides, the vegetation control programs may be awarded as "Guaranteed Performance" contracts, or as "Price-per-acre" contracts. Both may be awarded by competitive bidding. In the former case the railroad does not specify herbicides, or acreage, but pays a lump sum amount on the condition that the property will be maintained to the satisfaction of the company. In the later case, the railroad expects direct control of costs by specifying acreage quantities and herbicide rates per acre. The contractor provides a total cost per acre, which includes both the cost of the chemical and the cost of application per acre. The railroad may wish to ask for the price of each component in order to ascertain what percentage of the budget is labor, and what is materials. The following formula illustrates the point.

Herbicide \$/acre + Application \$/acre = Total \$/acre

Program cost is the product of Total Price per acre times the number of acres.

9.2.3.3 Survey

A number of methods may be used to determine the acreages involved in the proposed program. As stated above, weed control may be performed on the basis of fixed patterns, from which it is possible to estimate a constant acre per mile. This may or may not be supplemented by spot work, the density of which can best be determined by field survey. Areas such as yards may require treatment of the total facility, in which case acreage may be determined by plans. The determination for brush spray requirements usually requires field survey, since the density per mile varies widely. Treatment of such facilities as bridges and grade crossings may be specified on a unit, rather than an acreage basis.

The methods of estimating may vary, depending on scope of the work, level at which estimating is done and degree of familiarity of personnel with actual field conditions. In any case, it is necessary to define the phases of the program and to determine the quantities in each phase.

9.2.4 Scheduling Of Work

The type of treatment used may impose limitations upon the season when the work can be progressed. Availability of labor and equipment, climatic conditions and requirements for track occupancy are important considerations.

Proposed 1988 Manual Revisions To Chapter 4 - Rail

It is proposed to revise the following portions of Part 2 - Specifications for Steel Rails. Substantive changes involve replacement of the Drop Test requirements with Macro-Etch Standards for Testing New Rails.

Section 4.1

The limits of brinnell hardness for high-strength rail shall be revised to read "341-388".

Article 6.2.6

Revise to read: High strength rail shall be identified in accordance with Section 15.1.

Section 8.2

Revise to read: Full length of the rail shall be tested using in line ultrasonic testing equipment provided by the manufacturer except, if agreed to between purchaser and manufacturer, rails may be tested in accordance with Supplementary requirement S2. The rail shall be free from rough surfaces, loose scale or foreign matter which would interfere with the ultrasonic detection of defects. Testing shall be done when the rail temperature is below 150° F.

Section 8.3

Revise to read: The calibration test rail shall be a full section rail of the same section and general chemical content and process as that being tested. The test rail shall be long enough to allow calibration at the same rate of speed as the production rail.

Add After Section 8.4:

8.4.1 The in-line testing system sensitivity level, using the calibration rail, shall be adjusted to detect a minimum 3/32-in. diameter defect anywhere in the sound path in the head, a minimum of 1/16-in. diameter in the web, and longitudinal imperfections exceeding 1/2-in. length and greater than 1/16-in. depth occuring in the base.

8.4.2 Any indication equal to or greater than the references specified in 8.4.1 when scanning the rail at the production speed shall be cause for initial rejection. A record shall be made of each suspect rail. This record shall be available to the purchasers inspector.

Section 8.5

Revise to read: The calibration rail shall be run through the ultrasonic testing equipment at the start of each shift or at least once each 8 hour operating turn and additionally at any section change or at any indication of equipment malfunction. A record shall be maintained by the manufacturer of each time the calibration test rail is run through the test system. This record shall be available to the purchaser's inspector.

Section 8.7

Delete current section 8.7, renumber section 8.8 to 8.7 and revise to read as follows: The suspect rail may be retested using manual non-destructive testing techniques before final rejection. The testing criteria of the manual non-destructive retesting shall be in accordance with Section 8.4. The method of inspection shall be agreed to between purchaser and manufacturer.

Section 8.8

Renumber current section 8.9 to 8.8 and revise to read as follows: Rejected rails shall be cut back to sound metal as indicated by the ultrasonic testing subject to the length restrictions in Section 11. The cut shall be a minimum of 12-inches from any indication.

Section **"9. Resistance To Impact"** Thru Section **"11. Surface Classification"** are to be deleted and replaced with the following:

9. Interior Condition/Macroetch Standards

9.1 Sample Location and Frequency

9.1.1 Ingot Steel - A test piece representing the top end of the top rail from one of the first three, middle three, and last three ingots of each heat shall be macroetched.

9.1.2 Continuous Cast Steel - A test piece shall be macroetched representing a rail from each strand from the beginning of each sequence and whenever a new ladle is begun, which is the point representative of the lowest level in the tundish (i.e. the point of lowest ferrostatic pressure.) One additional sample from the end of each strand of the last heat in the sequence shall also be tested. A new tundish is considered to be the beginning of a new sequence.

9.1.3 Upon receipt the purchaser has the right to examine any rail from any part of a heat at his option, and if the purchaser determines that the rail sample selected is rejectionable, the entire heat shall be re-evaluated according to Section 9.4.

9.2 Sample Preparation

9.2.1 A full transverse section of the rail can be cut by abrasive or mechanical means as long as care is maintained in preventing metallurgical damage.

9.2.2 The face to be etched shall have at least a 125 microinch finish.

9.2.3 The sample shall be degreased and totally immersed in a hot (160° to 180°F) one to one mixture, by volume, of concentrated hydrochloric acid (38 volume percent) and water to sufficiently etch the specimen. Etching time shall be between ten and twenty minutes. The solution surface shall be at least one-inch above the etched surface.

9.2.4 Upon removal from the bath, the sample shall be rinshed and brushed under hot water and dried. The sample shall not be blotted dry. A rust inhibitor shall be applied to the etched face.

9.3 Macroetch Evaluation

9.3.1 According to Figure 9.1, the areas of cross section shall be defined as head, web, and base.

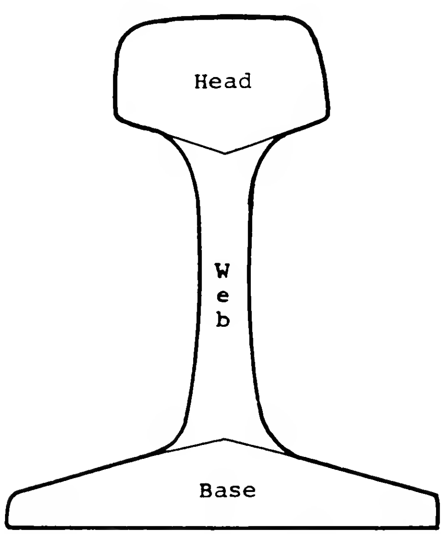


Figure 9.1 Definition of Rail Cross Sectional Areas for Macroetch Evaluation

9.3.2. Rejectionable Condition - Continuous Cast

9.3.2.1 Hydrogen flakes (Fig. 9.2)

9.3.2.2 Pipe; any size (Fig. 9.3 & 9.4)

9.3.2.3 Central web streaking extending into the head or base (Figs. 9.5, 9.6)

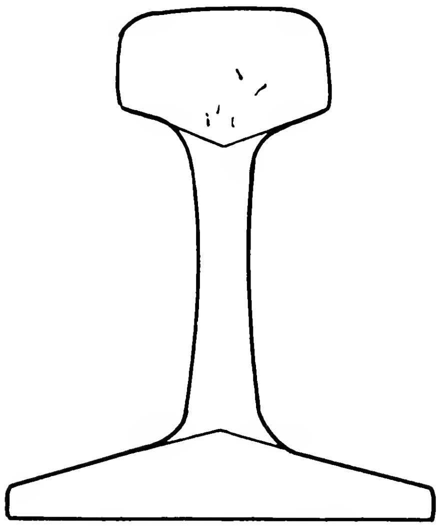


Figure 9.2 Hydrogen Flakes

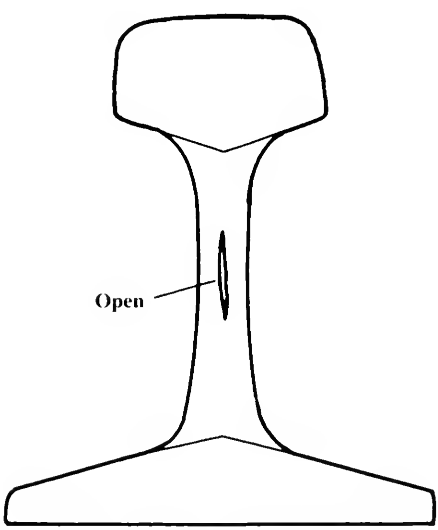


Figure 9.3 Pipe

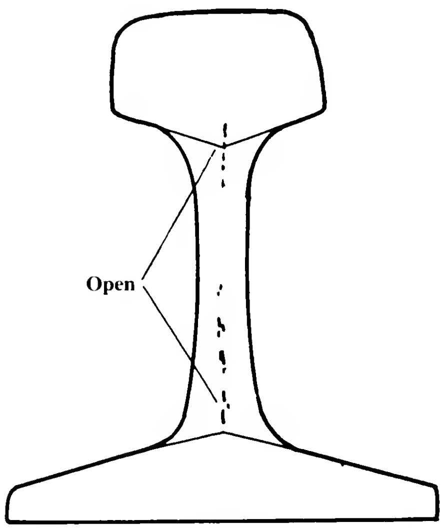


Figure 9.4 Pipe

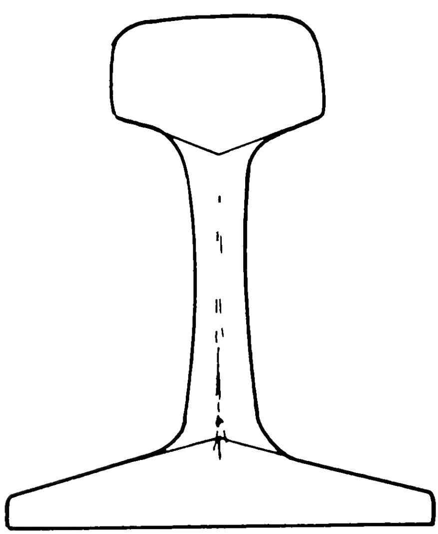


Figure 9.5 Central Web Streaking Extending into Base

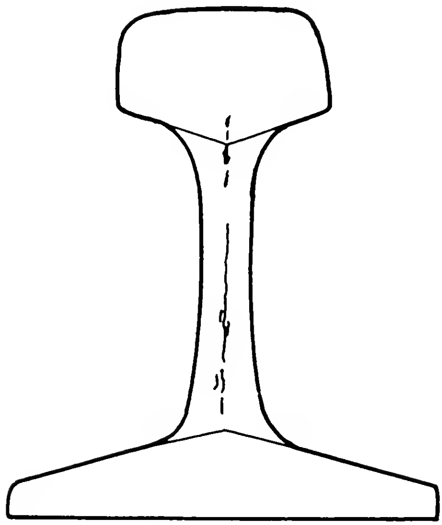


Figure 9.6 Central Web Streaking Extending into Head

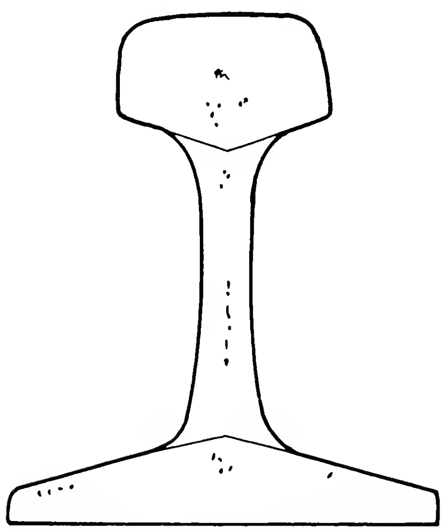


Figure 9.7 Scattered Central Web Streaking

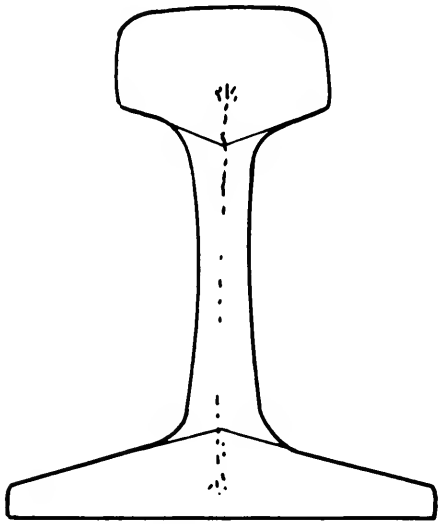


Figure 9.8 Scattered Segregation

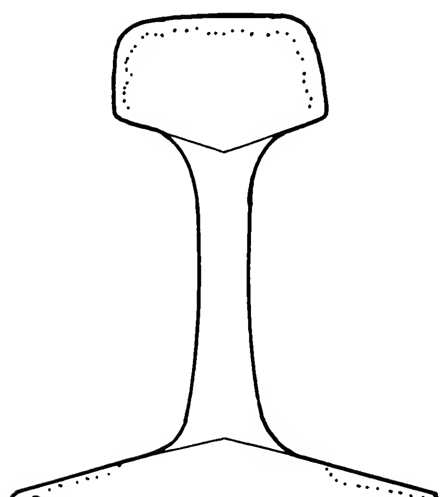


Figure 9.9 Subsurface Porosity

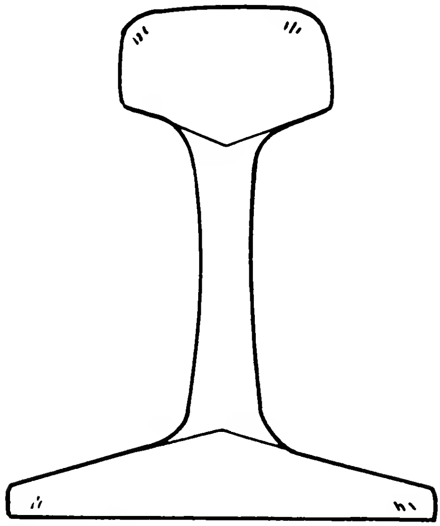


Figure 9.10 Radial Streaking

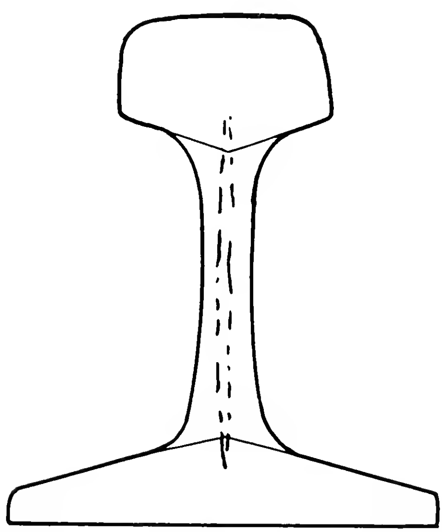


Figure 9.11 Scattered Central Web Segregation

9.3.2.4 Streaking greater than 2-1/2 in. in length

9.3.2.5 Scattered central web streaking greater than shown in Figure 9.7

9.3.2.6 Scattered segregation extending more than one-inch into the head or base (Fig. 9.8)

9.3.2.7 Subsurface porosity (Fig. 9.9)

9.3.2.8 Radial streaking greater than Fig. 9.10

9.3.2.9 Inverse or negative segregation having a width greater than 1/4-in. and extending more than 1/2-in. into the head or base.

9.3.2.10 Streaking greater than 1/8-in. in the head from internal bloom cracking:
Radial cracks
Halfway cracks
Hinged cracks

9.3.2.11 Other defects that could cause premature failure (i.e., slag, refractory, etc.)

9.3.3 Rejectionable Condition - Ingot Cast

9.3.3.1 Hydrogen Flakes (Fig. 9.2)

9.3.3.2 Pipe, any size (Fig. 9.3 & 9.4)

9.3.3.3 Segregation extending into the head or base

9.3.3.4 Segregation greater than 1/8-in. wide in the head or base

9.3.3.5 Scattered central web segregation greater than Fig. 9.11

9.3.3.6 Subsurface porosity (Fig. 9.9)

9.3.3.7 Inverse or negative segregation having a width greater than 1/4-in. and extending more than 1/2-in. into either the head or base.

9.3.3.8 Other defects that could cause premature failure (i.e., slag, refractory, etc.)

9.4 Retests

9.4.1 If any specimen fails to meet the macroetch standard for interior quality, two additional samples of rail representative of the same strand or one adjacent lower sample from the ingot shall be obtained.

9.4.2 These retests shall be taken from positions selected by the manufacturer and the material from between the two retest positions shall be rejected.

9.4.3 If any retest fails, testing shall continue until acceptable internal quality is exhibited.

9.4.4 All rails represented by failed tests shall be rejected.

9.4.5 Short Rails - If finished rail from the ingot process or the beginning of a strand shows defects, it shall be cut back through successive rails to sound metal and accepted as short rail, subject to the requirements of Section 11.

9.5 Magnified Inspection

In the event that there is a question of the seriousness of the indication, further examination may be performed at higher magnification.

9.5.1 Inspect sample with stereo microscope up to 5X.

9.5.2 A polished sample may be inspected at 100x for metallographic interpretation.

10. Surface Classification.

Rails which do not contain surface imperfections in such number or of such character as will, in the judgement of the purchaser, render them unfit for recognized uses, shall be accepted.

10.1 Hot Marks

10.1.1 Rails with hot marks such as from shearing, scabs, pits, or hot scratches greater than 0.020-in. in depth shall be rejected.

10.1.2 Rails with guide marks in the head greater than 0.020 in. deep or greater than 0.062-in. wide shall be rejected.

10.2 Cold Scatches

10.2.1 Rails with longitudinal cold scratches, formed below 700°F, exceeding 36-in. in length and 0.010-in. in depth shall be rejected.

10.2.2 Rails with transverse cold scratches, formed below 700°F, which exceed 0.010-in. in depth shall be rejected.

10.3 Protrusions

10.3.1 Rails with any protrusion of excess metal extending from the surface of the rail, such as could be caused by a hole in the roll or a roll parting in the web shall be rejected if the protrusion affects the fit of the joint bar or causes the fishing template to stand out more than 1/16-in laterally.

10.3.2 Rails with any protrusion in the web greater than 1/16-in. high and greater than 1/2-square inch in area shall be rejected.

10.3.3 No protrusion of excess metal shall be allowed on the head or the base of the rail.

Sections currently numbered **"12. Length"**, **"13. Drilling"**, **"14. Workmanship"**, **"15. Acceptance"**, **"16. Markings" and "17. Loading"** will be renumbered sections **"11."**, **"12."**, **"13."**, **"14."**, **"15."**, and **"16."**, respectively.

Under **Supplementary Requirements, S.2.2.4,** in the last sentence in parentheses, the hole diameter should be changed from 1/8'' to 1/16''.

Proposed 1988 Manual Revisions To Chapter 5 - Track

The following changes are proposed to Section 5.4, "Laying Procedure For Continuous Welded Rail (CWR) On Existing Track". The new recommended rail laying temperatures for CWR will be in closer agreement with present industry practice.

Replace Paragraph 5.4.16 with the following text and graphs except Table II - "Continuous Welded Rail Expansion Segments," which will remain a part of Paragraph 5.4.16.

5.4.16 CWR should be laid when the rail temperature is within the temperature range specified by the following equation:

$$\text{Minimum D.R.T.} = \frac{2H_t + L_t}{3} + 10$$

$$\text{Maximum D.R.T.} = \left[\frac{2H_t + L_t}{3} + 25\right] \pm 5$$

D.R.T. = Desired Rail Temperature
H_t = Highest Rail Temperature
L_t = Lowest Rail Temperature

Example: In an area where CWR is to be laid, the maximum summer rail temperature is 125°F and the lowest rail temperature in the winter is −35° F:

$$\text{Minimum D.R.T.} = \frac{2 \times 125 - 35}{3} + 10 = 82^\circ$$

$$\text{Maximum D.R.T.} = \left[\frac{2 \times 125 - 35}{3} + 25\right] \pm 5^\circ = 97^\circ \pm 5^\circ$$

In this case the rail may be installed at temperatures between 82° and 102°F.

(1) Rail should be heated or cooled as necessary to the desired laying temperature, or adjusted mechanically at a later time. When it is necessay to heat or cool the rail to the preferred laying temperature, the procedures to be followed are:

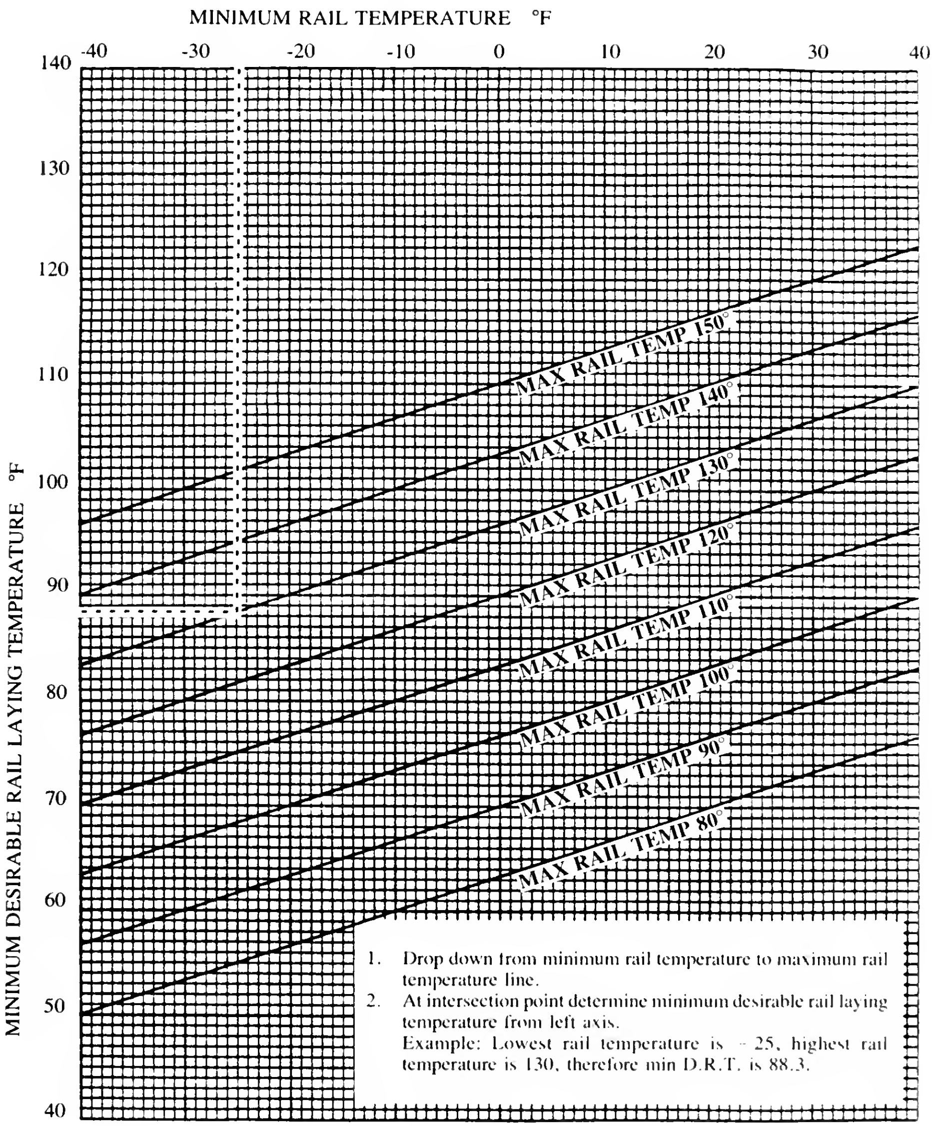
(a) A reliable contact-type pyrometer be used in order to determine the rail temperature immediately.

(b) Reference points should be marked on the rail, and tie plates and rail expanded in accordance with Table II - Continuous Welded Rail Expansion Segments, to insure that the rail string is being uniformly elongated.

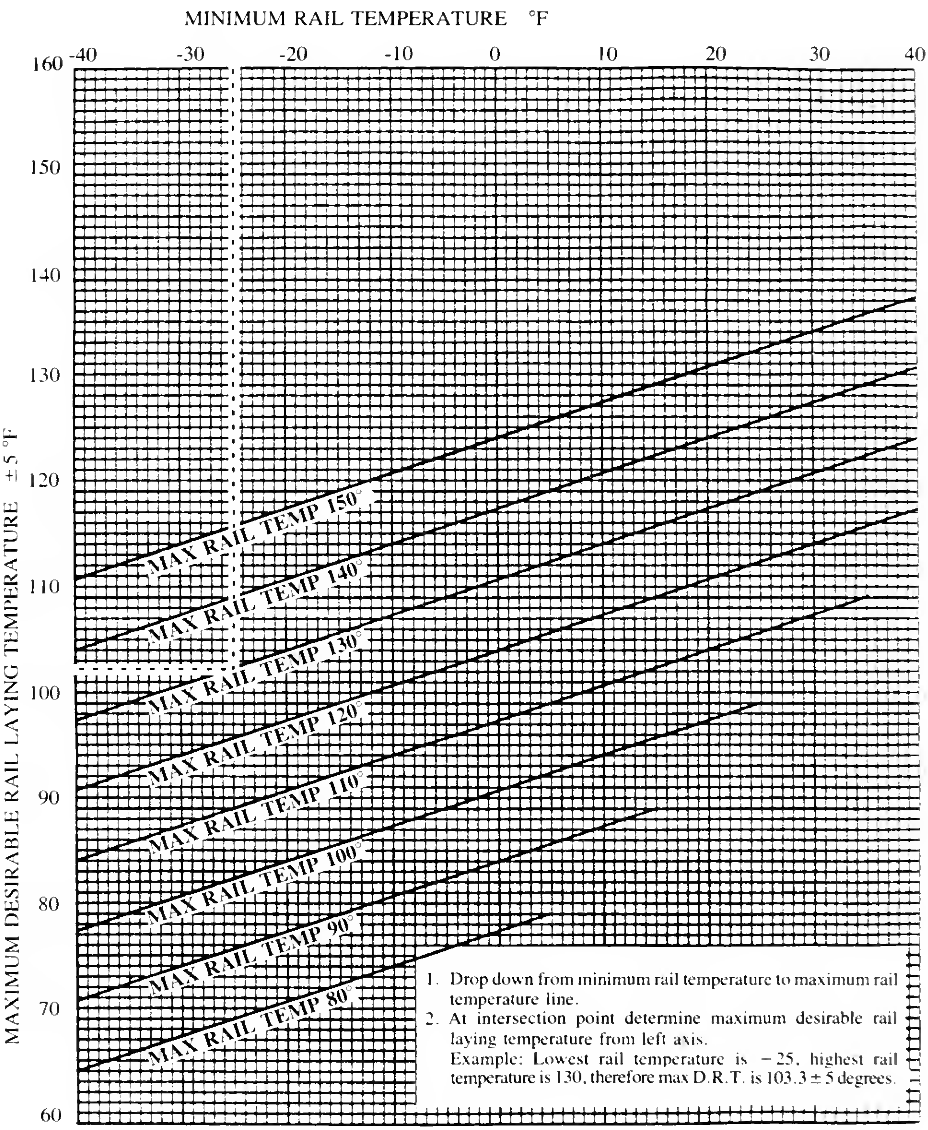
(c) To insure that the rail is elongating in accordance with the heat input, the tie plates should be tapped or rail vibrated to assist the movement of the rail.

(d) The laying and/or adjusted temperature and string number may be painted on the rail at the end of each string or similar effective tagging procedures carried out. A list of these temperatures should be forwarded to the proper office for engineering reference.

MINIMUM RAIL LAYING TEMPERATURE



MAXIMUM RAIL LAYING TEMPERATURE



Proposed 1988 Manual Revisions To Chapter 6 — Buildings

This revision involves a rewriting and renaming of Part 4, Design Criteria for Diesel Shops. Changes include a general updating of Part 4 material which was coordinated with Committees 13 and 14, and provides references to other parts of the Manual.

Part 4

Design Criteria for Diesel Repair Facilities

1988

(Rewritten 1988)

4.1 FOREWORD

4.1.1

The material presented herein is intended to familiarize the engineer and designer with the problems they will encounter and should consider in the design of a diesel facility.

(a) It is not intended to imply that other practices may not be equally acceptable.

(b) Definition of Light, Medium and Heavy Repair may vary among railroads but should not affect the concepts being presented.

(c) A check list of the facilities and processes necessary for the efficient operation of the diesel repair shop is presented at the end of this part as a design guide.

4.1.2

A diesel repair facility constitutes a "facility" designed to arrange an orderly progression of diesel locomotives for repairs, maintenance, servicing and cleaning as required, and to meet inspection requirements of the manufacturer and governmental authorities.

4.1.3

Diesel repair facilities are generally classified as "Heavy Repair," "Medium Running Repair" and "Light Running Repair and Servicing."

(a) HEAVY REPAIR—Consists of any work involving truck repair and maintenance, traction motor assemble, dynamic brake grids, etc.

(b) MEDIUM RUNNING REPAIR—Consists of any work involving repair, air reservoir test, brake change outs, repairs to injector, governors, turbos, etc.

(c) LIGHT RUNNING REPAIR AND SERVICE—Consist of any work involving oiling, lubricating, testing, minor adjustments and repairs, etc.

4.2 SITE CONSIDERATION

4.2.1

Traffic flow, proximity to supporting functions and material access to the facility are basic considerations to its most desirable location. Consultations with the operating departments should be progressed before finalizing the site location. Consideration should be given to the relationship of the ready tracks, the fueling and servicing facilities, material department, bulk fluid storage, and the location of the crew quarters.

4.3 BUILDING ARRANGEMENT

4.3.1

The primary consideration in diesel shop planning is that tracks be parallel and be serviced with through tracks where possible.

4.3.2

For greater efficiency of operation, the diesel shop is best serviced on a production line concept.

4.3.3

The size and arrangement of a diesel shop, the number of tracks and the type of equipment installed is dependent solely upon the type of servicing to be performed and the number of units to be serviced over a definite period of time.

4.3.4

The diesel shop design and layout should incorporate all functions required to perform major repairs, annual, semi annual and monthly inspections, minor repairs, routine servicing and maintenance as required.

4.3.5

The heavy repair track should be equipped with a drop table or 250 ton overhead crane for the removal and replacement of entire truck units, including an auxiliary table for the removal and replacement of a single pair of wheels with axle and traction motors when it is not necessary to remove the entire truck. It is recommended this area of the shop be furnished with at least a 30 ton overhead traveling crane with a 5-ton auxiliary unit. Inspection pits and elevated platforms may also be helpful in some repair functions.

4.3.6

The light and medium repair sections should be provided with pits, depressed floors, elevated platforms and light capacity cranes.

4.3.7

The shop should contain rooms or areas for related repairs, e.g. machine shop, electrical shop, metal shop, air brake, truck repair area, battery shop, tool room, etc.

4.4 EQUIPMENT AND RELATED FACILITIES

4.4.1 Pits

(a) Inspection pits should have a minimum depth of 4 ft. below the top of rail. The pit length should be a minimum of 10 ft. greater than the overall length of locomotives to be serviced.

(b) The pit walls of reinforced concrete should be either carried to the height of the base of rail or to level of the depressed floor area, with columns extended to the height of base or rail for track support. The latter detail is preferred since it affords a positive method of draining the adjacent depressed floor and provides access into the pit along its entire length. The distance between centers of parallel pits varies from 18 to 26 ft. This distance is established by the desired width of the elevated platforms, except that when a truck release track is introduced between pits, a minimum of approximately 34-ft. track centers is required. The rail on inspection pits should be of a heavy section. Pit drainage should be provided preferably by floor drains located at proper intervals along the length of the pit. Pit drains should be directed to a wastewater treatment system.

4.4.2 Depressed Floors

(a) The depressed floor along the inspection pits places the mechanic at proper height with respect to the locomotive for inspection and making repairs to trucks, braking systems and other under-body equipment. The elevation of this depressed floor area varies from 2 ft. 6 in. to 3 ft. below the top of rail on the inspection pits. The floor should be well drained and constructed with a surface that is easily cleaned. The recommended slope is 1/8 inch per ft.

4.4.3 Elevated Platforms

(a) Provide elevated platforms in the areas between adjacent maintenance tracks, as well as along the outer sides of these tracks. The height of the platforms with respect to the top of rail is 4 ft. 8 in. to 4 ft. 11 in., with some constructed at 5 ft. 6 in. The distance from edge of platform to center line of track must be held to the minimum of 5 ft. 6 in., or for the proper clearance of the equipment. Platforms should be constructed on non-combustible material usually consisting of steel columns and beams, or of reinforced concrete. Design loads of 250 psf are to be used for fork lift operation and 100 psf for all other platforms.

(b) Platforms should be designed to permit material handling trucks and storage of material.

(c) Platforms, where deemed necessary, should be provided with removable handrails along all edges, consisting of either pipe or a combination of pipe supports with chains between them. Access to the platforms from the normal top-of-rail level and depressed level floors should be provided by means of stairs at the ends and at intermediate points, where required.

(d) Ramps for equipment access to platforms may be used where adequate space is available. Ramps should have the same design loading as platforms with a maximum slope of 12% for fork lift use.

(e) Where space is at a premium, hydraulic lifts may be used at platforms enabling roll-on application at the three levels of shop levels.

(f) High-level platforms, approximately 15 ft. above the top of rail, are sometimes used. This platform is particularly desirable if locomotives require removal of power assemblies, etc. through the roof hatch. The high-level platform is usually the same width as the lower level platform, with stairs located at convenient points between the levels.

(g) Portable platforms are used in some instances where fixed elevated platforms and depressed floors are not desired.

4.4.4 Jacking Operation

Where truck changes are infrequent, portable electric or air jacks may be used, and jacking pads need to be included in the floor design, located at a point 7′-6″ from the center line of track.

4.4.5 Drop Tables

Drop tables are used for changing single wheelsets or complete trucks. The various types of drop table equipment available are:

(a) For dropping single wheelsets with traction motors, a table of 50-ton capacity should be used with a top 6 ft. 6 in. long measured parallel to the running rails. Flooring between the rails on the drop table top should be depressed below the top of the rail at least 2 ft. 6 in. in order to conform to types of locomotives being serviced. This provides room for working on motor leads and will accommodate the traction motor dolly. Equipment for servicing complete trucks should be of the long top type.

(b) If only two-axle trucks are to be handled, provide a drop table of 100-ton capacity with a top 18 ft. long.

(c) For three-axle trucks, the drop table should be 125-ton capacity with a top not less than 26 ft. long.

(d) When both single wheelsets with traction motors and complete trucks are to be dropped, a drop table with a sectional top should be used. The drop table should be 125-ton capacity and the top not less than 26 ft. long. In one end of the main top an auxiliary top is provided that is 6 ft. 6 in. long. Tops of this type normally have inspection pits between the rails.

(e) Drop tables described in items (b), (c), and (d) above must be equipped with locomotive body supports. These must be of the type that permits the support bar to be moved parallel to the running rail the full length of the drop table top and extend beyond one end 7 ft. 8 in.

(f) Drop table pits may be open, or closed with an elevating cover at the release track. If there are two active tracks, the release track should be between them. If there are more than two active tracks, there is no advantageous position for the release track.

(g) A consolidated drop table combines the drop table top and the hoisting mechanism, resulting in a considerable saving in pit depth. Available only in the long top type for dropping complete trucks, they do not lend themselves well to either multiple track operations or closed pit installations. Capacities are available from 50 to 150 tons, and top lengths can be from 15 ft. to 26 ft.

4.4.6 Locomotive Progression Systems

(a) Where a large number of units must be progressed daily through the shop, a number of mechanical pulling devices, and progression equipment are available and capable of moving diesel locomotives from the inbound position through the servicing positions in the shop and on to the outbound position. Some railroads also modify their diesels to move using loco batteries to energize loco's traction motors. The following advantages are inherent in the system:

(1) Eliminates need to idle locomotive for progression.
(2) Eliminates need for hostler engine.
(3) Units can be progressed in the uncoupled position.
(4) Reduced noise pollution.
(5) Reduced heating and ventilating costs.

4.4.7 Truck Repairs and Overhaul

Repairs and overhaul to trucks are made in an area somewhat removed from the area where work is done on the locomotive. This area should be provided with a truck washing platform for cleaning prior to the overhaul. Facilities for steam cleaning and the use of detergents should be provided. Wheel truing machines or lathe units for turning down locomotive wheels without their removal from locomotives are being used in many shops. A means of chip removal and handling should be an essential part of the installation. Refer to Section 4.9 for pollution control considerations.

4.4.8 Material Handling Platform

A material handling platform capable of being served by rail and by truck should be provided adjacent to the shop to facilitate distribution of material.

4.4.9 Store Room

Repair parts must be readily available. A store room for diesel parts should be established as an integral part of the diesel shop. As stock includes finely machined and finished parts, the room should be dry and dust-free. The purchasing and stores department should be consulted as to direct area requirements. Locomotive assignment at facility is directly related to the space required for material. Gang stock at platform areas in the shop itself must also be considered.

4.4.10 Office

An office area for the diesel shop supervisor and clerical staff should be located adjacent to the main shop area for proper supervision and the maintaining of servicing records, preferably at an elevated level to oversee the shop operations.

4.4.11 Locker and Toilet Facilities

Suitable locker, lunch, toilet and washing facilities should be provided and be so located as to be as accessible as possible. Individual state and local codes covering sanitary facilities should govern. Chapter 13, Part 2, Appendix B has a list of environmental agencies which may provide a starting point for determining applicable enforcing agencies. Drinking fountains, wash basins, water closets, and urinals should be installed at convenient locations in the shop and repair areas. When designing these facilities, provisions should be made to accommodate the handicapped and both male/female facilities in office and repair shop layout. Tool and tool box storage areas may also be required.

4.5 SERVICE FACILITIES

4.5.1 Lubricating Oil Supply

(a) Proper lubricating oil facilities are important at a diesel shop, as they make possible rapid oil changing and normal servicing with minimum of expense in the handling of oil. Modern oil handling equipment contributes to keeping the premises clean and minimizes fire hazards.

(b) Separate storage and dispensing facilities are required for as many different kinds of oil as are to be used. Storage tanks of such capacity as to permit purchases in tank-car or tank-truck lots are recommended where consumption dictates. Pumps should be of suitable capacity and should be valved and piped to permit their use for unloading tank cars and for distribution from the storage tank to the dispensing stations. Spill containment of at least 125% of stored volume should be provided. Refer to Chapter 13.

(c) Oil dispensing stations located on the elevated platforms consist of separate hose reels for each kind of lubricating oil with 50 ft. of hose. Dispensing stations should be located on approximately 60 ft. centers and hoses provided with spring-loaded nozzles for quick action control of oil flow. Meters may be provided to measure the quantity of oil used in servicing locomotives. Such a dispensing system is of value in adding small quantities of oil or in making complete oil changes. In some instances lubricating lines require heating, and pumps should be controlled from pressure tanks in lieu of dispensing stations to eliminate short cycling of the supply pump. Heating of lines and tanks should be provided for highly viscous oils.

4.5.2 Lubricating Oil Drainage

(a) Oil drainage systems usually consist of a tank placed at a level lower than the inspection pits, with connecting piping from the pits for gravity flow into the tank. On a gravity system minimum pipe size for good flow is 4″ with 6″ preferred. When possible, buried underground tanks should be avoided because the spill containment regulations for underground tanks are very stringent. Connection should be provided at intervals throughout the length of the pit for making hose connections with the engine drains. The dirty oil is pumped from the gravity storage tank into tank cars and returned to the reclamation plant, or removed directly by a scavenger. In some locales, used oil is a regulated waste requiring special handling procedures.

(b) Forced oil drainage systems are preferable and are installed with pumps of suitable capacity, with storage tanks kept above floor level.

(c) Portable tanks must be provided for servicing locomotives in the repair areas not provided with the drain oil systems.

4.5.3 Used Oil Filters

Provide a means of draining and disposing of used oil filters with a minimum of handling. Such filters may be a regulated waste in some states requiring special procedures. The area where filters are handled should have means to collect spillage.

4.5.4 Water Supply Systems (Raw and Treated)

(a) Treated radiator water and raw water outlets should be provided at convenient intervals along the maintenance tracks. These outlets are placed on the underside and above the elevated platform, as required.

(b) Treated water which may be toxic in nature or detrimental to streams or municipal sewage plants may require a separate drainage system or a means for retrieval and recycling. Consult Chapter 13, Part 1 for additional information.

4.5.5 Radiator Water Reclaim System

The system for reclaiming the used radiator water may be either gravity or pressure. The flow path through the system is the same with either method. The used radiator water is collected in a receiving tank and then pumped to a surge or holding tank. The water then goes to a skimming basin. After skimming, the water either goes directly to a mixing tank for the addition of chemicals or is pumped through pressure filters and then to the mix tank. After mixing to bring the reclaimed water back to strength, the radiator water goes to a storage tank ready for use in the locomotives. Depending upon the quality of local water, make-up water may be added raw or treated by softening or additional treatment by deionizing. A careful water analysis should be made at each site.

4.5.6 Compressed Air

Compressed air outlets should be provided at convenient intervals above and below platforms for the operation of tools, equipment and testing. Air supply should have dryers installed to remove moisture in air lines.

4.5.7 Locomotive Washing

(a) Locomotive washing (exterior car body and trucks) is usually carried out in a separate automated facility where the locomotive is sprayed with acid, alkaline and rinsed with water. Part 12 of this chapter "Design Criteria for a Locomotive Washing Facility" describes in detail that operation. However in areas where temperatures require the washer to be shut down on a seasonal basis, it is necessary to provide facilities inside the Diesel Shop building to wash locomotives manually.

(b) The system should provide for the cleaning of the engine room and the engine, wheel trucks, pilots and step wells, car body, front and rear hood ends, and cab interior.

(c) The system should include the pumping, storage, and supply of water, acid solution, light and heavy alkali solutions, including brushing action for scrubbing all unobstructed available exterior surfaces, including walkways.

(d) Drainage system should be provided with adequate treatment facilities to allow for discharge to nearby streams or municipal sewer. Consult Chapter 13, Part 1 for additional information.

4.5.8 General Washing System

Approved cleaners for floor washing and small parts cleaning should include the pumping storage and supply of detergents, as required through hose reels or valved outlets at strategic locations throughout the shop.

4.5.9 Electrical Cleaning Solvent

If a combustible product is used, insure that it is stored in an enclosed and well ventilated room with explosion-proof dispensing pump motor and electrical equipment and controls. If a vapor degreasing system is used, provide adequate ventilation in accordance with equipment manufacturer's recommendations. Disposal of solvent may be regulated.

4.5.10 Oxygen/Natural Gas/Propane Systems

The oxygen/natural gas/propane system can be a central system or consist of portable units depending upon the size of the shop.

4.5.11 Locomotive Toilet Servicing

Provision should be made within the shop at a designated area for servicing of locomotive toilet facilities. This can be accomplished by flushing toilet directly to a sanitary sewer line or by means of a portable scavenging unit where sanitary connection is not readily available. Approval of health department is usually required for sanitary sewer dump facilities.

4.5.12 Locomotive Deicing

In extremely cold environments where icing is encountered on the units, provision should be made for thawing out the equipment by use of steam hose or by use of fixed or portable infrared units, or industrial hot water. Provisions for ventilation of water vapor generated by thawing operations should be considered.

4.6 BUILDING SUPERSTRUCTURE DETAILS

4.6.1 Floors

Concrete floors throughout the shop with anti-slip treatment and hardeners resistant to chemical floor cleaners, acids, etc. are a very important criteria. Review repair functions in each work area to determine application to be made.

4.6.2 Walls and Roof

(a) It is recommended to construct a wainscot 8-10′ high at the perimeter walls of a material such as concrete to reduce maintenance from abuse in work areas (i.e.—hanging tools, fork lifts, material stored against the wall, etc.) Wall construction above the wainscot should be of non-combustible classification.

(b) The roof deck and framing should also be of non-combustible material due to possible fire hazard caused by oil residue if a locomotive is run inside the building. Sky lights to reduce power consumation for lighting may be included in areas not subject to diesel engine exhaust accumulations.

4.6.3 Track Doors

Diesel locomotive entrance doors recommended size is 14′ x 18′ minimum. Local clearance regulations should be reviewed. An operating system to open and close doors should provide a means to preclude partially open doors that can be damaged by equipment.

4.7 HEATING AND VENTILATING

4.7.1

Heating and ventilating diesel locomotive shops pose conflicting demands upon the design engineer. Operation of engines in buildings is not recommended. A locomotive shop is a large consumer of energy in cold climates because of its large door area and high ceilings. If diesel engines are operated in the shop building, then a large outside air heating load will also be imposed on the HVAC system to provide for ventilation. In warm climates, the heat from the operating engines create localized discomfort to the work force as well as air quality problems. Before specifying a solution to ventilation, the operating practices of the shop should be established with the shop management to determine where, how many, for how long, and the type of locomotives that will be operated in the building. It is recommended that engines in locomotives not be operated in buildings doing medium and heavy repairs and minimized during light running repairs. Many railroads have adopted practices that drastically reduce the total area of shops where locomotives will be operated. This is done by segregating maintenance functions with internal partitions to reduce the impacted volume of air that must be kept environmentally acceptable. Generally air contaminated with diesel exhaust will become irritating to eyes or throat long before occupational safety air standards for nitrous oxides are reached, providing adequate warning to personnel to mitigate their exposure without incurring personal risk.

4.7.2

Two accepted methods for handling diesel emissions in a shop are dilution and local capture by hoods.

(a) Dilution ventilation is usually employed when high ceilings and overhead cranes preclude the use of hoods. With dilution ventilating, the total volume of space to be exchanged should be kept as small as possible. Normally 6 air changes per hour will provide adequate dilution for locomotives that are idled in the shop at less than 350 rpm. This ventilation rate will permit recovery if a short run at higher speed is done on individual or multiple-unit rakes of equipment. Temperature stratification is a very important consideration because most diesel emissions are denser than air and drop toward the floor once they loose a 40 degree differential with ambient. In the introduction of dilution air, this air must be either tempered or introduced at a low elevation in the shop to insure the emissions are not cooled before they can be removed by roof or sidewall ventilation equipment. In cold climates, this poses a comfort problem for work force that must work around and underneath locomotives. In warm climates, the differential in temperature is quickly lost, hence dilution ventilation is not a desirable solution unless prevailing winds are reasonably strong and frequent. When the exhaust emissions cool, they tend to curl over and around the top of the locomotive and be ingested through the radiator cooling inlets, further compounding the problem of removal.

(b) In the designing of hoods to capture diesel emissions at the point of generation, care must be taken to ascertain the physical location of stacks of different types of locomotives, and their relationshiop on the shop floor to mate with other service equipment such as utility connections, jacking pads, and hoisting equipment. The exit velocity from a locomotive stack in throttle position above Run 6 will be too high to be effectively captured in a hood. Hood entrance velocity should normally be at least twice the locomotive discharge velocity, which becomes impractical at the higher throttle settings. If the hood is removed further from the top of the locomotive, the system quickly becomes a classic dilution ventilation system. Locomotive radiator fans also cause turbulence and disrupt the capture of emissions in certain conditions. Locomotives cannot be subjected to any significant increase in backpressure imposed by hoods or duct collection systems, hence any hood configuration should allow large, unrestricted cross-section that duplicates a free air discharge. In the design of collection hoods, occupational safety and railway clearance regulations should be reviewed.

(c) In designed mechanical ventilation systems, long duct runs should be avoided as they serve as collection surfaces for oily carbonous residues in the diesel emissions that eventually increase the risk of fire. In the design of duct work adequate provisions should be made for access panels and doors at the vanes, and other similar control devices often become coated with carbon residue which alters their aerodynamic and control properties. In specifying fan drives, every effort should be made to keep the fan motor out of the contaminated air stream by using belt drives. Fan bearings should be carefully checked for suitability in the higher temperature air streams that will be experienced.

4.7.3

In addition to the fresh air introduced into the building to replace that consumed by engine combustion and exhaust units, make-up air may also be used for space heating when large volumes of make-up air are continually required. Where the make-up air units need not be operated, it is economically justified to provide supplemental space heating units to offset natural building heat losses. This may be a composite system which might include under-floor warm air ducts, fin tube coil along exterior walls, unit heaters, warm air furnaces. Air to air heat exchangers to recover heat from exhaust air may be a feasible solution to provide some make-up air heat requirement.

4.7.4

Where codes allow, the use of direct-fired gas heaters where gas is available at a reasonable cost does not preclude the use of other types of heating, viz: steam, hot water, or even electric.

4.8 ELECTRIC LIGHTING AND POWER SUPPLY

4.8.1

This report will not go into detail as to specific requirements since most are code requirements dictated by locale.

Specific requirements for outlet locations, lighting type location are user related and vary from one facility to another.

For lighting in inspection pits, various types of lighting patterns and types have been used. Generally pit lights should be provided only for safety purposes and not for work light, and outlets (water proof) provided to allow use of trouble lights. The selection and placement will be dictated by applicable code interpretations.

4.9 POLLUTION (AIR NOISE-WATER)

4.9.1

In relating noise to hearing loss, six factors must be considered:

(a) Frequency of the noise

(b) Overall level of noise

(c) Exposure time during a working day

(d) Duration of noise exposure during a day

(e) Total exposure time during an estimated work life

(f) Individual's age and susceptibility

4.9.2

Diesel locomotive effluents are coming under increasingly stringent review by public authorities. Quantitative data on emissions from high-horsepower engines must be collected and evaluated in order to eliminate this source of pollutant. Emissions from use of chemical cleaners, welding etc., must also be evaluated. Consult Chapter 13, Part 1 for additional information.

4.9.3

Industrial wastes generated by locomotive shop operation, such as oils, corrosion inhibitors (i.e. chromates, borates, nitrates), detergents, etc. must be considered for treatment in pollution abatement facility whether discharging to stream, municipal sewer, landfill, or incinerator. Consult federal, state and local regulations prior to disposal.

4.10 COMMUNICATIONS

4.10.1

An adequate communications system between supervisor and maintenance personnel should be provided.

4.10.2

Communications system can consist of loudspeaker paging system, wireless paging system, public telephone system, short line telephone system and radio control system.

4.10.3

Loudspeaker paging system can be strategically located so that in essence you have a number of small speakers vs. one large speaker so that the disturbance level is kept to a minimum. Speakers should be located within the four corners of the shop and on the outside of the shop in areas directly involved in the shop operation. Part of the loudspeaker system should incorporate a short line (not part of public system) to office (communication center) in proximity of speakers.

4.10.4

Wireless paging system requires use of individual personnel receivers. Here a beep is used on the individual receiver for paging. It has the advantage of paging an individual not located within the area of a loudspeaker. The disadvantage is that only the individuals carrying receivers can be alerted.

4.10.5

Public telephones should be made available for office areas.

4.10.6

Radio control system for communication with road engines should be considered; one located in office area (communication center) and one located at fueling and sanding facility. This system can also be used to check radio operation in engines.

4.10.7

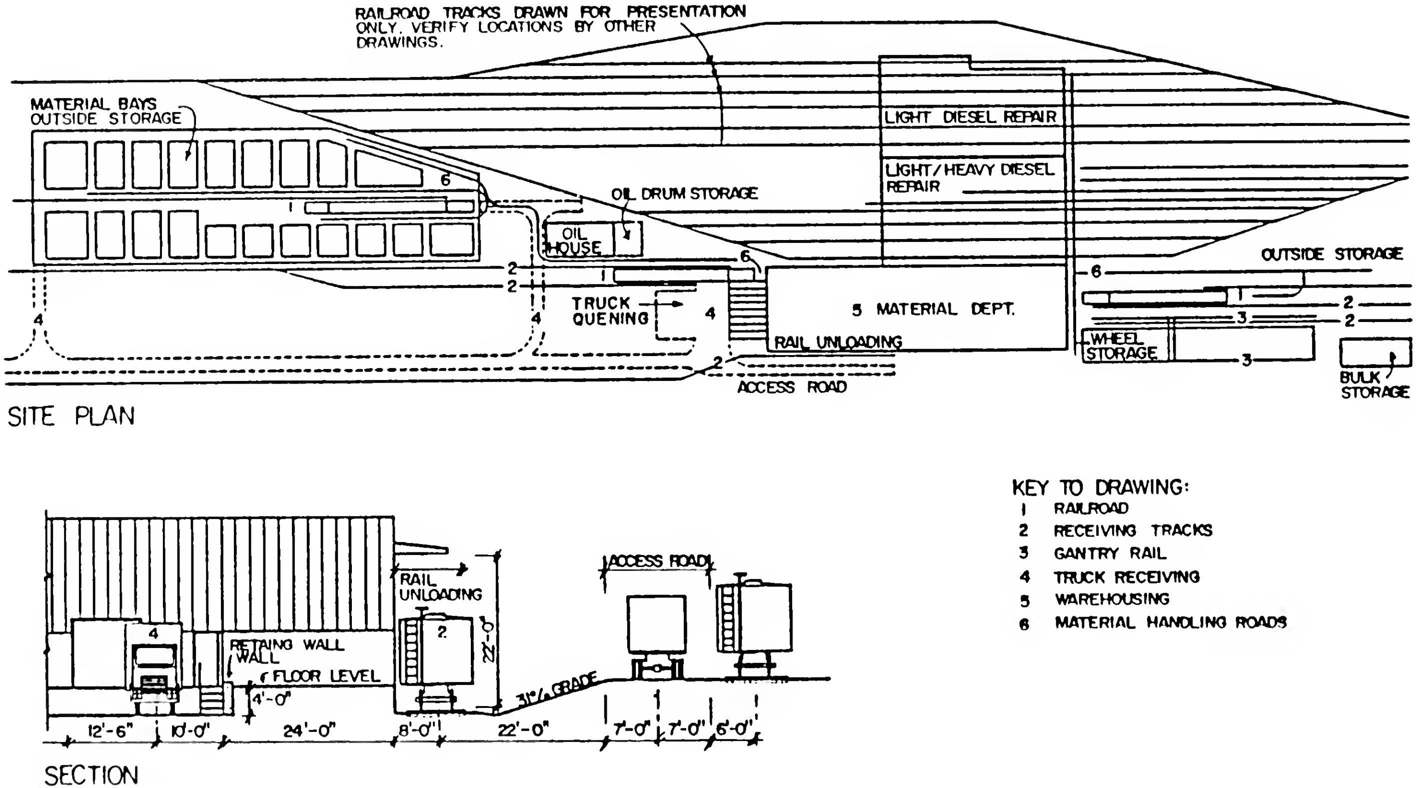
It is essential that the communication equipment be located in an office that has adequate personnel coverage for the receiving and sending of information.

4.11 FIRE PROTECTION

4.11.1

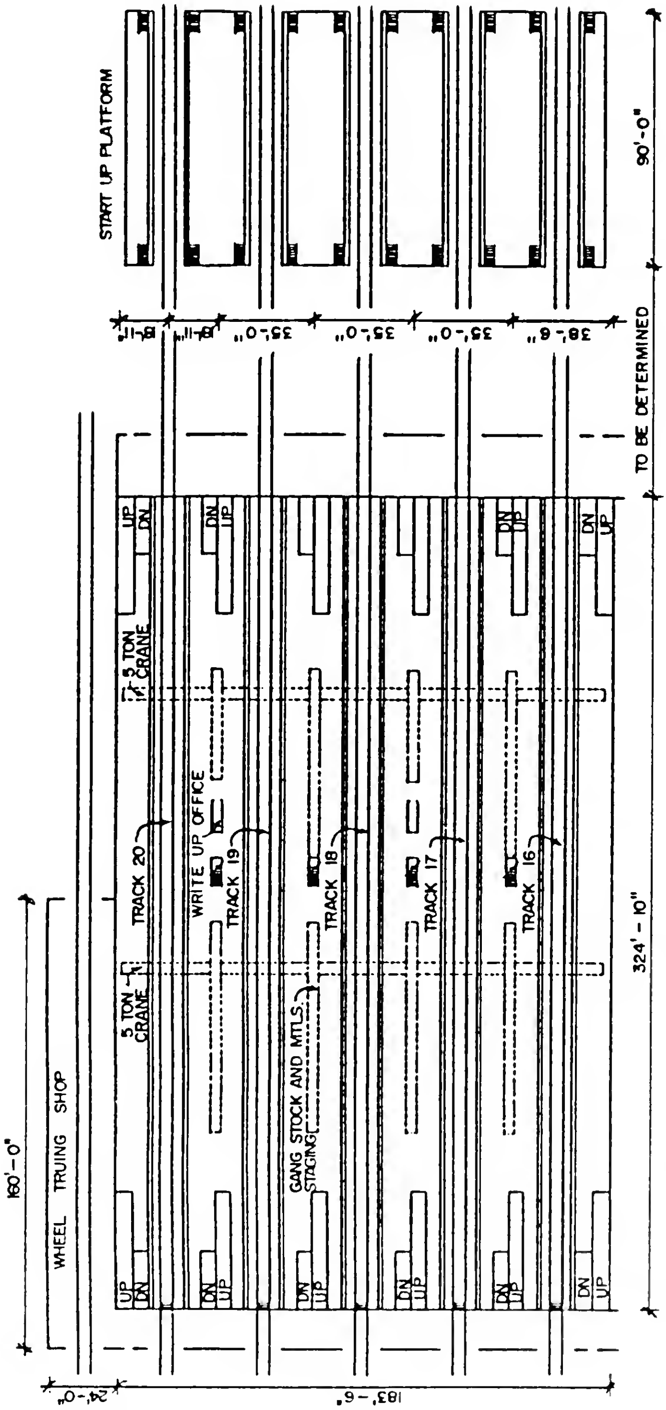
The basic fire protection should consist of fire hydrants strategically located on the outside of the building. Dependent on local codes or insurance requirements, the use of interior standpipes, dry chemical and carbon dioxide hand extinguishers and use of fire wall all should be evaluated. Wet pipe fire protection systems should be freeze-proofed in the vicinity of large overhead track doors in cold climates. If the railway company has an insurance or risk management program, the appropriate rating organization may be consulted during the design phase. In developing a site plan, locating yard hydrants to be accessible from multiple directions in case grade crossings are temporarily obstructed by locomotives or other equipment, is desirable.

AREA Chapter 6, Part 4 Design Criteria for Diesel Repair Facilities



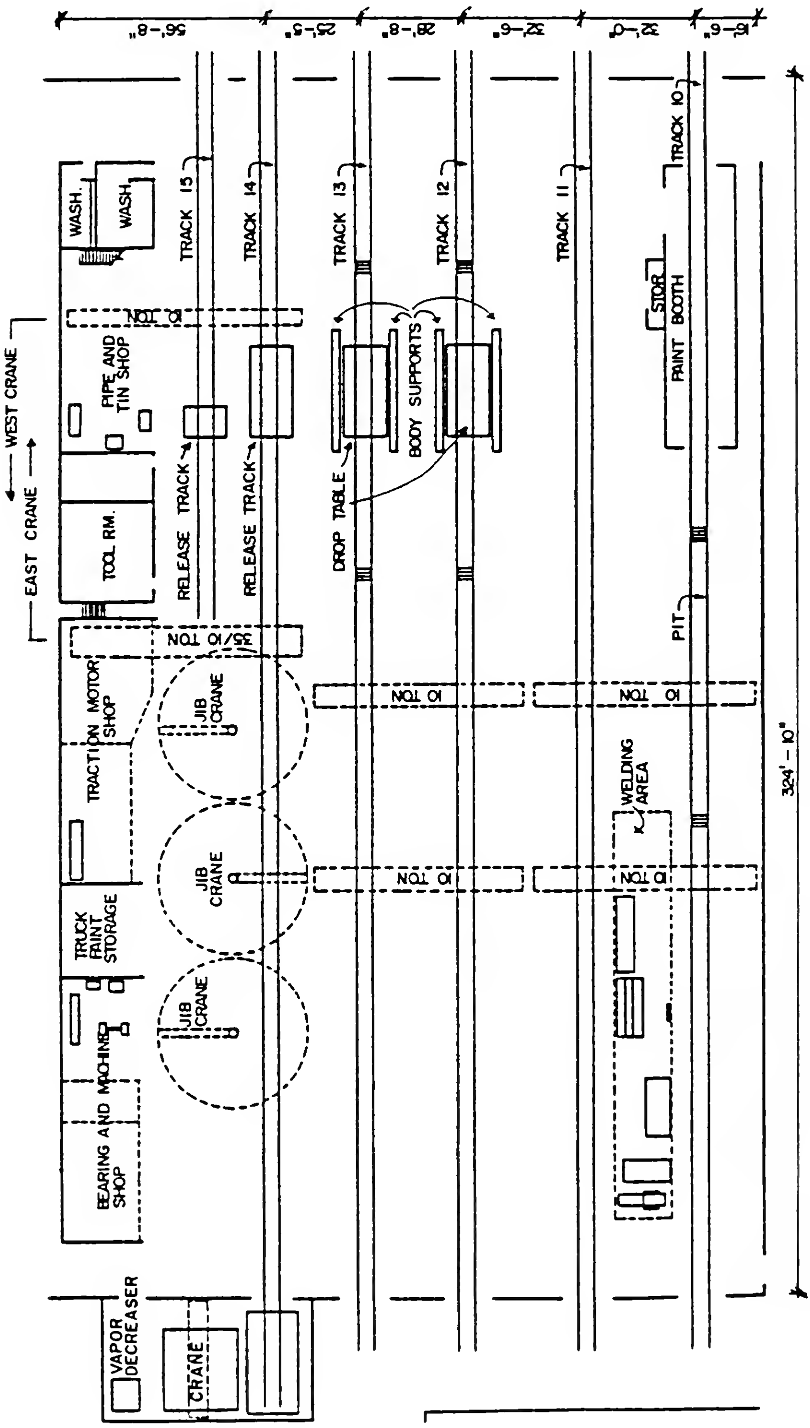
TYPICAL SITE PLAN

Figure 4-1



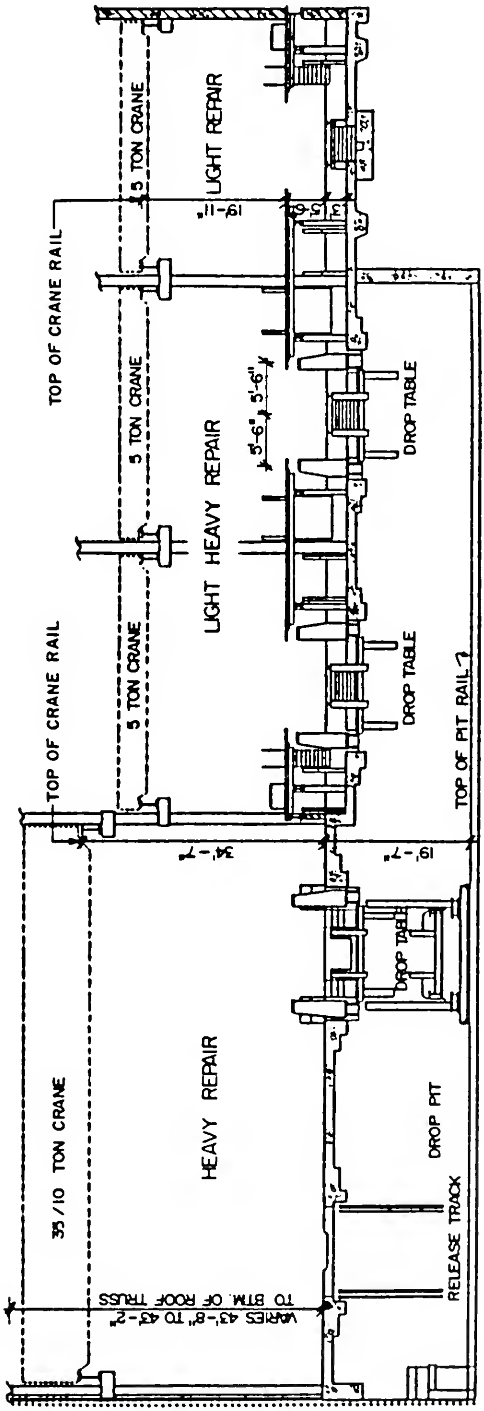
TYPICAL LIGHT REPAIR FACILITY

Figure 4–2



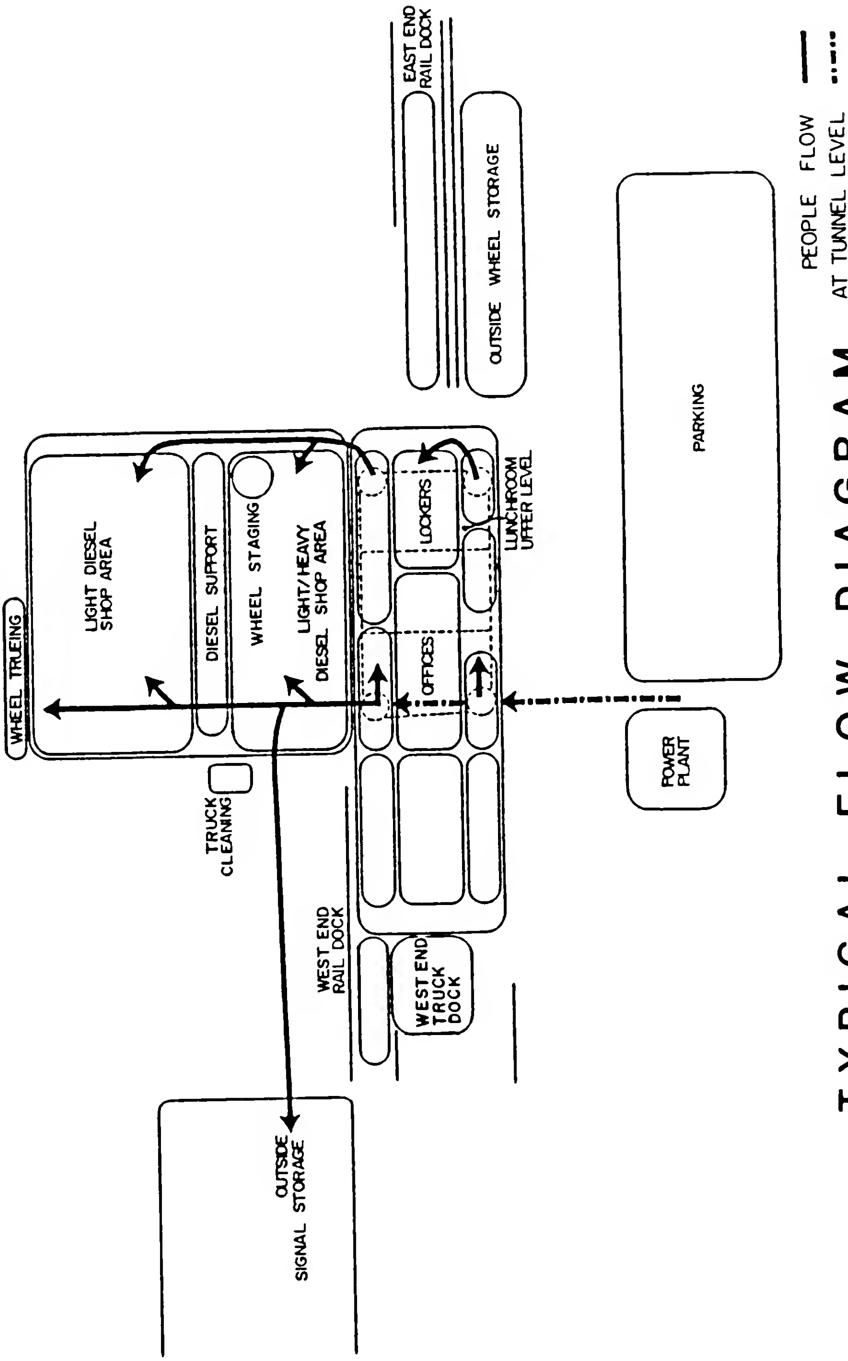
TYPICAL HEAVY REPAIR FACILITY

Figure 4–3



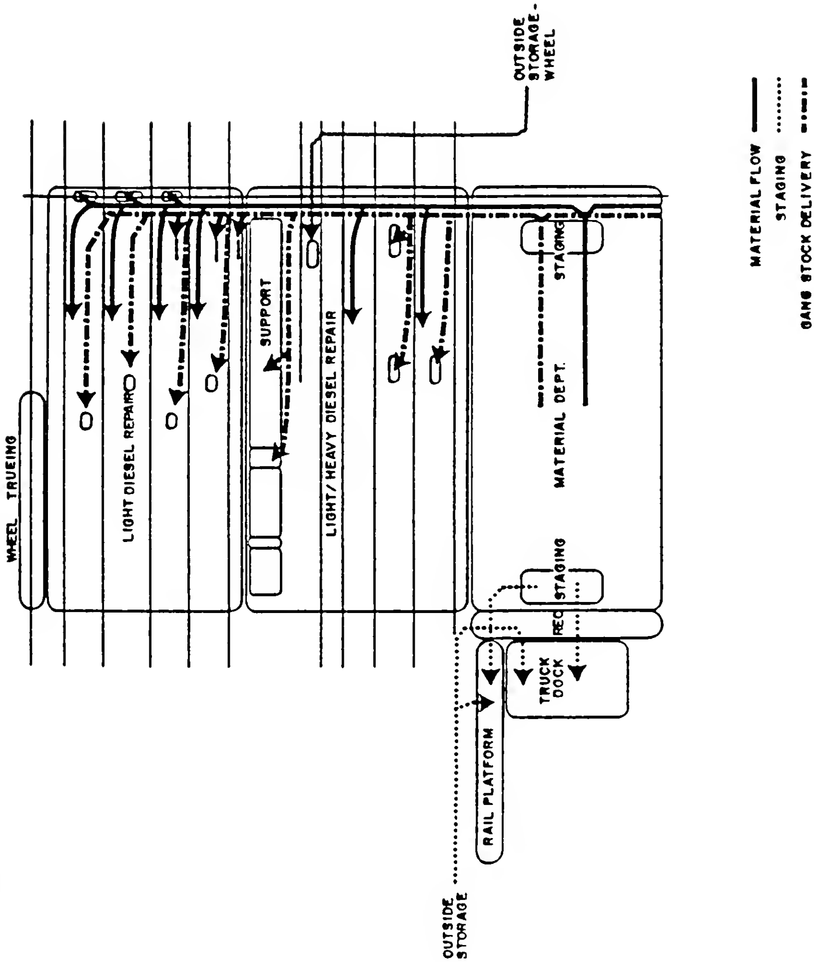
TYPICAL CROSS SECTION

Figure 4-4



TYPICAL FLOW DIAGRAM

Figure 4–5



TYPICAL MATERIAL FLOW DIAGRAM

Figure 4–6

LOCOMOTIVE SHOP CHECK LIST

A. Location

1. City ______________________________ State ______________________________
2. Yard ______________________________
3. Zoning Classification ____
4. Codes and Regulations
   a. Building
   b. Ventilation
   c. Heating
   d. Fire Protection
   e. Lighting
   f. Railroad Operating Criteria
   g. Handicapped
   h. Sanitary/Industrial Waste Treatment
   i. Solid Waste Disposal
   j. Air/Noise Control

B. Trackage

1. Yard Assess
2. Storage
3. Movements

C. Locomotive Fleet

1. Number
2. Models
3. Production
4. Bad Order Ratios

D. Functions

1. Inspection
2. Servicing
3. Cleaning
4. Running Maintenance
5. Light Repair
6. Light/Heavy Repair
7. Heavy Repair
8. Component Rebuild
9. Start-up
10. Load Test
11. Stripping/Painting
12. Fueling and Sanding

E. Departments Involved

1. Administration
2. Motive Power
3. Engineering
4. Maintenance of Way
5. Communications
6. Materials Handling

F. Site Constraints

1. Adjacent Tracks
2. Adjacent Buildings
3. Noise Impacts
4. Underground Utilities
   a. Electric
   b. Gas
   c. Steam
   d. Air
   e. Communications
   f. Sewers
   g. Water
5. Above Ground Utilities
   a. Electric
   b. Gas
   c. Steam
   d. Air
   e. Communications
6. Utility Easements
   a. Electric
   b. Gas
   c. Sewers
   d. Communications
7. Future Expansion
8. Soils Conditions
   a. Bearing Capacity
   b. Water Table
9. Parking
   a. Employee
   b. Company Vehicles
   c. Visitors

G. Locomotive Mover

1. Traction Motor Movement from Loco Batteries
2. Hy-Rail Tractor
3. Cable Progression System
4. Hostler

H. Equipment

1. Cranes
    a. Type (bridge, underhung, gantry, jib)
    b. Size/Capacity
    c. Number
    d. Control
    e. Hook Height

2. Drop Table
    a. Size/Capacity
    b. Number of Active Tracks
    c. Release Tracks
    d. Auxiliary Single Axle Tops

3. Jacks
    a. Type (fixed ______ portable ______)
    b. Size/Capacity
    c. Number

4. Washer/Cleaning
    a. Type (chemical, pressure, water, recirculating)
    b. Size
    c. Number

5. Wheel Truing
    a. Access
    b. Size

6. Progression System
    a. Type
    b. Size

7. Paint Booth

8. High Pressure Washers

9. Dust Collection

I. Material Handling

1. Conveyance
    a. Fork Lift
    b. Conveyor
    c. Totes
2. Material in (list)

3. Material out (list)

4. Storage—Parts
    a. Warehousing
    b. Work Station

5. Storage—Tools

6. Storage (Hazardous)

J. Pits

1. Depth

2. Drainage

3. Services and Utilities
4. Lighting
5. Access
   a. Ramp
   b. Stairs
6. Track Support
7. Storage Items
8. Material Movement

K. Platforms

1. Height
2. Clearance
3. Services and Utilities
4. Access
   a. Ramp
   b. Stairs
5. Storage Items
6. Material Movement
7. Railings and Protection

L. Mechanical Services

(List for each equipment and work station item) (Identify pressure, flow capacity, storage location & valving)

1. Oxygen
2. Acetylene
3. Natural Gas
4. Compressed Air
5. Cleaner
6. Bearing Oil
7. Journal Oil
8. Diesel Fuel
9. Lube Oil
10. Dirty Lube Oil
11. Treated Radiator Water/Radiator Water Treatment
12. Radiator Water Reclaim
13. Industrial Water
14. Potable Water
15. Solvents

M. Electrical Services

(List for each equipment and work station item) (Identify voltage, amps, light level)

1. Welding

2. Receptacles for tools
3. Battery Charges
4. Special Lighting
5. Special Equipment

N. Building
(Identify number and sex of users for each)

1. Offices
   a. Administrative
   b. Shop
2. Training Facilities
3. Lockers
4. Toilets/Showers
5. Lunchroom
6. Computer and Communication Requirements
7. Floor Treatments/Hardeners
8. Visual Control from Offices
9. Security

O. Building Environment
(Identify for each space)

1. Lighting levels
2. Ventilation (Air Changes/hour)
3. Air Conditioning (Temperature/Humidity Requirements)
4. Heating
   a. Fuel Availability
   b. Heat Source
   c. Distribution System
5. Exhaust Requirements by Specific Operations

P. Waste Treatment

1. Location
2. Effluent Limits
3. Collection System

Q. Drainage

1. Surface Run Off
2. Sanitary
3. Industrial
4. Oil Collection

R. Miscellaneous

1. Corrosive Cleaners and Exhaust
   a. In ducts
   b. On Building Components

2. Interferences
   a. Ducts
   b. Lighting
   c. Piping
   d. Trenches
   e. Structural
   f. Fire Protection
   g. Cranes
   h. Fork Tracks
   i. Hose Connections

Proposed 1988 Manual Revision To Chapter 7 - Timber Structures

Chapter 7 has been reorganized and decimalized. It will have four sections instead of the current six. (1-5 and M). Various changes have been made, including referencing some standards and changing the clearance diagram to conform with Chapter 28. This same chapter revision was submitted as a 1987 Manual Revision, however was not approved pending completion of associated artwork.

Because of the size of this proposed 160-page revision, it is not being printed here, but is available by writing A.R.E.A. Headquarters and enclosing $3.00.

Proposed 1988 Manual Revisions To Chapter 8 - Concrete Structures And Foundations

On the following pages are proposals for a complete revision of Part 11 — Lining Railway Tunnels and a new Part 25 — Slurry Wall Construction.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Part 11

Lining Railway Tunnels

1988

(Rewritten 1988)

SPECIFICATIONS FOR NON-STRUCTURAL CONCRETE RAILWAY TUNNEL LINING

11.1 GENERAL

11.1.1 Scope

(a) These specifications cover the lining of new tunnels and those portions of old tunnels which involve no extraordinary side pressure or special features.

11.2 DESIGN

11.2.1 Interior Dimensions

(a) The interior dimensions of the clear space provided for single and double-track tunnels shall not at any point be less than tunnel clearances recommended by the AREA Manual. Where legal requirements provide clearances greater than AREA, such legal requirements shall govern.

(b) On curved track, the lateral clearance shall be increased in conformance with AREA Manual Chapter 28, Part 1. The superelevation of the outer rail shall be in accordance with the recommended practice of the AREA, Chapter 5.

(c) To provide for drainage, minimum side clearance of 10 feet from centerline of track shall be used in tunnels likely to be wet. Where ventilation is required, the height of single-track tunnel shall be increased 1 foot or more.

11.2.2 Preliminary Data

(a) Information shall be obtained for design of new tunnels, consisting of field surveys showing geological formations, ground water conditions, locations of faults, core borings, hardness of rock to be encountered, together with any special features and data on existing tunnels through similar formations. Where a new tunnel is driven adjacent to an existing tunnel, records shall be searched for data as to ground water conditions, fault zones, and other special features. Consideration should be given to taking core borings from existing adjacent tunnels.

11.2.3 Floors

(a) Floors should, if practical, be paved and may have either ballasted floor track section, direct fixation to the concrete floor, or other suitable track design.

11.2.4 Sidewalls and Arch

(a) The depth of the sidewalls in sound rock shall be at least 6 inches below the bottom of the gutter for ballasted track sections and at least 6 inches below the intersection of the floor surface with the sidewalls for solid track sections. In unsound rock, the sidewalls shall be carried down to provide stable foundation. At portals and vicinity, sidewalls shall extend at least 6 inches below the frost line.

(b) The minimum thickness of the sidewalls and arch shall be:

1. Where temporary supports for excavation are not required:
   Single track — See Figure 11.2.4A or 11.2.4B
   Double track — See Figure 11.2.4C

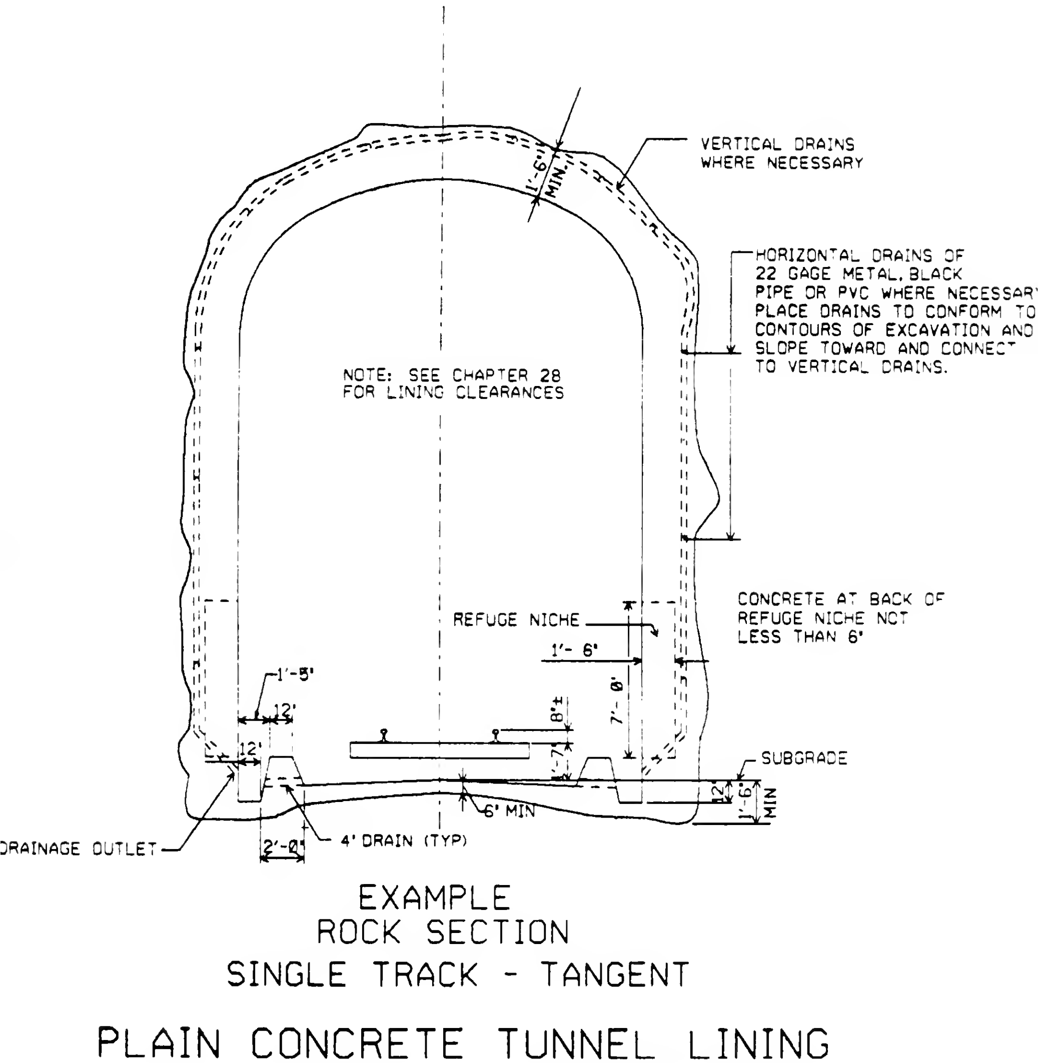
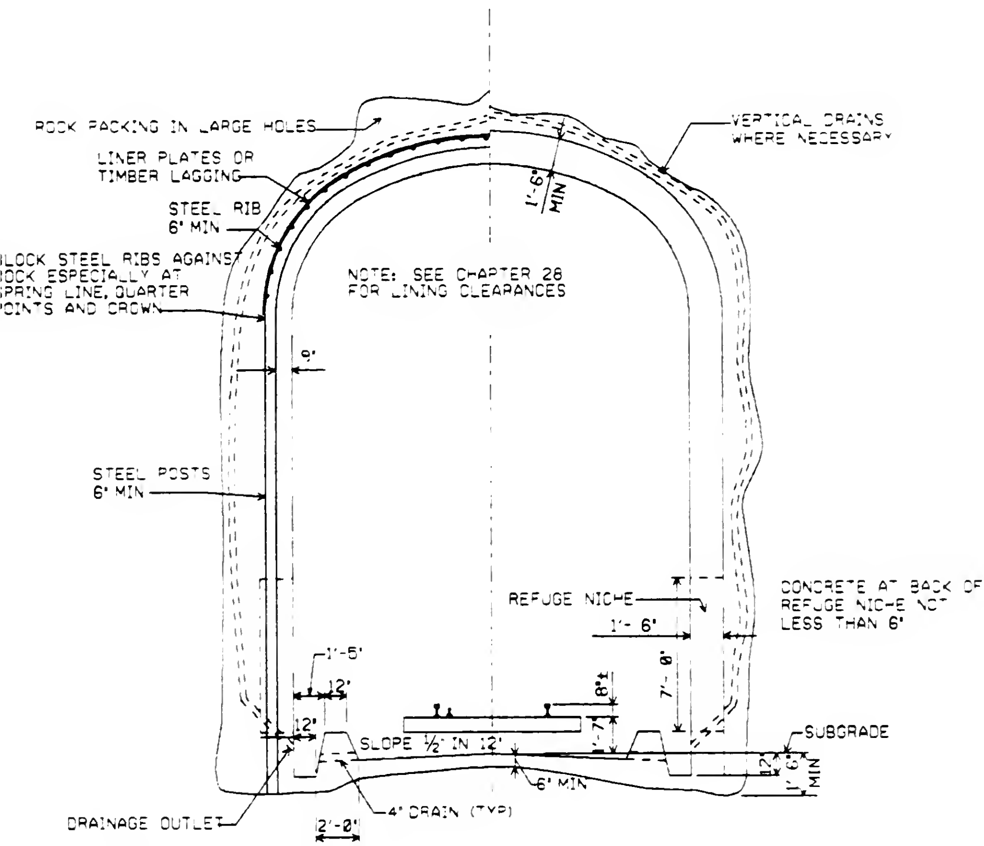


Figure 11.2.4A



STEEL SUPPORTS FOR WALLS AND ROOF

ROCK SECTION WITH BACK FORM

EXAMPLE

SINGLE TRACK - TANGENT

PLAIN CONCRETE TUNNEL LINING

Figure 11.2.4B

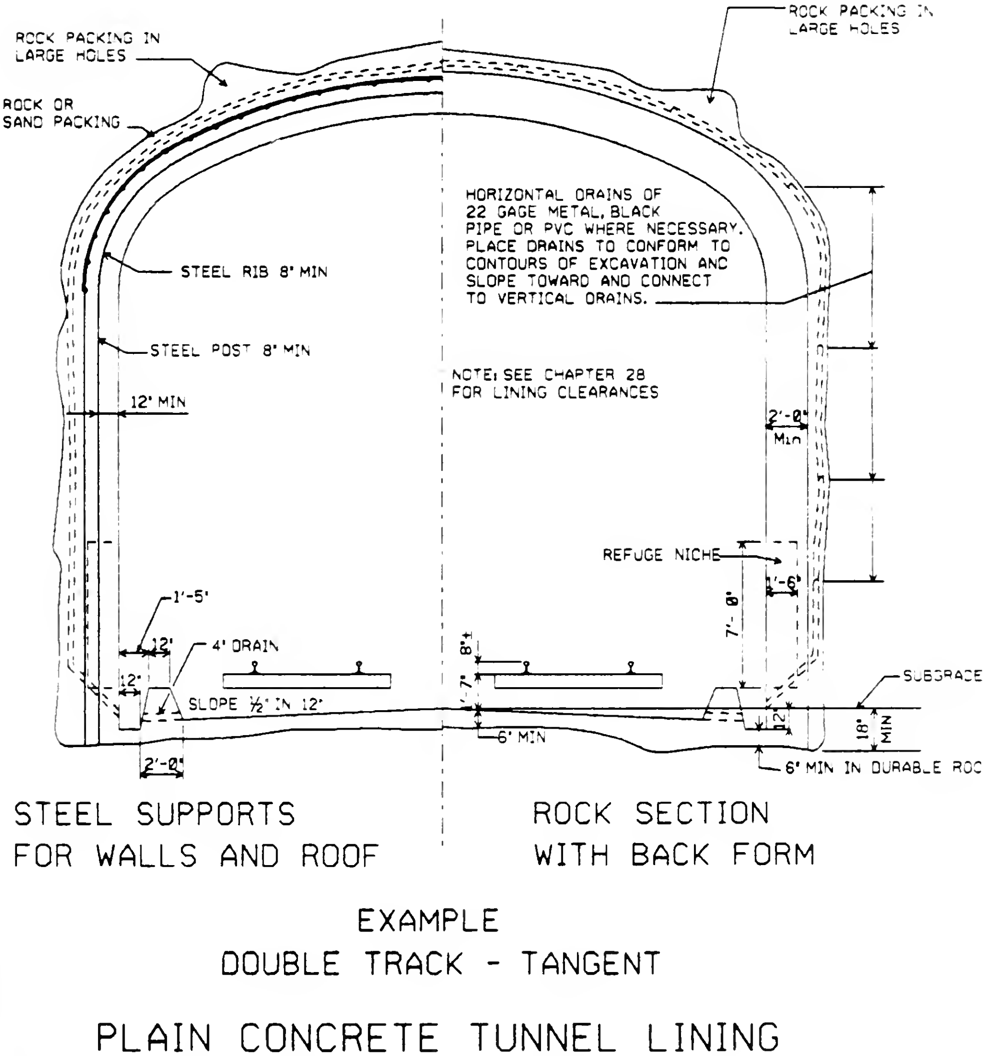


Figure 11.2.4C

2. Where temporary supports are required for face of excavation see Figure 11.2.4B or 11.2.4C.

(c) Encased timber sets are subject to decay and are not recommended. Exposed timber sets create a fire hazard and also are not recommended.

(d) Steel sets are spaced at least 8 inches apart, and in general not greater than 4 feet apart. Solid liners may also be considered.

(e) Lagging may be wood, steel lags, steel liner plates, or steel water-diverting lagging. Where the nature of the rock and water conditions permit, lagging shall be spaced to allow clearance of 4 inches or more between lags to permit free access of concrete to the face of the tunnel excavation. Prior to concreting, remove as many lags as is possible. Where it is necessary to solid-lag for protection during excavation and where it is impractical to open up the lagging just prior to concreting, the space between the lagging and face of excavation shall be packed with lean concrete, crushed stone, coarse gravel, or pea gravel placed pneumatically. Consolidation grouting shall be used to fill any voids behind lining.

11.2.5 Construction and Expansion Joints

(a) Properly placed and consolidated construction joints do not require keyways. Waterstops shall be provided as necessary. Monoliths shall be as long as practical to minimize the number of construction joints.

(b) Construction joints shall not be formed at such locations where they might reduce the effectiveness of the lining to resist pressure from surrounding earth or rock.

(c) No expansion joints need to be provided other than construction joints.

11.2.6 Drains

(a) Wherever ground water is encountered, vertical and diagonal openings, trench drains, PVC or iron pipe drains shall be installed between the concrete lining and rock. Adequate outlets shall be provided through sidewalls with the outer end of the outlets not less than 12 inches above the bottom of the gutter. Subdrains shall be provided under the concrete floor wherever ground water is found. Drains shall be provided through curb to drain ballast section.

(b) Wherever ground water drains are installed, they shall be attached to the rock so as to prevent being clogged when concrete is poured.

(c) Drain type selection should take into consideration an analysis of ground water constituents and effects of water aeration to discourage formation of precipitates or adverse chemical reaction which may plug or damage the drainage system.

11.2.7 Refuge Niches (Bays)

(a) Refuge niches shall be provided as shown on the example figures at approximate intervals of 200 feet and staggered with opposite sides so that spacing of niches shall be approximately 100 feet. Bottom of niches shall be at elevation of bottom of track ties for ballasted track sections and at elevation of intersection of invert and walls for solid track sections. Where tunnels are more than 1 mile in length, larger refuge niches shall be provided at appropriate intervals to accommodate motor cars.

11.2.8 Conduit and Inserts

(a) Where required, provisions shall be made in the lining for conduit or hangers for cables, wires, and lights.

11.3 FORMS

11.3.1 General

(a) Forms shall conform to requirements as outlined in Part 1 of this Chapter, together with additional provisions given herewith.

(b) The length of forms between construction joints shall be as long as possible to limit number of joints.

11.3.2 Filling of Forms

(a) The space between the face of the form and face of excavation or tight lagging shall be entirely filled with concrete, except for drainage openings, and except that large cavities back of the normal face of excavation may be packed as outlined in Article 11.2.4.

11.3.3 Removal of Forms

(a) Forms shall not be removed until concrete has reached a strength sufficient to prevent distortion and sustain its own dead load.

11.3.4 Inspection Doors

(a) Forms shall be provided with inspection doors in the arch and walls so that the concrete can be thoroughly vibrated and inspected during the placing.

11.4 CONCRETE

11.1.4 Specification

(a) Concrete for lining shall be proportioned and placed in accordance with Part 1 of this Chapter, together with the additional provisions given herewith.

11.4.2 Order of Placing

(a) A section of the wall and footing may be placed separately from the rest of the wall but construction joint shall not be more than 2 feet above the top of ballast curb elevation. The remainder of the wall and arch shall be placed monolithically. The floor ballast walls shall preferably be placed in one operation.

11.4.3 Consolidation

(a) All concrete shall be consolidated during and immediately after depositing by means of internal vibration applied in the mass of concrete and external vibration applied to the forms.

11.4.4 Laitance and Bonding

(a) Concrete surfaces receiving new concrete shall be roughened and cleaned of all laitance, dirt, and water before fresh concrete is placed. The consistency of the concrete and method of placement shall be such that laitance seams are not formed. If such seams are formed, they shall be completely removed before additional concrete is placed.

(b) All loose or unsound rock shall be removed below walls and floors before concrete is placed. Where the type of rock makes this impractical, the floor and foundations for the walls shall be reinforced.

11.4.5 Drainage During Placing

(a) Concrete shall not be placed in moving water. Separate and distinct provisions shall be provided to drain any area receiving fresh concrete. Effective weeps and drains shall be provided to prevent any hydrostatic pressure against the lining. Temporary drains shall be grouted after concrete liner has attained design strength.

11.4.6 Shotcrete

(a) Placement of shotcrete shall be in accordance with Part 14 of this Chapter.

Part 25

Slurry Wall Construction

1988

25.1 GENERAL

25.1.1 Purpose

(a) These specifications apply to the use of bentonite slurry trenching techniques for the construction of under ground foundations and cutoff walls.

25.1.2 Scope

(a) The use of bentonite slurry to permit deep, unshored excavation work is an effective construction method when properly employed. The susceptibility to slurry trench techniques of any proposed site must be established by subsurface investigation.

(b) In practice, excavations are kept constantly filled with a bentonite slurry during both digging and backfilling operations. The excavation is held open by the hydrostatic thrust of the slurry. Formation of an impermeable bentontitic seal, or filter cake, at the trench interface prevents slurry loss and allows the development of the hydrostatic head. Presence of slurry in the trench also prevents the drawdown of the ground water table, a frequent result of open excavation work.

(c) Slurry applications include temporary and permanent construction of concrete foundation walls, both precast and cast-in-place, and flow-controlling cutoff walls. Critical procedures such as cleaning the slurry, cleaning the bottom of the trench and checking slurry density prior to placing tremie concrete should be considered.

(d) The engineer's decision to use the slurry trench method on an excavation project, and the design of the appropriate slurry, must be based on:

1. Analysis of subsurface investigation findings.
2. Soil stability analysis.
3. Risk assessment.
4. Site constraints.
5. Economic alternatives analysis.
6. Possible adverse effects of stray current on slurry quality.

25.2 DESIGN

25.2.1 General

(a) Slurry walls are designed in large part according to accepted foundation engineering practices; however, the interaction of the slurry and the surrounding soil affects the stability and functionality of the wall to a much greater degree than in most other structure types.

(b) Slurry walls must be designed for both the construction and the final conditions. While the design for one condition affects the other, different forces and criteria apply.

25.2.2 Qualifications

(a) The engineer for the design of the slurry wall shall demonstrate previous experience in the design of slurry trench construction.

25.2.3 Subsurface Investigation

(a) Subsurface investigation prior to the design of the slurry system shall be in accordance with Part 22 of this Chapter. Additional information, such as permeability and pH of the soil, may also be required as part of this investigation.

25.2.4 Construction Phase

25.2.4.1 Trench Design

(a) Design of the slurry trench for the construction phase basically has the following goals:

1. Provide stability of the trench during excavation
2. Prevent drawdown of groundwater
3. Minimize settlement of surrounding soil and structures bearing thereon
4. Minimize loss of the slurry into the groundwater, of particular concern in very porous soils
5. Assurance of integrity of adjacent structures

25.2.4.2 Stability Analysis

(a) The hydrostatic pressure from the slurry in the trench provides the main stabilizing force to offset the pressures acting on the trench walls. These include pressures due to:

1. Soil loads
2. Surcharge loads, including structures and construction equipment
3. Fluid pressures due to groundwater.

(b) The factor of safety of the trench, with respect to stability based on these pressures, may be calculated as follows:

$$F.S. = \frac{P_f}{P_a + P_s}$$

For cohesive soils

$$P_a = \frac{\gamma H^2}{2} - 2S_u H$$

$$P_s = q_s H$$

Assuming $\phi = 0$

For non-cohesive soils

See figure 25.2.4.2

$$P_a = P_1 + P_2 + P_3 + P_w$$

$$P_1 = (H-H_w)\ \gamma\ K_a\ \frac{(H-H_w)}{2}$$

$$P_2 = (H-H_w)\ \gamma\ K_a\ (H_w)$$

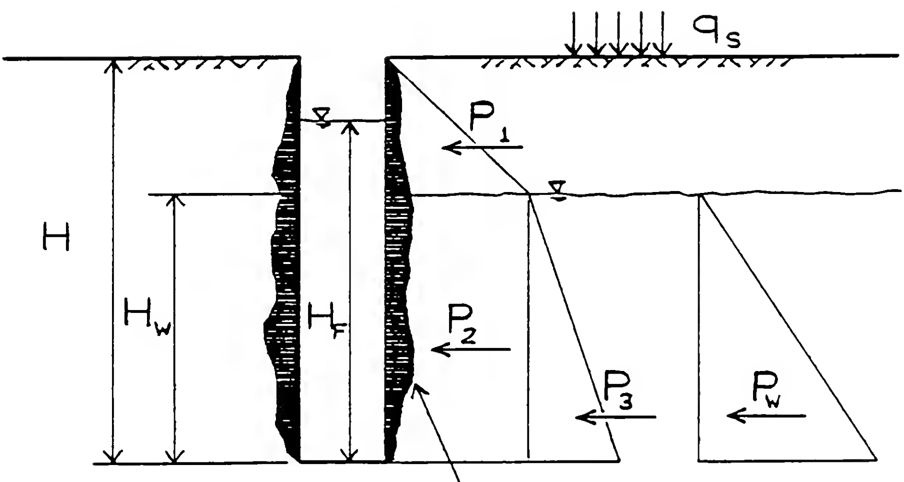
$$P_3 = (H_w\ \gamma' K_a\ \frac{(H_w)}{2}$$

$$P_w = H_w \gamma_w \frac{(H_w)}{2}$$

$$P_a = \frac{(H-H_w)^2}{2} \gamma K_\alpha + H_w (H-H_w) \gamma K_\alpha + \frac{(H_w)^2}{2} (\gamma' K_\alpha) + \frac{(H_w)^2 \gamma_w}{2}$$

$$P_s = K_\alpha q_s H$$

where S_u = Undrained Shear Strength
q_s = Surcharge Loading
H = Depth of Trench
H_f = Depth of Slurry
H_w = Depth of Water Table Above Bottom of Trench
γ = Unit Weight of soil
γ_f = Unit Weight of Slurry
γ_w = Unit Weight of Water
γ = Unit Weight of Submerged Soil
K_α = Active Coefficient
P_a = Active Pressure
P_s = Pressure Due to Surcharge
P_f = Slurry Pressure



FORCES IN NON-COHESIVE SOILS

Fig. 25.2.4.2

(c) Fluctuations in groundwater elevations have a large effect upon the stability equation above. Therefore, in areas of porous soil adjacent to bodies of water or other locations where the water table may vary quickly, the water table shall be monitored.

(d) In addition to the force from the fluid pressure of the slurry, the formation of the slurry cake which develops at the soil-slurry interface may contribute to the stability of the trench. Due to this, the minimum allowable factor of safety for slurry trenches is often lower than that used in the stability analyses of other systems where this interaction between the soil and the retaining substance does not occur. The appropriate factor of safety for the trench shall be determined by the Engineer, based upon previous experience with slurry walls, the soil type and an overall project risk assessment, including the risk involved to the surrounding track or structures.

25.2.5 Methods of Increasing Stability

(a) A number of measures may be taken to increase the stability of the trench:

1. Adjusting slurry level and density to increase the hydrostatic pressure within the trench.

2. The water table outside of the trench may be lowered by means of well points to decrease the hydrostatic pressure outside the trench. Lowering the water table may increase settlement outside of the trench.

3. Grouting to lessen loss of slurry into coarse gravel layers, to lessen sloughing off of wall surfaces into the trench in loose materials or to increase bearing capacity in areas with surcharge loads.

4. Adjusting the length of cut open at one time in order to increase the arching action in the soil.

25.2.6 Final Condition

25.2.6.1 Wall

(a) The design of the wall for the final condition is dependent upon the type and purpose of wall.

25.2.6.2 Cutoff Walls

(a) Slurry cutoff walls may be of either soil-bentonite or cement-bentonite construction. The design of either system shall be based, in part on the following factors:

1. Permeability—In order to be effective, cutoff walls must be keyed into an underlying aquaclude (impervious layer). The soil-bentonite or cement-bentonite mixture shall be designed and tested for the desired degree of permeability, as required to contain the lateral flow of the groundwater. It shall be determined that chemical attack on the cutoff wall from toxic wastes or acids will not reduce the efficiency of the walls.

2. Strength—The cutoff wall shall have sufficient strength to withstand the hydraulic gradient across the wall, in addition to pressures from any embankment or surcharge.

3. Flexibility—The wall shall be sufficiently flexibile to withstand movements due to deformation of the adjacent soil under the loads mentioned above without cracking.

25.2.6.3 Foundation Walls

(a) Foundation walls shall be designed, (see Part 2 of this Chapter) for the following applicable horizontal and vertical loads:

1. Earth pressure (the wall and the accompanying bracing or anchorage systems shall be designed as a braced cut for the differential earth pressures on the wall)

2. Hydrostatic pressure from the difference in water table on the opposite sides of the wall

3. Live load and structure surcharges on the retained fill

4. Direct live and dead loads on the wall

25.3 MATERIALS

25.3.1 Slurry

25.3.1.1 Bentonite-Water Slurry

(a) Slurry shall consist of a stable colloidal suspension of bentonite in water and shall be controlled in accordance with the most current American Petroleum Institute (API) Standard 13B, "Standard Procedure for Field Testing Drilling Fluids," and the following requirements:

1. At the time of introduction of the slurry into the trench, the slurry shall be a mixture of not less than 18 pounds per barrel (42 gallons) of betonite and water. Additional bentonite may be required, depending on the hardnesss and temperature of the water and the quality of the bentonite. The slurry shall have a minimum apparent viscosity of 15 centi-pose or 40 seconds reading through a Marsh Funnel Viscosimeter, a maximum filtrate loss of 30 cubic centimeters in 30 minutes at 100 psi, and a pH of not less than eight.

2. The slurry mixture in the trench shall have unit weight not less than 64 pcf (1.03 gm/cc), not greater than 87 pcf (1.40 gm/cc).

25.3.1.2 Soil-Bentonite Slurry

(a) The slurry mixture, with backfill material, shall be either slurry taken from the trench or slurry meeting the requirements of slurry introduced into the trench. If slurry from the trench is used, it shall be cleaned of unsuitable excavated materials (lumps) and tested prior to reuse.

25.3.1.3 Cement-Bentonite Slurry

(a) The Cement-Bentonite slurry shall consist of a stable suspension of cement in a bentonite water slurry and shall be controlled in accordance with the most current API Standard 10: "Specifications for Materials and Testing of Well Cements" and the following requirements:

1. At the time of introduction of cement in the bentonite-water slurry, the bentonite slurry shall have a minimum 34 seconds reading through a Marsh Funnel, 1,500 ml in and 1,000 ml out.

2. Cement shall be weighed and added to the bentonite slurry to produce a cement-water ratio of 0.20 by weight.

3. At the time of introduction in the trench, the cement-bentonite slurry shall be generally proportioned, so as to have a viscosity corresponding to a Marsh Funnel reading not less than 40 seconds or more than 50 seconds, as measured at the batch plant. If a reading falls outside these limits, the next batch will be corrected to fall within the limits.

25.3.2 Bentonite

(a) Bentonite used in preparing slurry shall be pulverized (powder or granular) premium grade sodium cation montmorillonite and shall meet the most current API Standard 13A "API Specifications for Oil-Well Drilling—Fluid Materials."

25.3.3 Cement

(a) Cement used in Cement-Bentonite slurry shall conform to ASTM C 150, "Requirements for Portland Type 1 Cement."

(b) Cement used in Tremie Concrete shall conform to the requirements of Part 1 of this Chapter.

25.3.4 Water

(a) Fresh water, free of deleterious substances that adversely affect the properties of the slurry, shall be used to manufacture bentonite slurry. It is the responsibility of the Contractor that the slurry resulting from the water shall always meet the standards of this Specification.

25.3.5 Additives

(a) Admixtures of the type used in the control of oil-field drilling muds, such as softening agents, dispersants, retarders or plugging or bridging agents, may be added to the water or the slurry to permit efficient use of bentonite and proper workability of the slurry. Additives shall be used, only with the approval of the Engineer.

25.3.6 Backfill

(a) When consolidation of the trench backfill is a concern, the material for trench backfilling for a Soil/Bentonite slurry trench cut-off wall shall be composed of slurry and selected granular soils obtained from the excavation and/or designated borrow areas. The soil shall be friable and free from roots, organic matter, or other deleterious materials. The backfill shall be thoroughly mixed and reasonably well-graded between the following gradation limits:

Screen Size (U.S. Standard)	Percent Passing by Dry Weight
3/8"	65 to 100
No. 20	35 to 85
No. 200	15 to 35

(b) When a coefficient of permeability for the backfill must be less than or equal to 1 x 10^{-7} cm/sec., the fines in the backfill mix shall have sufficient plasticity so that the material can be rolled into an 1/8 inch thread without crumbling. The water content of the backfill material shall not exceed 20 percent prior to blending with bentonite slurry. Laboratory permeability tests shall be run to verify the suitability of the mix. Dry bentonite can be added to further decrease the permeability if needed.

(c) If consolidation of the back fill is not a concern and 1 x 10^{-6} cm/sec. for the wall is acceptable, the excavated soil, cleaned of deleterious material, should be used for economy.

(d) The material used to backfill trenches where precast panels are used shall be composed of any fine grain soil of low plasticity capable of flowing in place between the precast panel and the walls of the trench excavation. Alternately, the void between panels can be filled with an approved grout mix such as Cement/Bentonite.

25.3.7 Tremie Concrete

(a) Unless otherwise stipulated in this Specification, concrete shall be produced and placed in accordance with Part 1 of this Chapter. Concrete shall have a minimum compressive strength of 4,000 psi in 28 days. Approved additives, such as set retarders, may be used to improve workability. Slump at time of placement shall not be less than 8 inches.

25.3.8 Precast Panels

(a) Precast panels shall meet all requirements of Part 2 of this Chapter.

25.3.9 Permanent Joint Beams

(a) If used with cast-in-place concrete walls, permanent joint beams shall be precast concrete or steel shapes.

25.3.10 Materials Quality Control

(a) Proper quality control shall be maintained for the cutoff wall construction, under the direction of a qualified engineer. Testing requirements are summarized in Table 25.3.10.

(b) Results of all tests performed in accordance with the Specification should be recorded.

MATERIALS QUALITY CONTROL PROGRAM

Subject		Standard	Type of Test	Minimum Frequency	Specified Values
Materials	Water	—	— pH — Total Hardness	Per Water Source or as Changes Occur	As Required to Properly Hydrate Bentonite with Approved Additives
	Additives	—	Manufacturer Certificate of Compliance with Stated Characteristics		As Approved by Engineer
	Bentonite	API Std. 13A	Manufacturer Certificate of Compliance		Premium Grade Sodium Cation Montmorillonite
	Backfill Soils	—	Selected Soils Obtained from a Borrow Area Approved by the Engineer		65% to 100% Passing 3/8″ Sieve 35% to 85% Passing #20 Sieve 15% to 35% Passing #200 Sieve Roll to 1/8″ Thread
	Cement (for Cement—Bentonite Slurry Wall)	ASTM C 150	Manufacturer Certificate of Compliance		Portland, Type 1
Slurry	Prepared for Placement into the Trench	API Std. 13B	—Unit Weight —Viscosity —Filtrate Loss —pH	One Set per Shift or Per Batch (Pond)	Unit Weight ≥ 1.03 gm/cc V ≥ 15 Centipose or 40 Sec-Marsh @ 68° Loss ≤ 30 cc in 30 min. @ 100 psi pH ≥ 8
	In Trench	API Std. 13B 1	—Unit Weight	One Set per Shift at Point of Trenching and Near the Bottom of Trench	Unit Weight = 1.03 – 1.36 gm/cc
Backfill Mix	At Trench	ASTM C 143	—Slump —Gradation	One Set per 200 Cubic Yards	Slump 2 to 6 Inches 65% to 100% Passing 3/8″ Sieve 35% to 85% Passing #20 Sieve 15% to 35% Passing #200 Sieve
Cement-Bentonite Slurry	Upon Introduction in the Trench	API Std. 13B API Std. 10	—C/W Ratio —Viscosity	Each Batch Five per Shift	C/W = 0.20 V = 40 to 50 Sec-Marsh

25.4 CONSTRUCTION

25.4.1 General

(a) The construction of precast, cast-in-place, and flow-controlling cutoff walls all generally follow the same construction techniques, i.e., trench excavation under the influence of a restraining bentonite slurry fluid, and fluid replacement by a wall or barrier material. Construction methods shall be such that slurry material is contained and controlled to prevent loss of trench excavation, leaks, spillage, and then properly disposed.

25.4.2 Trench Excavation

25.4.2.1 General

(a) The trench shall be constructed to line and grade and tolerances as shown on the plans. Boring logs indicate the general type of materials to be excavated.

25.4.2.2 Pretrenching

(a) Pretrenching shall be performed to relocate, remove, or preserve utilities. Isolated additional excavations "in the dry" may be needed to remove obstructions.

25.4.2.3 Trenching Method

(a) Trenching shall be performed using suitable earth-moving equipment, such as grab or clamshell buckets, backhoe, chisels, drills, special patented equipment, or other means for the removal of material. Excavation shall be to full-depth at the point of start, proceed along the trench line full-depth and be performed under bentonite slurry. Methods and techniques chosen are to minimize over-excavation, loosening and/or caving of material outside the designated wall width.

(b) Guide walls are commonly constructed ahead of the trenching operations to assist in the control of line and grade, protect the trench sides against sloughing and/or caving of material, support surcharge loads, and act as a reservoir for the slurry.

(c) The distance of trench excavation at any one time should not exceed practical limits for placement of permanent wall material in a given period of time.

(d) Additional equipment, such as an air lift, pump, or clamshell buckets, may be needed to clean the trench bottom of loose material. Means shall be provided to verify the trench depth and condition prior to wall construction.

(e) Continuous trenching may be allowed in soil-bentonite wall construction, but individual panels with joints are required for reinforced concrete wall construction.

(f) Joints are very important and their design and detail should be carefully considered.

25.4.3 Slurry Material

25.4.3.1 General

(a) Sufficient batch plant mixers, pumps, supply lines, ponds and tanks, and reserve material shall be provided to assure proper mixing and placement of the slurry. No slurry shall be prepared in the trench. Mixing of water and bentonite shall continue until bentonite particles are fully hydrated and the resulting slurry appears homogeneous. The slurry shall be agitated or recirculated in storage ponds or tanks as required to maintain a homogeneous mix.

25.4.3.2 Slurry Introduction

(a) At the start of trench excavation, the bentonite slurry shall be introduced into the excavation.

24.4.3.3 Slurry Maintenance

(a) The slurry shall be maintained in the excavated trench until the completion of the excavation and displacement of the wall construction. The slurry level shall meet the design requirements of Section

25.2 and be maintained within a reasonable distance from the top of excavation, generally within 3 feet, and at least 2 feet above the groundwater level. The Contractor shall have sufficient personnel, equipment, and material ready to raise the slurry level at any time.

25.4.3.4 Quality Control

(a) The Contractor shall maintain his own quality control under the direction of a qualified engineer. Testing of the slurry shall be performed each working shift and shall include testing slurry pH, unit weight, filtration loss, and viscosity.

24.4.3.5 Slurry Disposal

(a) As the slurry is displaced by the construction of the wall, means shall be provided for holding the fluid or for its disposal. No slurry shall be left in ponds at the site. Proper disposal of the slurry shall be the Contractor's responsibility.

25.4.4 Wall Construction

25.4.4.1 General

(a) In addition to the above general construction requirements and methods, the following should be considered by the designer:

25.4.4.2 Cutoff Wall (Soil-Bentonite)

(a) Trench; introduce and maintain bentonite-water slurry. It is essential that the bottom of the slurry trench be keyed a minimum specified penetration into the underlying aquaclude, as indicated by soil borings.

(b) Prepare wall material per project requirements. Soil-bentonite wall material (backfill) shall be composed of slurry and selected soils obtained from designated borrow areas. The soil shall be free of organic or other deleterious materials. The backfill shall be thoroughly mixed to a homogeneous paste consistency and reasonably well-graded.

(c) The wall material shall be placed continuously, starting at the beginning of the trench in a manner that will produce a homogeneous wall free of voids or pockets of slurry. Before drying occurs, the top of the wall shall be capped.

25.4.4.3 Cutoff Wall (Cement-Bentonite)

(a) Trench; introduce and maintain cement-bentonite slurry. If, at any time, the slurry in the trench begins to set or gel before excavation is complete to the full-depth, or otherwise becomes unworkable, additional freshly prepared cement-bentonite shall be introduced. Addition of water to slurry in the trench shall not be permitted.

(b) It is essential that the bottom of the slurry trench be keyed a minimum specified penetration into the underlying aquaclude, as indicated by soil borings.

(c) After initial set, the top of the completed wall shall be checked for decantation. After the wall has been topped off and set, but before drying occurs, the wall shall be capped.

(d) Any time that a wall segment is extended where the slurry in the previously excavated trench has taken a set, the excavation shall remove a minimum of 3 feet overlap into the previous excavated trench.

25.4.4.4 Cast-in-Place Concrete Wall

(a) Trench to the line and grade shown on the plans, introducing water-bentonite slurry as trenching progresses. Trench length open at any one time should not exceed the capacity for placing concrete.

(b) Set panel end forms or joint material as required by the plans.

(c) Place reinforcing (bars or structural steel) in slurry (for reinforced wall construction).

(d) Place wall concrete by tremie (gravity flow or pump) using high slump concrete with 3/4 inch maximum size aggregate, of the compressive strength designated on the plans. The concrete placement shall be controlled to prevent segregation and not be allowed to fall through the slurry, but rather placed on the trench bottom and allowed to displace slurry in accordance with "Depositing Concrete Under Water—Tremie" of Part 1 of this Chapter.

(e) The wall top shall be finished to the grade designated on the plans.

(f) Additional requirements for cast-in-place concrete wall construction are beyond the scope of these specifications.

25.4.4.5 Precast Panel Wall

(a) Trench to the line and grade shown on the plans, introducing water-bentonite slurry as trenching progresses. Trench length should not exceed the capacity for placing precast panels and tremie concrete.

(b) Place precast panels in trench (held in position by guide restraints); displacing the slurry fluid.

(c) Place tremie concrete at toe of set precast panels as shown on the plans.

(d) Backfill with granular material between panel and trench after concrete has set and remove panel restraints.

25.4.5 Inspection

(a) Only competent and experienced contractors, prequalified by the Railroad, should be engaged for slurry wall construction. Slurry trench specialists (as approved by the Railroad) shall supervise the construction, slurry preparation, and quality control. Documentation of all materials used shall be furnished the Railroad, along with certification that the wall construction conforms to the requirements of the plans.

25.5. REFERENCES

API 1985: Recommended Practice, Standard Procedure for Field Testing Drilling Fluids, API RP 13B Eleventh Edition.

API 1985 Specification for Oil-Well Drilling-Fluid Materials, API 13A Eleventh Edition.

Bowles, J. E., 1982: "Foundation Analysis and Design," McGraw-Hill, New York.

Clough, G. W., 1973: Analytical Problems in Modeling Slurry Wall Construction, FCP Res. Rev. Conf., San Francisco.

Gill, S. A., 1978: Applications of Slurry Walls in Civil Engineering Projects, ASCE Preprint 3355.

Millet, R. A., and Perez, J. Y., 1981: Current USA Practice: Slurry Wall Specifications, Proc. ASCE, Aug. 1981.

Xanthakos, P. P., 1979: "Slurry Walls," Published by McGraw-Hill, New York.

Proposed 1988 Manual Revisions to Chapter 10 — Concrete Ties

FOREWORD

Add this sentence as the last sentence of the first paragraph of the FOREWORD:

"These specifications are applicable for conditions using 1987 AAR interchange requirements with respect to axle loads."

Paragraph 1.1.2.3 Load Distribution

Change first sentence to read "The foregoing discussion and the requirements following are based on the knowledge that wheel loads applied to the rail will be distributed by the rail to several ties."

Fig. 1.1.2.3.1

Substitute revised sheet as shown on following page.

Paragraph 1.1.2.4 Impact Factors

Change last sentence to "An impact factor of 200 percent has been assumed."

Page 10-1-7

Calculated sample at foot of page should be changed to reflect new distribution factor (0.56 for 28 inch spacing).

Average Ballast Pressure (psi)

$$= \frac{60{,}000\ (3.0)\ (0.56)}{102 \times 12}$$

$$= 82.4 \text{ psi}$$

Paragraph 1.2.3.12 (a)

Revise to Read: "Steel used for tie bars of two block concrete ties shall provide double the corrosion resistance of 1018 steel as determined by ASTM Specification B-117. Corrosion protection systems such as painting or galvanizing, which may be abraded by sharp angular ballast particles, are not acceptable. Minimum thickness of the tie bar shall be 0.236 inches (6mm)."

Article 1.4.1

Retain heading but remove Table 1.

Add New Paragraphs 1.4.1.1 and 1.4.1.2 as follows:

1.4.1.1 Figure 1.4.1.1 gives the unfactored positive bending moment at the centerline of the rail seat for tie lengths of 8′-0″, 8′-6″, and 9′-0″ for various tie spacings.

Bending moments may be interpolated for other tie lengths.

Requirements for factored design flexural values are obtained by the method described in 1.4.1.2.

1.4.1.2 In consideration of the influence of speed and annual tonnage on tie design, the factored design flexural capacity may be determined from:

M = B.V.T.

Where:

M is the factored design positive bending moment at the center of the rail seat.

B is the bending moment in inch kips taken from Figure 1.4.1.1. for a particular tie length and spacing.

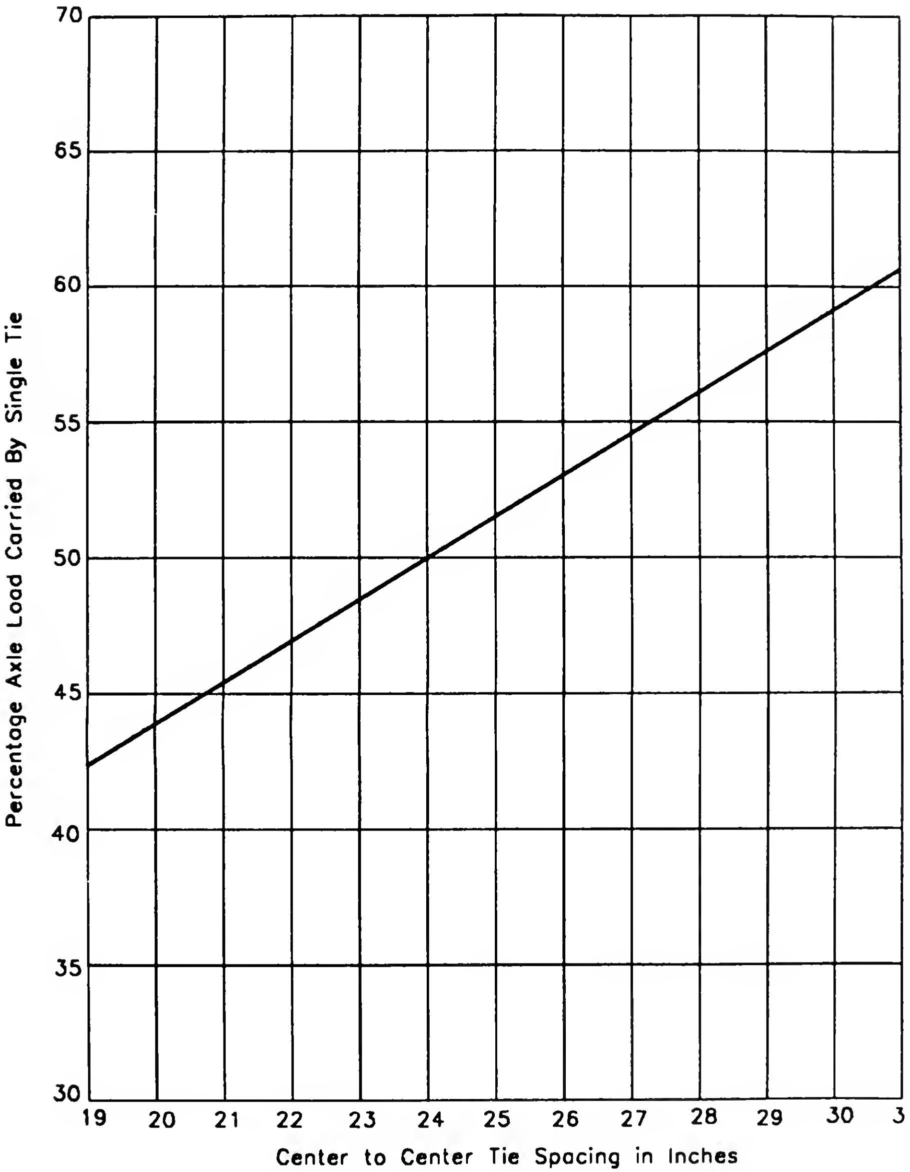


Figure 1.1.2.3.1

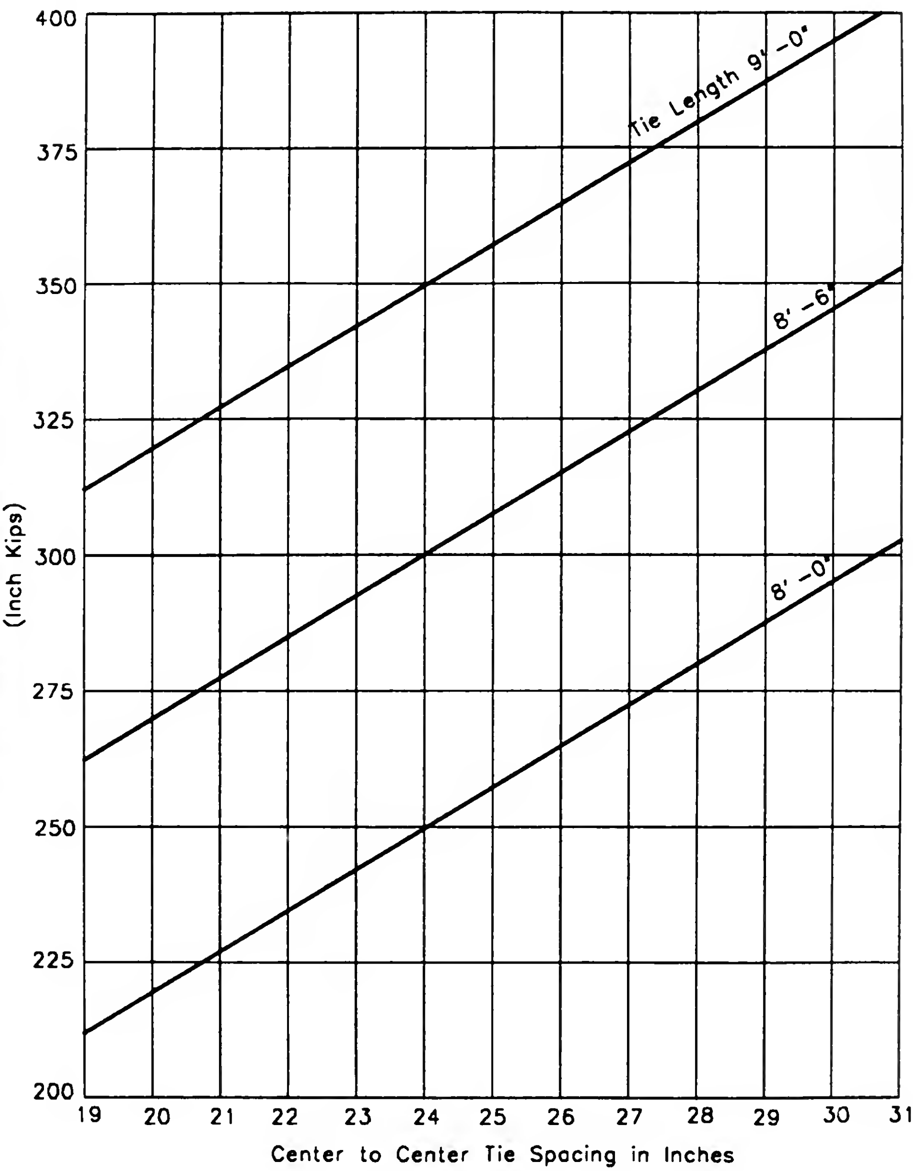
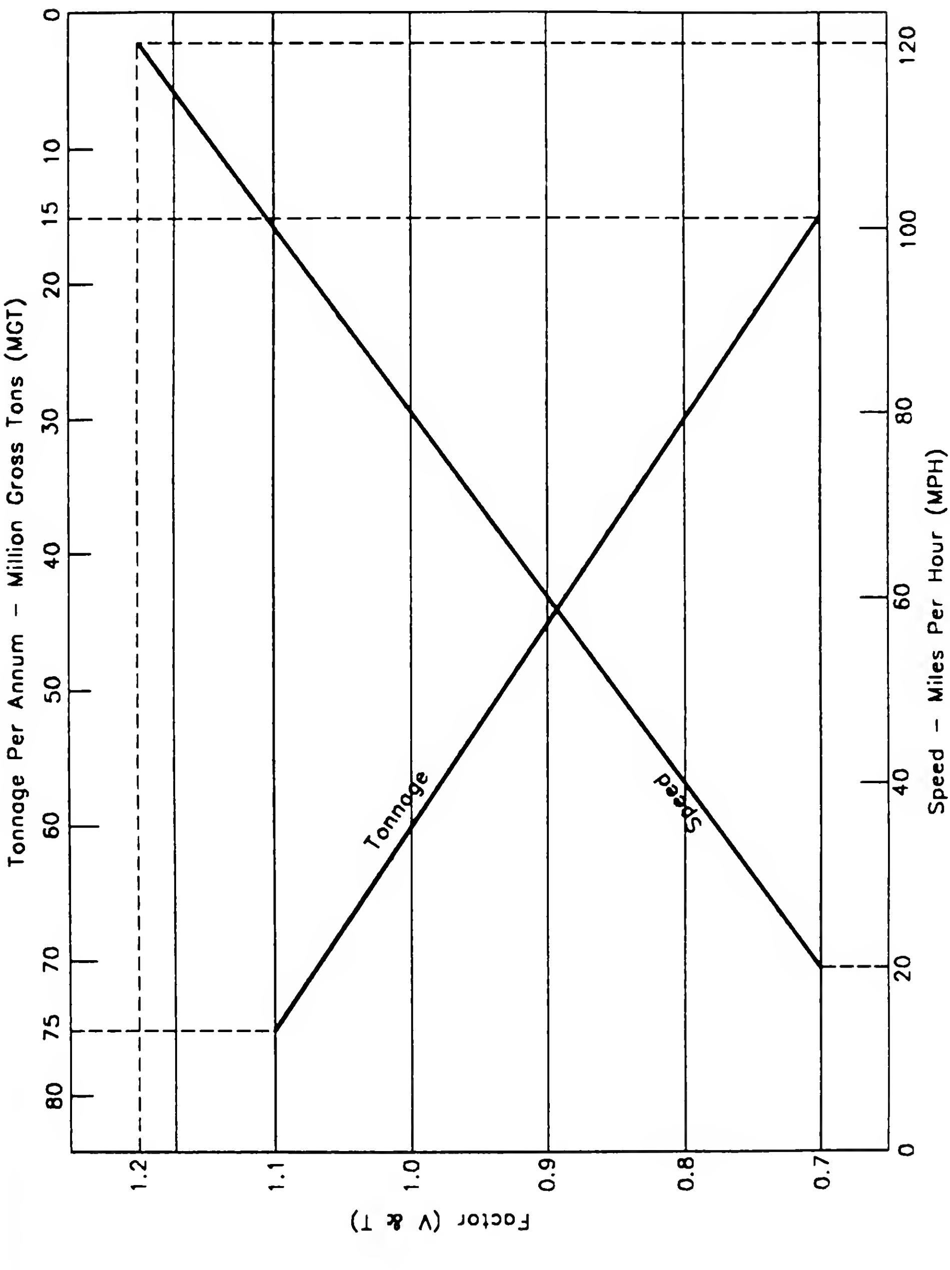

Positive Bending Moment of C/L Railseat (B)
(Inch Kips)
400
375
350
325
300
275
250
225
200
19
20
21
22
23
24
25
26
27
28
29
30
31
Center to Center Tie Spacing in Inches
Tie Length 9'-0"
8'-6"
8'-0"

Figure 1.4.1.1


Tonnage Per Annum - Million Gross Tons (MGT)
0
10
15
20
30
40
50
60
70
75
80
Speed - Miles Per Hour (MPH)
120
100
80
60
40
20
0
Factor (V & T)
1.2
1.1
1.0
0.9
0.8
0.7
Tonnage
Speed

V is the speed factor obtained from Figure 1.4.1.2.

T is the tonnage factor obtained from Figure 1.4.1.2.

The use of strain attenuating tie pads in the rail fastening system has been shown to reduce positive bending moments. The factored design flexural capacity value, M, may, therefore, be reduced at the option of the engineer.

Factored design rail seat negative, tie center negative and tie center positive bending moments may be calculated from the factored design positive bending moment M, using the following factors and interpolating if necessary.

Tie Length	Rail Seat Negative	Center Negative	Center Positive
8′-0″	0.64M	0.92M	0.56M
8′-6″	0.53M	0.67M	0.47M
9′-0″	0.46M	0.57M	0.40M

For tie designs having a reduced bottom width at the center of the tie, the positive moment at the rail seat will increase and the negative moment at the tie center will decrease when compared with a tie with a uniform bottom width, for a given ballast pressure.

In view of this condition, the rail seat and center positive flexural requirements and the negative center flexural requirements shall be modified accordingly. Required moment calculations are to be based on the geometry of the bottom surface of the tie subjected to uniform ballast pressure.

In lieu of moments based on calculations, the rail seat and center positive flexural requirements shall be increased by 10% and the center negative flexural requirements shall be decreased by 10%.

Page 10-1-17:

In each of the following paragraphs, substitute "Section 1.4.1" for the reference to "Table 1."
1.4.2.1
1.4.3.1
1.4.3.2
1.4.3.3

Paragraph 1.4.2.3

Revise to state: "Furthermore, there should be a mimimum pre-compressive stress at any vertical cross section through the rail seat area of 500 psi after all losses and without any applied load."

Section 1.5.1

Retain heading but remove Table II. Renumber Paragraph 1.5.1.1 to 1.5.1.4. Add Figure 1.5.1.1.

Add the new paragraph 1.5.1.1 which should read:

"Figure 1.5.1.1 gives the unfactored positive bending moment at the center line of the rail seat for tie block lengths of 30″, 33″ and 36″ for various tie spacings for Reinforced Two-Block Ties. Bending moments may be interpolated for other tie block lengths. Requirements for factored design flexural values are obtained by the method described in 1.4.1.2."

Add new Paragraphs 1.5.1.2 and 1.5.1.3 as follows:

1.5.1.2 Figure 1.5.1.2 gives the unfactored positive bending moment at the centerline of the rail seat for the block lengths of 30″, 33″, and 36″ for various tie spacings, for Prestressed Two-Block Ties. Bending moments may be interpolated for other tie block designs.

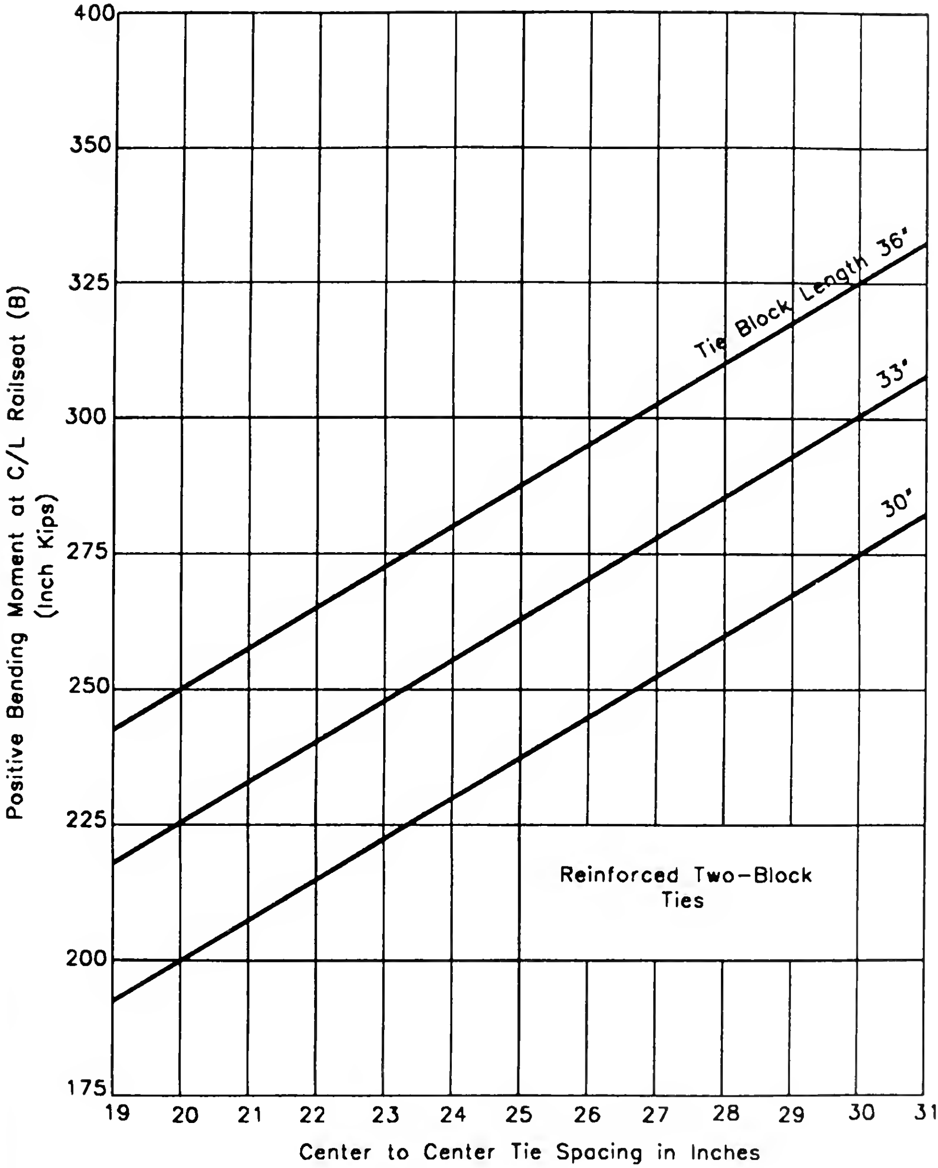

Positive Bending Moment at C/L Railseat (B) (Inch Kips)
400
350
325
300
275
250
225
200
175
19
20
21
22
23
24
25
26
27
28
29
30
31
Center to Center Tie Spacing in Inches
Tie Block Length 36"
33"
30"
Reinforced Two-Block Ties

Figure 1.5.1.1

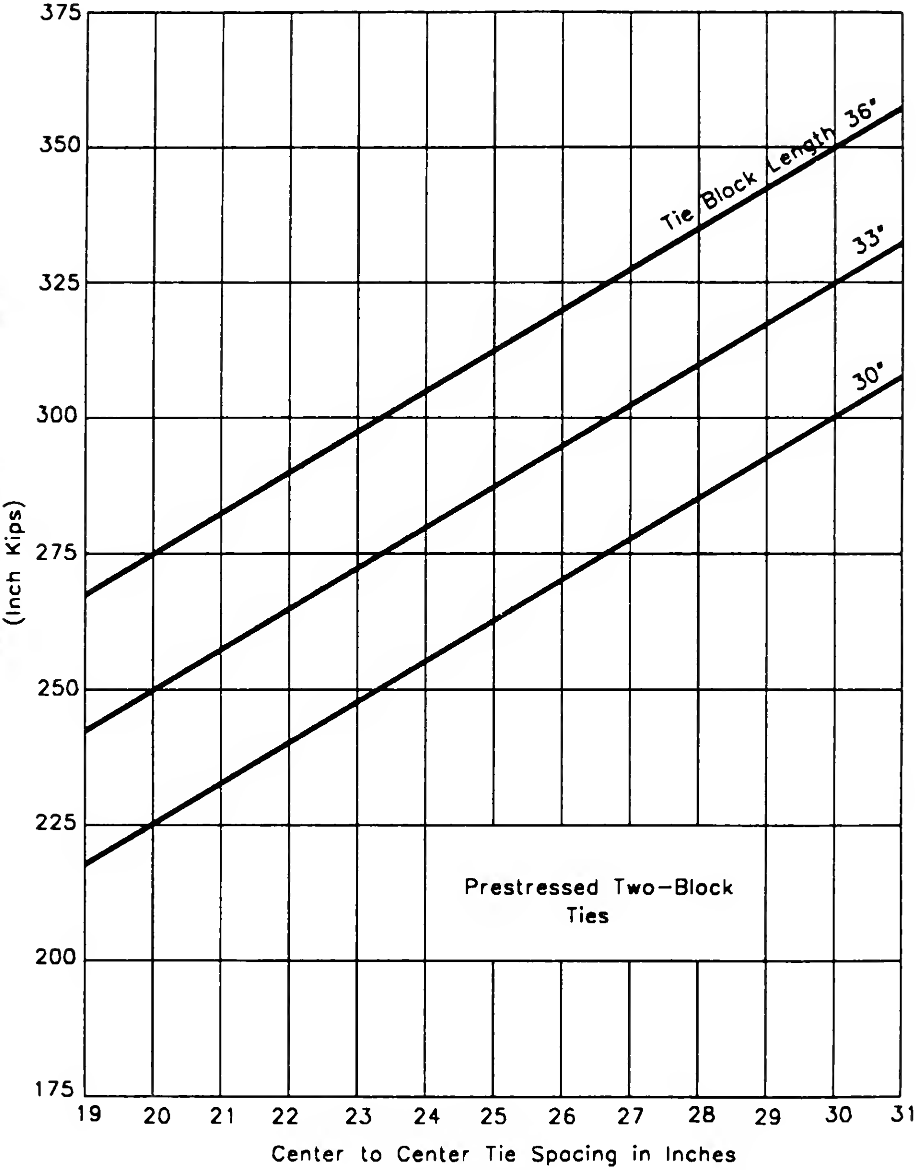

375
350
325
300
275
250
225
200
175
(Inch Kips)
Tie Block Length 36"
33"
30"
Prestressed Two-Block Ties
19
20
21
22
23
24
25
26
27
28
29
30
31
Center to Center Tie Spacing in Inches

Figure 1.5.1.2

1.5.1.3 For two-block reinforced and two-block pre-stressed ties, negative bending moments may be calculated from the calculated rail seat positive bending moment, M as follows:

Tie Block Length	Rail Seat Negative
30″	0.72M
33″	0.71M
36″	0.70M

To New Paragraph 1.5.1.4—Allowable Cracking

Add subsection (e) Maximum and average crack widths shall not exceed those values shown in Table III.

Also delete "1.5.1.1.e" reference next to Table III.

Paragraph 1.5.2.1

Substitute "Article 1.5.1" for reference to "Table II."

Paragraph 1.9.1.5 Rail Seat Repeated—Load Test

Change first sentence to read: "Following the vertical load test for positive moment on rail seat B, the load shall be increased at a rate of at least 5 kips per minute until the tie is cracked from its bottom surface up to the level of the lower layer of reinforcement."

Page 10-1-21

Revise footnote at bottom of page to read:

"Test shall be conducted on three pads. The two pads providing highest and lowest spring rate values shall be discarded and remaining pad shall be used for tests (b) through (h)."

Paragraph 1.9.1.14 Electrical Impedance Test

Change subparagraph (a) to read: "Two short pieces of rail are affixed to Tie 2 using tie pads, insulators and fastenings in a manner appropriate to the fastening system to be used."

Paragraph 1.10.1.1 Sequence of Tests (Tie "1")

Delete (d) Center Positive Bending Moment Test (described in Paragraph 1.10.1.7).

Relabel existing subparagraphs (e) and (f) to subparagraphs (d) and (e) respectively.

Paragraph 1.10.1.2 Sequence of Tests (Tie "2")

Add subsection (a) Center Positive Bending Moment Test (described in Paragraph 1.10.1.7).

Relabel existing subparagraphs (a), (b), and (c) to subparagraphs (b), (c), and (d) respectively.

Paragraphs 1.10.1.4 and 1.10.1.5

Substitute "Article 1.5.1" for reference to "Table II."

Paragraph 1.10.1.6 Center Negative Bending Moment Test

Change first sentence to read "With Tie "1" supported and loaded as shown in Figure VIII, a load increasing at a rate not greater than 5 kips per minute shall be applied until a load of 11 kips causing a moment of 55 inch-kips has been reached."

Paragraph 1.10.1.7 Center Positive Bending Moment Test

Change first sentence to read "With Tie "2" supported and loaded as shown in Figure IX, a load increasing at a rate not greater than 5 kips per minute shall be applied until a load of 11 kips causing a moment of 55 inch-kips has been reached."

Paragraph 1.13.1.2 Rail Seat Load

Add after the first sentence: "In order to determine the rail seat load, a maximum axle load of 82,000 pounds was chosen. Therefore, using a distribution factor of 0.5 for concrete ties spaced at 24 inch centers from Figure 1.1.2.3.1, page 10-1-6 and an impact factor of 200% from Paragraph 1.1.2.4, page 10-1-7, the calculated rail seat load is:

$$\frac{82000}{2} \times 0.5 \times 3.0 = 61{,}500 \text{ pounds}$$

This rail seat load is used to determine the flexural requirements in Art. 1.4.1, for monoblock ties. The design flexural performance values for monoblock ties for other than 24 inch spacing may be determined directly from Figure 1.4.1.1 and by applying the appropriate speed and tonnage factors."

Eliminate second sentence and all that follows.

Article 1.13.2 Flexural Strength of Two-Block Ties

Add new sentence after last. "The rail seat load of 61,500 pounds as determined in Paragraph 1.13.1.2 is used to determine the flexural requirements in Art. 1.5.1, for two-block ties. The design flexural performance values for two-block ties for other than 24 inch spacing may be determined directly from Figure 1.5.1.1 for reinforced two-block ties and Figure 1.5.1.2 for prestressed two-block ties and by applying the appropriate speed and tonnage factors."

Proposed Manual Revision To Chapter 11 - Engineering Records And Property Accounting

A new Chapter 11 is proposed and changes are described in the following Executive Summary.

Executive Summary

As currently presented, Chapter 11 of the AREA Manual outlines specifications for a multitude of forms that were formerly used to report changes to physical property and to maintain permanent property records. Changes occurring in the railroad industry in the past few years have rendered these specifications for all roads less important than in the past. The easing of the reporting requirements of the Interstate Commerce Commission have given roads more latitude in determining the format and detail of their property records. As roads have computerized their reporting and record keeping processes, they have revised their documents to better interface with the particular computer package installed. And finally, property accounting itself has undergone a major change: The adoption of depreciation accounting for track structure.

With these changes in mind, it was felt that the emphasis in the Committee 11 area should be shifted from form specification to practical discussions of basic policy and procedures, regulations, etc. except in the case of map preparation, the thrust is toward a more general outline of requirements rather than specific formatting.

The existing Part 1, General Records and Reports, and Part 2, Construction Reports and Property Records, contain material which, with few exceptions, was reapproved with or without revisions in 1961 and 1962. These sections for the most part describe in detail reports and records designed to be kept by hand. Some space is devoted to use of punch cards for recording data for machine processing.

The existing Part 3, Cost Accounting Methods, Statistical Record and Forms for Analyzing Expenditures for assistance in Controlling Expenditures, contains material written in 1952 with some material revised in 1962. It describes statistical methods and procedures for developing unit costs and other statistics for measuring the efficiency of maintainance of way operations. The forms and reports discussed are designed to be kept by hand.

The existing Part 4, Office and Drafting Room Practices, contains mostly material that was reapproved with revisions in 1962. It illustrates standards for lettering, graphic symbols, titles, etc. for hand drafting of engineering drawings. It also provides specifications for preparation of maps and profiles which have not been changed since 1953.

In view of the age and obsolescence of the existing material Committee 11 had decided that a whole new chapter should be written with the contents of this chapter centered around Committee 11's primary subcomittee topics: Accounting; Office and Drafting Practices; Taxes; and Planning, Budgeting and Controls. A brief synopsis of the new parts follows:

Part I, Accounting, seeks to clarify and explain the Interstate Commerce Commission policy governing the accounting and reporting of property changes. It is a guide which specifies for all personnel engaged in designing, constructing, maintaining or accounting for property the type of work that shall be charged to an Authority for Expenditure (A.F.E.). It also sets forth the information to be reported when a physical change, such as an addition, retirement or upgrade, is made to property requiring the authorization of an A.F.E.

The ICC primary accounts are defined. Representative examples of the items included in and the minimum information to be reported are given for each account. This information in the form provided is not available in this form in any other publication.

The criteria for determining proper charges to capital accounts are given.

In 1983, railroads were required to implement depreciation accounting for *road* accounts which in the past had been expensed. The application of depreciation accounting to these road accounts is described.

A brief review of the basis for Authorities for Expenditure and the procedures for approval are given.

The use of property asset ledgers to record the roadway property assets of the corporation including the use of roadway completion reports to provide for the inclusion of newly completed assets are discussed.

Part 2, Cartographic Specifications, provides updated cartographic specifications. Effective January 1, 1982, the Interstate Commerce Commission eliminated Part 1263, Map Specification, from the Code of Federal Regulations and transferred significantly reduced map specifications to the property account instructions in the Uniform System of Accounts for Railroad, Part 1201. Due to improved technology in map making, the Commission ruled that it is no longer necessary to require railroad companies to maintain the detailed records previously required in part 1263. However, because the Commission has a need for Class I railroad property records in rate, abandonment, merger and purchase proceedings and for accounting, audit and valuation purposes, these carriers are still required to maintain certain basic map information. This rule substantially reduced the regulatory burden associated with maintaining and filing property maps with the Commission. Additionally, this rule relieved Class II and Class III railroads of all map requirements.

Class I railroads are subject to a five-part map specification incorporated as Instruction 2-21, Map Specifications, in Part 1201. The revised map specifications require Class I railroads to:

1. Maintain a current map of its rail property.
2. Furnish copies of such maps to the Commission upon request.
3. Maintain sufficient detail to show right-of-way, track and other important facilities.
4. Provide appropriate indices and titles.
5. Comply with generally accepted map principles.

In keeping with the ICC regulations, general guidelines for map creation and production by railway carriers is provided. The guidelines are flexible to allow their use by individual railroads to meet their special requirements while meeting ICC regulations.

The suggested specifications are divided into the following major areas.

1. General Cartographic Practices - updated relative to ICC regulations and railway carrier operations.
2. Digital Mapping - as applied to rail carrier cartographic requirements.
3. Land Information - relative to mapping.

Part 3, Taxes, provides general discussions of the following topics: Federal Income Tax, State Income Tax, Investment Tax Credit, Property Tax, and Sales and Use Tax.

The differences between ICC and IRS values in capitalizing assets is described. A review of the evolution of federal tax laws is provided with the Tax Reform Act of 1986 treated in detail. The other sections provide succinct presentations on tax related subjects which are of value to everyone involved in constructing, maintaining and accounting for real and personal property.

In Part 4, Planning, Budgeting and Control, the planning and control process is outlined, starting with the setting of corporate goals that deal with strategic issues and ending with the more specific long-term plan and the quite specific annual budget. There is a discussion of the interrelationship of the various planning function, examples of common issues to be addressed, and suggestions of how railroad planning can be organized and accomplished.

The budgeting process, including the preparation of annual capital and maintenance budgets, selection of capital projects, authorization process, accounting for expenditures, and cost control for the projects, is covered in detail. There is a brief synopsis of the setting up of a permanent data base for the capturing of all details. Examples are given for each part of the budgeting and control process as a guide for recommended practice.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

MANUAL FOR RAILWAY ENGINEERING

CHAPTER 11

ENGINEERING RECORDS AND PROPERTY ACCOUNTING

(Rewritten 1988)

FOREWORD

The world of railroading has seen a significant change in all methods of operation since the Technical Manual of Committee 11 was last revised. Much of this change has caused all companies, and individuals within them, to reexamine their business objectives on a long term basis with particular emphasis on how to achieve these objectives in the most economical way possible.

Change has also altered the original scope of Committee 11 in much the same way as companies as a whole have been affected. The Committee has constantly studied and analyzed evolving concepts in an attempt to provide the AREA membership with current and accurate information that can be used as a useful management tool.

It is with this concept of aiding members in mind that this revision to Chapter 11 was prepared. The contents of this chapter will be centered around Committee 11's primary subcommittee topics: Accounting; Office and Drafting Practices; Taxes; and Planning, Budgeting and Controls.

In 1983, individual companies implemented Depreciation Accounting for track structures. Most companies had applied Depreciation Accounting to non-track accounts for a number of years. The Interstate Commerce Commission's order to adopt Depreciation Accounting for track related assets caused all organizations to make measurable changes in Accounting applications. There are still issues surrounding Depreciation Accounting that remain unresolved as of the revision date of this manual.

In the area of Office and Drafting Practices, automation has, in many instances, replaced many former manual tasks. Much of Part 2 in Chapter 11 concerns computer aided drafting systems which many companies have acquired and have working within their Engineering Departments. Many companies without these systems have, at a minimum, begun studies on them to determine individual applications within their organizations.

Two legislative actions had a profound affect on the railroad industry in the 1980's. Deregulation was one action that changed the operating complexion of every company during this period. The second momentous change was the 1986 Federal Tax Act. Part 3 of the Manual revision addresses some of the changes at the Federal Tax level which will have an emphatic impact on business decision making within individual railroad companies.

Part 4 of the Manual contains information on a relatively new topic of study for Committee 11, that of *Planning*, *Budgeting* and *Controls*. Widespread deregulation has caused all of these issues to become extremely important to the survival of all rail organizations in a deregulatory environment. Part 4 addresses a number of different but interconnected disciplines which have become integral parts of successful business practices in the rail industry today.

It should be noted that contents of this Manual revision do not reflect any guidelines pertaining to operations subject to jurisdiction of the Canadian Transport Commission, nor is there mention of recommended practices in the area of equipment accounting. These issues will be addressed in subsequent Manual revisions.

This Manual revision was an effort brought about by the concentrated input of a number of Committee 11 members. The revision was completed by our members for other members of the AREA with the intent of providing a guideline for recommended practices within the scope of study of Committee 11. Furthermore, it is hoped that this Manual will become a useful aid to a wide range of Engineering, Valuation and Planning personnel, as well as other members of the AREA.

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Issued 1988

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Part 1

Accounting

1988

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Part 1

Accounting

1988

1.1 INTRODUCTION

1.1.1 The purpose of this section is to clarify and explain the Interstate Commerce Commission policy governing the accounting and reporting of property changes. It is a guide which specifies for all personnel engaged in designing, constructing, maintaining or accounting for property what type of work shall be charged to an Authority for Expenditure (A.F.E.). It also sets forth the information to be reported when a physical change, such as an addition, retirement or upgrade, is made to property requiring the authorization of an A.F.E.

1.1.2 The main objectives of this section are:

(a) To explain property accounts and define construction and retirement activities applicable to each account.

(b) To achieve complete and uniform field reporting for property additions, changes or retirements with a minimum of detail.

(c) To serve as a guide in the proper preparation of A.F.E. estimates, retirement estimates, reports of completed improvements and reports of property retired.

1.2 EXPLANATION OF CONTENTS OF ICC ACCOUNT LISTINGS

1.2.1 Account Definition

This definition shall be used for proper classification of capital and expense items to the proper ICC account.

1.2.2 Typical Items Included

This is intended only as a representative listing and is not all inclusive. There are many items of material that are common to several units.

1.2.3 Information to be Reported

This identifies the minimum descriptive information which must be shown. This list should be used in conjunction with the instructions and mimimum capitalization rule as presented in each individual company's accounting procedures.

1.2.4 Units of Property

The appropriate units of property are shown for each account. In some case, different units of property are used for the various components of a unit.

1.3 DEFINITION OF UNIT OF PROPERTY

1.3.1 A unit of property may be defined as an operating or functional division of property separately identified and subject to removal as a separate entity.

1.3.2 A unit of property may be one specific item or it may be a group of items so associated on an operating or functional basis that the items can be considered to form one assembly, such as:

(a) A building - composed of foundation, floors, walls, roof, doors, windows, lighting fixtures, plumbing system, heating system, etc.

(b) An interlocker - composed of a building, interlocking machine, mechanical or electrical connections, signals, circuiting, etc.

1.3.3 Generally, the cost and description of each unit of property should be identified, however, for certain "mass" units, such as roadway fences or ballast, the units are grouped and an average price is shown.

1.3.4 The "cost" of each unit includes the cost of material, the cost of labor to install and all other costs incurred in placing the property in service.

1.4 ICC PRIMARY ACCOUNTS

1.4.1 The ICC primary accounts section which follows is presented as a guide for proper account classification and should be used in conjunction with the accounting procedures adopted by each individual company.

1.4.2 ACCOUNT 2 — LAND FOR TRANSPORTATION PURPOSES

Definition

The land for transportation purposes account includes the cost of land and appurtenant water rights, easements and other rights in land, and the cost of assessments for public improvements.

Items Included	To Be Reported	Units of Property
Land	Location	Acre
Assessments	Description	Square Foot
Legal fees	Parcel number	
Appraisals		
Condemnation		

1.4.3 ACCOUNT 3 — GRADING

Definition

The grading account includes the cost of clearing and grading the roadway; clearing, grubbing, and excavating for a tunnel being converted to an open cut and the filling of a bridge. When the height of the track is raised, the cost of the additional ballast added to the existing ballast base is charged to this account.

Items Included	To Be Reported	Units of Property
Clearing	Location	Acre
Ditching	Description	Linear Feet
Excavation		Cubic yard
Embankment		Square Yard
New channels for streams		
Retaining walls		
Rip rap		

1.4.4 ACCOUNT 4 — OTHER RIGHT-OF-WAY EXPENDITURES

Definition

The other right-of-way expenditures account includes the cost of improvement projects across the carrier's right-of-way other than railway facilities and public improvement projects.

Items Included	To Be Reported	Units of Property
Farm crossings	Location	Each
Private crossings	Description	Linear feet
Pipe Lines		
Power Lines		
Other facilities		

1.4.5 ACCOUNT 5 TUNNELS AND SUBWAYS

Definition

The tunnels and subways account includes the cost of tunnels and subways used for the passage of trains and, with the exception of signals, of all ventilating, lighting and safety apparatus therein.

Items Included	To Be Reported	Unit of Property
Tunnels	Location	Each
Subways	Description	
	Length	

1.4.6 ACCOUNT 6 BRIDGES, TRESTLES AND CULVERTS

Definition

The bridges, trestles and culverts account includes the cost installed of all bridges, trestles and culverts which carry tracks over watercourses, ravines, public and private highways, and other railways. The cost of bridges to carry tracks over undergrade crossings, including the necessary piers and abutments to sustain them, is also included.

Items Included	To Be Reported	Unit of Property
Bridges	Location	Each
Trestles	Description	
Culverts	Bridge number	
Pipes		

1.4.7 ACCOUNT 7 ELEVATED STRUCTURES

Definition

The elevated structures account includes structures which are for the purpose of elevating tracks above the grade of streets.

Items Included	To Be Reported	Unit of Property
Elevated structures	Location	Each
Foundations	Description	
	Structure number	
	Length	

1.4.8 ACCOUNT 8 TIES

Definition

The ties account includes the cost of track ties, labor for unloading, distributing and installing the ties during the construction of tracks, as well as the cost of additional ties subsequently installed.

Items Included	To Be Reported	Unit of Property
Cross ties	Location	Each
Switch ties	Track number	
Bridge ties	MP to MP	

1.4.9 ACCOUNT 9 RAILS AND OTHER TRACK MATERIAL

Definition

The rails and other track materials account includes the cost of rail and other track material, labor for unloading and installing those materials during the construction of tracks, as well as the cost of welding two or more lengths of rail into continuous lengths.

Items Included	To Be Reported	Unit of Property
Rail	Location	Each
Switches	Track Number	
Frogs	MP to MP	
Joints		
Tie plates		
Anticreepers		
Spikes		
Crossing frogs		
Guard rails		
Inner guard rails		
Derails		
Switch heaters		

1.4.10 ACCOUNT 11 BALLAST

Definition

The ballast account includes the cost of the various materials used in ballasting tracks, the cost of work train service and of labor for installing ballast in tracks.

Items Included	To Be Reported	Unit of Property
Ballast	Location	Cubic Yard
	Track number	
	MP to MP	

1.4.11 ACCOUNT 13 FENCES, SNOWSHEDS AND SIGNS

Definitions

The fences, snowsheds, and signs account includes the cost installed of fences protecting the right-of-way; snowsheds and the initial cost of planting trees for protecting tracks from snow; any sign that does not identify a bridge, signal, station or other structure. Excluded are fences around buildings and structures which are included in the appropriate building account.

Items Included	To Be Reported	Units of Property
Fences	Location	Linear feet
Signs		Each

1.4.12 ACCOUNT 16 STATION AND OFFICE BUILDINGS

Definition

The station and office buildings account includes the cost installed of a building and permanently attached fixtures, as well as the cost of preparing and completing the building site. Office buildings used exclusively for either Maintenance of Way or Maintenance of Equipment functions are not included.

Items Included	To Be Reported	Unit of Property
Stations	Location	Each
Office buildings	Description	
Platforms		
Yard Offices		

1.4.13 ACCOUNT 17 ROADWAY BUILDINGS

Definition

The roadway buildings account includes the cost installed of the building with drainage, utility connections, all machinery and permanently attached fixtures, as well as the cost of preparing and completing the building site.

Items Included	To Be Reported	Unit of Property
M/W bases	Location	Each
Tool houses	Description	
Rail welding plants		
Rail reclamation plants		
Machines		

1.4.14 ACCOUNT 18 WATER STATIONS

Definition

The water stations account includes the cost installed of the fully equipped permanent water supplying facility, preliminary water analysis, as well as the cost of preparing and completing the site.

Items Included	To Be Reported	Unit of Property
Dams	Location	Each
Pipelines	Description	
Pump houses		
Penstocks		
Tanks		
Reservoirs		

1.4.15 ACCOUNT 19 FUEL STATIONS

Definition

The fuel stations account includes the cost installed of the fully equipped locomotive and floating equipment fuel supplying facility, as well as the cost of preparing and completing the site. Track is not included.

Items Included	To Be Reported	Unit of Property
Dikes	Location	Each
Fuel houses	Description	
Fueling assembly		
Machinery		
Pipelines		
Tanks		
Unloading assembly		

1.4.16 ACCOUNT 20 SHOPS AND ENGINEHOUSES

Definition

The shops and enginehouses account includes the cost of building and associated drainage, sewerage, water supply systems, plants for heat and light and permanently attached fixtures, as well as the cost of preparing and completing the building site. Maintenance of equipment material storehouses are also included.

Items Included	To Be Reported	Unit of Property
Shops	Location	Each
Enginehouses	Description	
Storehouses		
Warehouses		
Material and supply truck tracks		

1.4.17 ACCOUNT 22 STORAGE WAREHOUSES

Definition

The storage warehouses account includes the cost of buildings, which are actually operated as storage warehouses, and of permanently attached fixtures, as well as the cost of preparing and completing the building site.

Items Included	To Be Reported	Unit of Property
Storage warehouses	Location Description	Each

1.4.18 ACCOUNT 23 WHARVES AND DOCKS

Definition

The wharves and docks account includes the cost of various landings for vessels with the required operating and protection devices, as well as the cost of preparing and completing the site.

Items Included	To Be Reported	Unit of Property
Wharves Docks Bulkheads Transfer bridges Ferry bridges Ferry slips	Location Description	Each

1.4.19 ACCOUNT 24 COAL AND ORE WHARVES

Definition

The coal and ore wharves account includes the cost of facilities for the transfer, treatment, blending, or storage of coal or ore, the cost of dredging and of permanently attached fixtures, as well as the cost of preparing and completing the site.

Items Included	To Be Reported	Unit of Property
Bulkheads Blending bins Conveyors Dumpers Machinery Wharves	Location Description	Each

1.4.20 ACCOUNT 25 TOFC/COFC TERMINALS

Definition

The TOFC/COFC terminals account includes the cost of terminal structures and permanently attached fixtures used for the loading and unloading of trailers and containers from flat cars, as well as the cost of preparing and completing the site.

Items Included	To Be Reported	Unit of Property
TOFC/COFC terminal office Terminal Paving Floodlighting Fencing Machines	Location Description	Each

1.4.21 ACCOUNT 26 COMMUNICATION SYSTEMS

Definition

The communication systems account includes the cost of telegraph, telephone, radio, radar, inductive train communication and other communication systems, including terminal equipment. Not included is communication equipment permanently attached to rolling stock or floating equipment and limited special purpose systems which are not connected with other systems.

Items Included	To Be Reported	Units of Property
Portable radios	Location	Each
Terminal equipment	Description	Linear feet
Telegraphs		
Telephones		
Pole Lines		
Underground cables		
Buildings used exclusively for communications		

1.4.22 ACCOUNT 27 SIGNALS AND INTERLOCKERS

Definition

The signals and interlockers account includes the cost installed of interlocking and railroad crossing protection installations, including towers, other structures and permanently attached fixtures. Included is the cost of roadway installations for train control, including remote; the cost of buildings and machinery of power plants used primarily for the production of power for the operation of signals and interlockers, as well as the cost of preparing and completing the site.

Items Included	To Be Reported	Unit of Property
Car-retarder systems	Location	Each
Centralized traffic control system	Description	
Crossing flashlight signals		
Crossing gates		
Interlocker tower		
Signal buildings		
Hot box detectors		
Automatic signal systems		

1.4.23 ACCOUNT 29 POWER PLANTS

Definition

The power plants account includes the cost of power plant and substation buildings with foundations, dams, pipe lines, etc. required for the utilization of water for power; gas and sewer pipes with connectors; fixtures with wiring for lighting and heating and permanently attached fixtures.

Items Included	To Be Reported	Unit of Property
Buildings	Location	Each
Coal pockets and trestles	Description	
Fuel oil tanks		
Paving and platforms		

1.4.24 ACCOUNT 31 POWER TRANSMISSION SYSTEMS

Definition

The power transmission systems account includes the cost installed of complete systems, including structures, for the transmission or distribution of electric, steam or compressed air.

Items Included	To Be Reported	Units of Property
Air lines	Location	Complete system - each
Catenary systems	Description of system	Components - use units as appropriate
Compressed air lines	Facilities served	
Duct lines	Description and quantities of major components	
Fences		
Light systems for general lighting		
Manholes		
Meter houses		
Poles with fixtures		
Power lines - cable, wire and conduit		
Steam lines		
Substations (complete)		
Third rail		
Transformers		

1.4.25 ACCOUNT 35 MISCELLANEOUS STRUCTURES

Definition

The miscellaneous structures account includes the cost of all permanent structures not provided for elsewhere, including all fixtures and furniture to equip them for use.

Items Included	To Be Reported	Units of Property
Buildings	Location	Complete structure - each
Floodlight towers	Description of structure	Components - use units as appropriate
	Facilities served	
	Description and quantities of major components	

1.4.26 ACCOUNT 37 ROADWAY MACHINES

Definition

The roadway machines account includes the cost of roadway machines with appurtenances and of on/off track automotive vehicles permanently equipped with special purpose roadway machines which are used exclusively in maintenance of way and structures.

Items Included		To be Reported	Unit of Property
Adzing machines	Jacks	Type of machine	Each
Air compressors, portable	Pile drivers	Function of machine	
Ballast regulators	Rail grinders	Quantity	
Ditchers	Rail saws	Manufacturer	
Dredging machines	Scarifier - inserters	Serial number	
Engines, portable	Spike drivers	Model number	
Grinders	Spike pullers	Company assigned machine number	
Hoists, portable	Tie tampers		

1.4.27 ACCOUNT 39 PUBLIC IMPROVEMENTS; CONSTRUCTION

Definition

The public improvements; construction account includes the entire amount assessed on carrier property by government authority relating to the cost of constructing public improvements as well as the carrier's portion of the improvement construction cost.

Items Included	To Be Reported	Units of Property
Curbing streets and highways Drainage systems Flood protection Grading streets and highways Grade crossings Guttering streets and highways Overhead highway bridges, including approaches Paving streets and highways including such pavings at crossings Sewer systems Sidewalks Street lighting systems	Location Description of improvement Facilities served Description and quantities of major components	Complete improvement - each Components - use units as appropriate

1.4.28 ACCOUNT 44 SHOP MACHINERY

Definition

The shop machinery account includes the cost of machinery and other apparatus used in shops and enginehouses including installation and foundations special to particular machines.

Items Included	To Be Reported	Unit of Property
Air compressors Boring machines Cranes Drilling machines Forgers Grinding and polishing machines Hoists Hydraulic jacks Lathes Milling machines Pipe cutting and threading machines Pneumatic hammers Punchers Riveters Steam hammers Vises Welding machines Woodworking machines	Location Building in which used Type of machine Function of machine Quantity Manufacturer Serial number Model number Company assigned machine number	Each

1.4.29 ACCOUNT 45 POWER-PLANT MACHINERY

Definition

The power-plant machinery account includes the cost of machinery and other apparatus used in power plants and substations for generating and transforming power used for the operation of trains and cars or to furnish power, heat, and light for stations, shops, and general purposes. Included is the cost of installation and of foundations special to particular machines or other apparatus.

Items Included	To Be Reported	Unit of Property
Air compressors	Location	Each
Boilers and fittings	Building in which used	
Circuit breakers	Type of machine	
Condensers	Function of machine	
Engine room appliances and tools	Quantity	
Furnaces	Manufacturer	
Lubricating devices	Serial number	
Metal stacks on boilers	Model number	
Switchboards	Company assigned machine number	
Tanks		
Transformers		
Water meters		

1.4.30 ACCOUNT 59 COMPUTER SYSTEMS AND WORD PROCESSING EQUIPMENT

Definition

The computer systems and word processing equipment account includes the cost of specialized computer equipment and peripherals.

Items Included	To Be Reported	Unit of Property
CRT terminals	Location	Each
Disk packs	Quantity	
Mainframe processors	Manufacturer	
Modems	Serial number	
Multiplexers	Model number	
Personal computers		
Plotters		
Printers		
Storage units		
Tape drives		

1.5 CAPITAL EXPENDITURE OR OPERATING EXPENSE

1.5.1 Any project which will result in the addition of a complete unit of property to the asset ledgers of the corporation and exceeds the minimum capitalization rule (currently $2,000) is a capital expenditure. A project which is not a replacement of an existing item and will add less than a complete unit of property to the asset ledgers is a capital expenditure if the cost of the project exceeds the minimum capitalization rule.

1.5.2 Projects which do not meet one of the above criteria are to be charged to operating expense.

1.5.3 It is important to note that certain operating expenses are of such significance that they should be reflected in permanent engineering records such as track charts, maintenance records, etc. Individual railroads should provide the capability to capture this type of cost through both an expense cost tracking system and a detailed categorization of expenses by operating account for use by the engineering department.

1.6 AUTHORITY FOR EXPENDITURES

1.6.1 Each company establishes procedures for approving the commitment of operating and capital funds to specific projects. These procedures pertain to the preparation, processing, approval and review of AFE's and related internal documents; they should not be read as a delegation of authority to any management personnel to execute documents which bind the corporation to expend corporate funds or dispose of or encumber corporate assets. Such authority is specifically delegated in the corporations' procedures manual.

1.6.2 In general, corporate policy will require an authorized AFE for the following items:

(a) Capital investment expenditures.
(b) Capital asset retirements whether through sale, scrapping, abandonment in place, or conversion to other service.
(c) Replacement of capital assets because of theft or other involuntary removal from the company.
(d) Overruns and revisions to a previously authorized AFE.

For further information, please reference Part 4 of this chapter.

1.7 DEPRECIATION ACCOUNTING

1.7.1 Depreciation accounting is now generally required for all assets except land. Under depreciation accounting, a monthly charge is made to operating expense in order to amortize assets over their service lives. Each carrier is required by the ICC to perform asset studies on their properties to determine specific asset service lives on which to base the calculations of charges to operating expense.

1.7.2 For all road accounts except track, the original cost of the asset less the estimated gross salvage value is used in determining the amount to be charged to expense over the life of the asset. At retirement, the cost of removal of the asset is charged to operating expense.

1.7.3 For track accounts, the original cost of the asset less estimated salvage value and estimated removal costs are used in determining the amount to be charged to operating expense over the life of the asset. At retirement, actual removal costs are charged to the depreciation reserve rather than operating expense.

1.8 JOINT FACILITIES

1.8.1 Reporting for jointly owned property should be included in the property asset records of the corporation. Jointly owned property should be noted as such in the database so that it can be readily identified as either property owned by one carrier for which rental is charged or as property owned jointly with one or more other carriers.

1.8.2 For property rented to others, the various cost factors involved must be analyzed to establish a per annum rental rate.

1.9 ROADWAY COMPLETION REPORTS

1.9.1 A roadway completion report is a detailed itemization of the additions and retirements which occured during a project and summarizes those items by ICC account for inclusion in the asset ledgers of the corporation.

1.9.2 Each roadway completion report should include the following minimum information:

(a) Authority for expenditure (AFE) or work order number
(b) Significant facts of ownership and operation (i.e. ownership and lease information, improvements made to leased property, etc.).
(c) Location
(d) Description
(e) Distribution of the cost and units of property by ICC account.
(f) Completion and service dates of the project.
(g) Book to tax adjustments information.

1.10 PROPERTY ASSET LEDGERS

1.10.1 Corporate property asset ledgers, whether manually kept or mechanized, provide for the maintenance and updating of the fixed asset records of the corporation. All pertinent information regarding fixed assets such as location, bridge or building number, AFE number, and cost are maintained.

1.10.2 The property asset ledgers permit the retrieval of the following information:

(a) Original cost of a unit of property and of any subsequent additions or retirements.
(b) Retirement information for a particular asset.
(c) Data for determining the cost of a line abandonment or of the investment in a particular line.
(d) Data to be used as the basis of performing depreciation or age distribution studies.

Part 2

Cartographic Specifications

1988

2.1 OVERVIEW

2.1.1 ICC Regulation

2.1.1.1 Effective January 1, 1982, the Interstate Commerce Commission eliminated Part 1263, Map Specification, from the Code of Federal Regulations and transferred significantly reduced map specifications to the property account instructions in the Uniform System of Accounts for Railroads, Part 1201. Due to improved technology in map making, the Commission ruled that it is no longer necessary to require railroad companies to maintain the detailed records previously required in Part 1263. However, because the Commission has a need for Class I railroad property records in rate, abandonment, merger and purchase proceedings and for accounting. audit and valuation purposes, these carriers are still required to maintain certain basic map information as herein described. This rule substantially reduced the regulatory burden associated with maintaining and filing property maps with the Commission. Additionally, this rule relieved Class II and Class III railroads of all map requirements.

2.1.1.2 Class I railroads are subject to a five-part map specification incorported as Instruction 2-21, Map Specifications, in Part 1201. The revised map specifications require Class I railroads to:

(a) Maintain a current map of its rail property.
(b) Furnish copies of such maps to the Commission upon request.
(c) Maintain sufficient detail to show right-of-way, track and other important facilities.
(d) Provide appropriate indices and titles.
(e) Comply with generally accepted map principles.

2.1.2 United States National Map Accuracy Standards

With a view of the utmost economy and expedition in producing maps which fulfill not only the broad needs for standard or principal maps, but also the reasonable particular needs of individual railroads. Standards of accuracy for published maps are defined as follows:

2.1.2.1 Horizontal accuracy. For maps on publication scales larger than 1:20,000, not more than 10 percent of points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well defined points only. Well defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general what is well defined will also be determined by what is plottable on the scale of the map within 1/100 inch. Thus while the intersection of two road or property lines meeting at right angles would come within a sensible interpretation, identification of the insection of such lines meeting at an acute angle would obviously not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits, such as timber lines, soil boundaries, etc., are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map.

2.1.2.2 Vertical accuracy, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.

2.1.2.3 The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown with corresponding positions as determined by surveys of a high accuracy. Tests should be made by the producing railroad, which shall also determine which of its maps are to be tested, and the extent of such testing.

2.1.2.4 Published maps meeting these accuracy requirements shall note this fact on their legends, as follows: "This map complies with National Map Accuracy Standards."

2.1.2.5 Published maps whose errors exceed those as specified in Article I, Section B, Paragraph 1-3 shall omit from their legends all mention of standard accuracy.

2.1.2.6 When a published map is a considerable enlargement of a map drawing (manuscript) or of a published map, that fact shall be stated in the legend. For example, "This map is an enlargement of a 1:20,000 scale map drawing," or "This map is an enlargement of a 1:24,000 scale published map."

2.1.2.7 To facilitate ready interchange and use of basic information for map construction among all Federal map making agencies, manuscript maps and published maps, wherever economically feasible and consistent with the uses to which the map is to be put, shall conform to latitude and longitude boundaries, being 15 minutes of latitude and longitude, or 7.5 minutes, or 3-3/4 minutes in size.

2.1.3 Objectives

The specifications herein described propose the development and adoption of general guidelines for map creation and production by railway carriers. In keeping with the intent and spirit of the ICC regulation, the objective of this specification is to eliminate antiquated and restrictive cartographic standards for affected railway carriers. This specification should in no way be viewed as the definitive standard for railroad related cartographic practices. Those practices must be adopted and utilized by individual railway carriers to suit their parochial business needs and to fulfill existing ICC regulations. This specification permits flexibility for map development and production.

2.1.4 Scope

This specification should serve as a flexible guideline to those railway carriers obligated under existing regulations to provide map and map related information to the ICC. Other railway carriers may wish to adopt the herein described standards to assure industry compatibility and for use as a resource management tool. In any event, the specifications should be considered broad enough to encompass the needs of individual railway business practices including historical and current uses as well as the application of new and innovative technologies.

2.1.5 Organization

The suggested specifications are divided into the following major areas:

(a) General Cartographic Practices - updated relative to ICC regulations and railway carrier operations.
(b) Digital Mapping - as applied to rail carrier cartographic requirements.
(c) Land Information - relative to mapping.

2.2 GENERAL CARTOGRAPHIC PRINCIPLES

2.2.1 Intent

In order that the requirements and interests of the railway carriers be best served, and that the needs of the Interstate Commerce Commission be provided for, it may be necessary to prepare certain maps of the property and have available methods of reproducing copies thereof to meet the requirements and demands as occasions arise. Although maps are not typically viewed as basic accounting records, they have proven to be an integral part of railroad property records. Maps are used extensively to identify and value rail property. Therefore, it is necessary to prescribe a uniform and consistent basis for identifying rail property. The specifications described herein substantially reduces the burden of maintaining and producing maps. The revised map specifications will provide railroad management greater latitude in developing and maintaining rail property maps.

2.2.2 Map Specifications

2.2.2.1 Class I Railroad companies shall maintain current maps of its property and shall promptly record any changes that may take place.

2.2.2.2 Class I companies shall furnish, on request, copies of maps showing its property as it exists on such date or dates as may be fixed by the ICC.

2.2.2.3 Class I companies shall maintain planimetric maps that show right-of-way, track and other important facilities at a scale to show sufficient detail.

2.2.2.4 Maps shall be indexed and titled to clearly indicate the specific area depicted.

2.2.2.5 All maps shall be prepared in accordance with generally accepted mapping practices.

2.2.3 Classes and Titles

Two general classes of maps may be made by the railway carriers:

(a) Right-of-way and track maps.
(b) Station maps.

2.2.4 Description and Purpose

2.2.4.1 The right-of-way and track maps should be a true horizontal projection of the right-of-way, tracks and other structures. The maps shall be made of materials of standard and durable quality, using conventional symbols and plain lettering.

2.2.4.2 Station maps should be made when necessary to supplement the right-of-way and track maps at terminals or other locations where the properties of the carriers are so extensive and complicated that full and complete information cannot be shown on the regulation right-of-way and track maps.

2.2.5 Size of Sheets

The maps should be made on sheets 24 inches by 56 inches. A plain single line border should be drawn on each sheet, dimensions inside of which shall be 23 inches by 55 inches. When more than one sheet is required to show the property, the maps should be made upon "matched marked" sheets in such manner as to require the minimum number of copies. The 24 inch by 56 inch map size is normally maintained by the railway carrier based on historical cartographic practice. However, the railway carrier is not restricted to the previous standard size and may elect to adopt any engineering size format to suit individual business requirements.

2.2.6 Scales

The right-of-way and track maps should be made on a scale of 1 inch equals 100 ft., 200 ft., or 400 ft., as the importance of the maps may warrant.

The station maps should be made on a scale of 1 inch equals 100 ft. or in complicated situations, 1 inch equals 50 ft.

The railway carrier may elect to utilize a different scale at its discretion. However, such scale must be large enough to accommodate all features as may be required by ICC regulation.

2.2.7 Arrangements of Data

At the railway carrier's discretion, the maps should be made with the zero or lowest numbered station at the left side of each sheet and should be plotted continuously from left to right. Where the use of the method would involve the abandonment of established survey station numbers of a railway, the plotting should be done in such a way as to preserve them, provided the maps for any given main line or branch are continuous in same direction between termini of main line or branch. The general direction of the center line of track should be as nearly as possible parallel to and half way between the long sides of sheets, so that the maximum space each side of plotted right-of-way lines may be available for showing adjacent topography and property lines and for delineation of such other features as may be deemed necessary. The maximum length of main line roadway, represented on any one sheet of right-of-way and track maps between "match marks", should generally be 1 mile, if scale is 1 inch equals 100 ft., 2 miles if scale is 1 inch equals 200 ft., and 4 miles if scale is 1 inch equals 400 ft. (subject to 2.2.6).

2.2.8 Cardinal Points

On all maps an arrow showing the true north and south line, as nearly as can be ascertained from existing records, shall be placed. This arrow should be less than 3 inches in length and shall have the letter "N" marked as its north end. On each end of each sheet there should be shown a pointer directing to a terminal or important station.

2.2.9 Indexing

2.2.9.1 All right-of-way and track map sheets should be numbered serially, beginning with sheet 1. The sheets representing valuation sections should form separate series and the valuation sections should be numbered serially with the letter "V" preceding the number. Index numbers should be in the lower right-hand corner of the sheet and enclosed in a plain single line circle measuring 1 inch in diameter. Valuation numbers should be in the upper half of the circle and the sheet number below separated by a straight horizontal line.

2.2.9.2 The station maps should be given the same serial number preceded by the letter "S" as the sheet of the right-of-way and track map which they supplement.

2.2.9.3 In case a right-of-way and track map sheet is supplemented by more than one station map, a subscript letter should be used after the number as follows: S 32a, S 32b, etc., where land and track features are combined; S-L 32a, etc., where land only is shown; and S-T 32a, etc., where the track features only are shown.

2.2.9.4 On the right-of-way and track map sheets reference to all station maps should be shown by outlining the limits of station maps and giving the number of the station map sheets.

2.2.9.5 Indexing is within the purview of individual railroads and should be maintained in accordance with stated ICC regulations (See 2.2.2.4).

2.2.10 Title

The title should be placed as near the lower right-hand corner as practicable. The following are generally accepted types of information which may be given therein:

(a) Class
   1. Right-of-way and track map
   2. Station map

(b) Corporate name of railway

(c) Name of operating company

(d) Name of railway division or branch line

(e) Beginning and ending survey station numbers on sheet

(f) Scale or scales

(g) Date as of which maps represent the facts shown thereon

(h) Office from which issued

2.2.11 Certification

A certificate as to the correctness of all maps shall be executed and shall accompany such maps when submitted to the Interstate Commerce Commission.

2.2.12 Right-of-Way and Track Maps

On these maps the following data should be shown:

2.2.12.1 Boundary lines of all rights of way, regardless of how acquired. The term "right-of-way" as herein used includes all lands owned or used by the carrier for common carrier purposes. Show width of right-of-way in figures at each end of the sheets and at points where a change of width occurs with station and plus of such points. Where known, boundary lines and dimensions of each separate tract acquired should be shown. A schedule of land acquisitions for the lands embraced on each sheet should be shown giving custodians reference, the name of grantor and of grantee, kind and date of instrument of title. Each separate parcel acquired should be serially numbered on the sheet and the corresponding number shall appear in the schedule reference. Where space is available this schedule should appear on the sheet to which it applies. In terminal locations or complicated situations where space on the sheet is not available, a separate schedule sheet properly referenced should be prepared to contain the information.

The schedule should include leases to the company, franchises, ordinances, grants and all other methods of acquisitions.

2.2.12.2 Boundary lines of detached lands. The term "detached lands" as herein used includes:

(a) Lands owned or used for purposes of a common carrier, but not adjoining or connecting with other lands of the carrier.

(b) Lands owned and not used for purposes of a common carrier, either adjoining or disconnected from other property owned by the carrier.

Show: Boundary lines and dimensions where known, distance and bearing from some point on the boundary line to some established point or permanent land corner where practicable, and separately on the map where the lands are not used for railway carrier purposes.

2.2.12.3 Intersecting property lines of adjacent landowners. Where known, show: The property lines of adjacent landowners, the station and plus of important intersections of property lines with the center line of railway carrier or other railway base line, and the names of owners of the land adjacent to the right-of-way.

2.2.12.4 Intersecting divisional land lines. Where known, show: Section, township, county, state, city, town, village or other governmental lines, with names or designations; the width and names of streets and highways which intersect the right-of-way; and the approximate station and plus at all such points of crossing or intersections with the center line of railway carrier or other railway base line.

2.2.12.5 Division and subdivision of lands beyond the limit of the right-of-way. Where known, show: The section and quarter section lines for a reasonable distance on each side of the center line or base line of railway where the land has been subdivided into townships and sections; such data as to divisions, tracts, streets, alleys, blocks and lots, where the land has been divided in some other way than by sections; the distance from the railway base line to permanent land corners or monuments; and the base line from which the railway's lands were located (center line of first, second, third, or fourth main track or other base line).

2.2.12.6 Alignment and tracks. Show: The center line of each main and sidetrack when such tracks are outside the limits covered by the station maps and the center line of each main track inside station-map limits; the length, in figures, of all sidetracks from point of switch to point of switch, or point of switch to end of track; all other railways, crossed or connecting, and state if crossing is over or under grade, and give name of owner of such tracks; survey station number at even 1,000 scale-feet intervals, and station and plus at points of all main line switches at points of curves and tangents and at beginning and ending points on each sheet; and the degree and central angle of main line curves.

2.2.12.7 Improvements. Show: Important facilities in general outlines and give station and plus thereof.

2.2.12.8 Topographical features. Where practicable show: Water courses, highway crossings, etc., give names where known and when highway crossings are over or under grade, so state.

2.2.13 Station Maps

The purpose of the large scale station maps is to permit the showing of improvements in more detail than is practicable on the right-of-way and track map. Where the station property to be mapped is extensive and complicated, it should be delineated on two separate maps and should show the following:

(a) All data relating to ownership of lands
(b) Tracks and structures and external land boundaries.

Where practicable, without sacrificing the clearness of the map, the two may be combined into one map. Show all information set forth under items 2.2 thru 2.2.12, when inside of station-map limits. Tracks should be represented on station maps either by center lines or by rail lines.

2.3 DIGITAL MAPPING

2.3.1 Overview

2.3.1.1 Digital maps and automated cartographic information is generally formatted as either vector or grid data. Vector data describes area information as polygons and linear features as line segments. Grid data partitions land into a mathematical framework with locations specified by row and column numbers. The usual method of data collection from maps or similar source documents is by manually following the map feature lines on a digitizer table. Another approach to automate cartographic data acquisition is through use of scanning devices with either single-element detector or linear array.

2.3.1.2 Storage of enormous amounts of digital map data requires an organized system for access and retrieval. A powerful interactive system is the primary working tool for digital data storage and manipulation. The software and hardware should work together to:

(a) Create digital map data bases
(b) Edit digital map data bases
(c) Merge and manipulate digital map data
(d) Selectively retrieve map detail levels either in graphic or textual/alpha- numeric form
(e) Produce reports and data tapes.

2.3.1.3 Cartographic data should be entered and stored within the system in multiple detail layers/ levels. The hardware and software should be powerful and extensive enough to support multiple layer/level scenarios. Each level of map data is stored on its own layer in conjunction with other like elements. This allows the retrieval of any number of desired combinations of levels. Each data layer/level should be digitized or scanned from all available original source maps. Special attention should be given to parcel "slivers" or information gaps.

2.3.1.4 Finally, appropriate indices for maps and attribute data files should be established for each data base. A "key" or index map or equivalent should be developed to serve as a cartographic directory to all map sheets. Where appropriate or as may be required, alphanumeric "cross-key" and sequential systems should be utilized for cartographic levels and corresponding attribute data as applicable.

2.3.2 Layer/Level Concept

Development of cartographic data base structures call for each level of map information to be stored in its own layer (level) in conjunction with similar data elements. Use of a number of different levels or layers is essential in order to provide the flexibility needed to meet the different requirements for varied user purposes. Information can be separated digitally into a maximum number of data levels which will permit efficient updating and precision plotting onto a single composited base map sheet using data levels as may be required. In order to fulfill various user needs and provide a flexible analytical tool and data, the following serves only as suggested layer/level designations:

(a) Coordinate Reference Network Systems: Geodetic control and/or local state plane coordinate systems
(b) Topographic Detail: Contouring, foliage, water systems and wetlands
(c) Planimetric Details: Transportation systems, roads, building "footprints", other man-made features
(d) Cadastral Detail: Property boundary lines
(e) Leased Properties: Where railroad is lessor
(f) Tenant Properties: Where railroad is lessee
(g) Occupancies: Licenses between railroad and others
(h) Zoning/Land Use/Taxing and Assessment Data
(i) Deed and Conveyance, Rights/Interests Detail
(j) Railroad Valuation Map Detail

Additions or deletions of layers/levels can be made to accomodate individual business requirements.

2.3.3 Coordinate Network

Geodetic control and state plane coordinates systems should comprise a separate level within the data base and should be utilized as the primary means for expressing and determining locations in continuous space so that shifts in parcel and feature positioning may be accurately adjusted, manipulated or analyzed (land parcels will be referenced spatially to man-made features). The accurate mapping of topographic, planimetric and cadastral and other land features requires a system of survey and cartographic controls which consists of a framework of points whose horizontal and vertical positions have been established and to which map details are adjusted and against which such details can be verified.

2.3.4 Topographic Detail

A separate layer/level depicting topography need only be included for those railway carriers requiring this detail for specific uses. In such cases, contour intervals should be selected in conjunction with map scale, terrain relief and elevation data needs. Horizontal accuracy standards for large scale maps specify that 90% of points tested should be plotted with 1/30th inch of true position. Vertical accuracy standards specify that 90% of points tested should be shown in elevation within one half of contour intervals used on map.

2.3.5 Planimetric Detail

A separate layer/level should be established to delineate select culture detail and man-made ground features. These features include, but are not limited to, building "footprints", bridges, track, fences, catenaries, transmission lines, highways, and other structures and improvements. Planimetric details should be tied to coordinated points which are referenced to a horizontal and/or geodetic control network. The planimetric detail thus becomes a high accurate layer/level for precision position determinations, allowing for the employment of grid oriented mapping techniques (see 2.2.12.6 and 2.2.12.7).

2.3.6 Cadastral Detail

The cadastral detail layer or level depicts spatial positioning of property boundary lines in relation to other features shown on the planimetric layer/level and as related to the coordinate network level. This level should provide for a timely, complete and available inventory of all existing land parcels. Cadastral (or property) boundaries should be viewed as lines which connect points having unique identities and records, and through which these boundaries can be physically located on the ground. Those boundaries can be expressed by points or corners, and straight or curvilinear lines (See 2.2.12.1 thru 2.2.12.5). Each parcel of land depicted on the cadastral level should have a unique identifier for correlation to attribute records. These unique parcel identifiers should provide the means by which to "link" the parcel to attribute data containing information about land ownership, use, value, area and so forth. Parcel identifiers can be developed or expressed in terms of one or a combination of the following:

(a) Abstract Identifier: tract index based on a sequential numbering system.
(b) Name Related Identifier: identifier for individuals or legal entities having an interest in a parcel of land.
(c) Alphanumeric Identifier: random letters and numbers identifier.
(d) Location Identifers:
1. Hierarchical - based on graded series of political units such as federal, state, county, city, town, ward, precinct, etc.)
2. Coordinate - relates parcel to reference grids, either through the use of geodetically derived latitudes and longitudes, or through the use of arbitrary or state plane coordinate systems.
3. Hybrid - any combination of location identifiers.

2.3.7 Lease Properties

Lands leased to individuals or other entities should be delineated on a separate layer/level. Leased parcels should be correlated to the planimetric and cadastral levels for the purpose of ascribing accurate representations of affective properties. Metes and bounds (bearing and distance) descriptions devised for the leased areas should be registered to the coordinate network. Attribute data should be tied to cartographic representations through the use of unique parcel identifiers (See 2.2.12.1 thru 2.2.12.5).

2.3.8 Tenant Properties

Lands leased by the railroad from individuals or other entities should be delineated on a separate layer/level. Tenant properties should be correlated to the planimetric and cadastral levels in order to ascribe accurate representations of affected parcels. Property boundary line descriptions (metes and bounds) should be registered to the coordinate network. Attribute data should be linked through use of unique parcel identifiers to cartographic representations of tenant properties (See 2.2.12.1 thru 2.2.12.5).

2.3.9 Occupancies

Occupancies include pipe and wire, sidetrack, crossing and similar license agreements affecting railway carrier properties and rights-of-way. Precise positioning of occupancies in relation to railroad facilities is a mandatory record keeping need. Consequently, these occupancies should be delineated on a separate layer/level correlated to cadastral and planimetric levels in order to develop accurate representations. All descriptions and locations should be registered to the coordinate network. Applicable attribute data should be linked through the use of unique parcel identifiers to cartographic representations of occupanies. Occupancies should be completely and accurately delineated and inventoried to satisfy individual railway requirements, as well as public and safety needs.

2.3.10 Zoning/Land Use/Taxation and Assessment Detail

Assessment, land use, and zoning details can be developed as a separate cartographic level (with accompanying attribute details) or encompassed within the cadastral level's attribute file (See 2.2.2.4 and 2.2.12.1 thru 2.2.12.5). If shown as a separate cartographic level, assessment, land use, and zoning details should be shown as special or colored boundary lines to differentiate between varying classifications. Assessment parcels should be shown for railroads, whereas land use and zoning details should be delineated for both railway carriers and adjacent properties. Assessment, land use, and zoning cartographic details are retained at the discretion of the railway carrier based on individual business requirements.

2.3.11 Deed and conveyance, Rights/Interests Detail

A separate level/layer can be established for deed and conveyance, and rights and interests with pertinent attribute files. This level should show inconveyances (parcel/land acquisitions), outconveyances (land sales), property interests, and other rights (aerial, surface, subsurface and operating). This level should sequentially depict deed, easement and other legal descriptions. These descriptions should be correlated to cadastral and planimetric levels in order to ensure accurate representations and should be registered to the coordinate network. Applicable attribute data in terms of title histories, execution and recording information, agreements and similar data or documentation should be linked through the use of unique parcel identifiers to cartographic representations (See 2.2.12.1 thru 2.2.12.5).

2.3.12 Railroad Valution Detail

Unless incorporated within the planimetric detail level (2.3.5) or on a text level (2.3.13) separate level for valuation map detail should be developed to include the centerline of mainline and side track and the length of side tracks. Length of side track measurements should be shown from point of switch to point of switch, or point of switch to end of track. Additionally, survey stations should be shown at even 1000 foot intervals as follows: for station and plus designations at points of all main switches; at all crossing and bridges; at all structures and buildings; at point of curvature and tangency; and at beginning and end points (match or seam lines) on each sheet.

2.3.13 Lettering

Unless shown on each individual detail level, lettering should be shown on a separate level. Attention must be given to alignment, spacing, size, style, form, and locating for all lettering appearing on all map detail levels.

2.4 LAND INFORMATION

2.4.1 Overview

2.4.1.1 Effective land management and digital mapping encompasses a broad range of activity revolving around land resource assessment, planning, and regulation processes. Detailed land data on an individual parcel basis is required for day-to-day operations and the adminstration of buildings and lands.

2.4.1.2 Comprehensive data base development requires the gathering and processing of vast amounts of information from numerous internal and external sources. This information is used to locate and identify parcels, describe land and structures erected on it, and meet specific system user needs. Data collection and structure development should address the organization's broad based purposes including comprehensive real property or right-of-way inventorying, accurate parcel valuation, equitable real estate assessment, and maximum utilization of land. Each data base should be individually structured to accomodate railway carrier business requirements. Attribute data should be linked to cartographic elements through the use of unique parcel identifiers. This will provide a continuously updated comprehensive record of land at the parcel level.

2.4.2 Planimetric Details

2.4.2.1 Attribute data files relative to planimetric details includes information concerning tracks, buildings, structures (bridges, viaducts, etc.), electrical, communications and signal transmission networks and other physical man-made features. Attribute data for planimetric details are defined in terms of size, shape, design characteristics, construction materials and quality, and age and condition as follows:

(a) Size is identified in terms of total area, volume, height, leasable space and/or clear span.
(b) Shape is described in terms of a ratio of area to perimeter and number of corners or by matching shape or perimeter with a generalized pattern (rectangular, L shaped, G shaped or H shaped).
(c) Design characteristics describe intended or designed use, arrangement and type planimetric detail and period of construction.
(d) Construction materials include those elements used in the construction of foundations, frames, floors, walls, roofs and other structural features.

(e) Construction quality refers to the composite characteristics of construction. This encompasses the cumulative effects of workmanship, costliness of materials, individuality of design, and specific costs of structures.

(f) Age and condition, the effects of wear and tear either in chronological age or "effective age" (adjusted for condition and remodeling) and the remaining economic life can be a part of the attribute file for a specific planimetric detail.

2.4.2.2 Additionally, the value of planimetric details can be encompassed within the attribute data files. Attribute data should either be "attached" to each planimetric feature depicted on the map or developed in conjunction with the creation of a planimetric symbol. Planimetric attributes can be included within the cadastral detail attribute data files.

2.4.3 Cadastral

2.4.3.1 The cadastral attribute data file is composed of demographic information concerning the location, shape and dimensioning of real property holdings. This should include, but is not limited to, area (square footage/acreage), ownership names, premise address, map/parcel identifiers, applicable file numbers, grantor/grantee data (optional), mile posting/val stationing, valuation and assessment data, date of acquisition, ownership type, zoning, and land use.

2.4.3.2 The cadastral attribute data files should provide a complete and available inventory of all existing land parcels encompassing a distinct division between operating and non-operating properties. Parcel sizes should be recorded including dimensions (lot frontage and depth), total land area versus useable land area, setbacks, shape, and topographic soil characteristics. Land uses and improvement data should also be included.

2.4.3.3 Additionally, the cadastral attribute data file should encompass locational and neighborhood characteristics. Locational characteristics are external to land parcels and involve view, presence of nuisance, and distance to services (communications, utilities, water, etc.). Neighborhood characteristics are elements such as physical barriers, geo-political boundaries and cultural aspects.

2.4.3.4 The cadastral attribute file should be "attached" to a unique identifier (coordinate or other) as depicted on the corresponding railroad map.

2.4.4 Lease and Tenant Properties

Lease and tenant property attribute data files should be handled in the same manner a cadastral attribute data. However, in addition to general information (location, size, shape, value, etc.), detailed data concerning the area of lease, term of lease, date executed, leasee, amount of lease, payment schedule, incremental lease costs and other lease or tenant data variables should be included. Such data elements or files should be "attached" to the appropriate map through use of a unique identifier (account number, coordinate point, etc.).

2.4.5 Occupancies

2.4.5.1 Occupancy attributes files (pipe, wire, sidetrack, crossing, or similar license agreements) should be developed like those for cadastral and lease and tenant level details. In addition to the data elements normally depicted in the cadastral and lease and tenant files, occupancy attribute files should include the type of occupancy (pipe, wire, sidetrack, crossing, etc.), the term of license and exact location.

2.4.5.2 A description of the license should also be included within the attribute data file. This description should encompass area and linear measurements as follows: if a wire crossing - the length, number of poles, conduit type and type of transmission (communications, electrical, etc.); if pipe - type, size, length, pressurized/non-pressurized; if sidetrack and other types of area - data relative to specific nature or type of license. The occupancy attribute data file should be attached to the map through an identifier.

2.4.6 Zoning, Land Use, Taxation/Assessment Detail

A separate attribute data file can be created for each affected property and should detail zoning, land use, taxation/assessment information. Zoning data should be retained to determine whether land can be developed and how property can be used. A record should be retained of planning actions, zoning changes, the impact of master plans on affected and adjacent properties, and urban renewal or redevelopment requirements. Land use data should include land use codes, business licensing history, evaluations of proposed development, and site selections of proposed developments. Taxation and assessment information is necessary to support financial assistance requests and will aid in the administration of equitable real property taxation and assessment.

The data recorded with this attribute file should contain site and improvement characteristics, factors and methods used in appraising or valuating properties, cultural and environmental conditions and marketing data (sale prices and terms, rental revenues, operating expenses, building costs and valuation models). Zoning, land use and taxation/assessment information can be included as part of the cadastral attribute data file.

If maintained as a separate data file, the zoning, land use and taxation/assessment attribute file should be linked to the appropriate map level detail through use of a unique identifier.

2.4.7 Deed and Conveyance Information

A separate detailed attribute data file should be developed for each map. Information contained in this file should include title and transfer information, identification and nature of property interests (simple, fee simple, aerial, subsurface or surface), type of transfer (deed, land contracts, condemnation, wills, etc.) and terms of sales and/or transfers. Also, information concerning recordation, execution, railroad recordation, and the purpose of the transfer should be included. This attribute data file should be linked to the appropriate map level through use of an applicable identifier.

2.4.8 Data Base Development

Relationships between data elements should be identified for system design, implementation and maintenance and for the coordination of related user requirements with data element definitions. System analysis begins with interviews with user groups to determine functional responsibilities, informational needs, analytical/decision making processes and the availability and condition of existing data sources. A concept of system design (what the system should or will be) should be created to support a decision for either internal or external system development. In implementing the system, consideration must be given to making sure that it performs in the manner in which it was designed.

2.4.9 Symbology Specifications

2.4.9.1 Symbology specifications include line construction specifications, symbol construction criteria and the identification of detailed instructions coded into the symbol file. These instructions result in an appropriate graphic image display on the graphic CRT (cathode ray tube) and in accurate plottings of the graphic element.

2.4.9.2 Symbols representing items for current source documents should be:

(a) Evaluated to provide information concerning the quantity and conditions surrounding the use of individual symbols.

(b) Analyzed to determine whether elements can be consolidated into a common representation, eliminated if not of value, created if required and not currently existing, or displayed or depicted with a more appropriate representation.

2.4.9.3 Uniform symbology permits the railway carrier to efficiently maintain each data base.

Part 3

Taxes

1988

3.1 INTRODUCTION

3.1.1 The subject of Taxes is very large and complex. Many of the rules guiding tax submissions are interpreted in differing ways by different railroads. Therefore all allusions to methods and practices must be extremely general in nature and liberal in interpretation.

3.1.2 This submission will deal with the following topics: Federal Income Tax, State Income Tax, Investment Tax Credit, Property Tax and Sales-Use Tax.

3.2 FEDERAL INCOME TAX

3.2.1 The investment records accumulated for ICC purposes may on some roads also be used for ICC purposes.

3.2.1.1. Some differences between ICC and IRS values might occur when recapitalizing assets at depreciated values where ICC and IRS depreciation rates differ. When a building is leased its use has changed from operating purposes to income producing purposes; it should then be retired from railroad operating accounts and recapitalized at is depreciated ledger value in non operating accounts. Since depreciation rates differ for ICC and IRS purposes the recapitalized values will be different.

3.2.1.2 Other differences occur when applying differing rules for capitalization. For example, second hand rail is capitalized at some fraction of the cost of new rail for ICC purposes, yet for IRS purposes second hand rail has zero basis. Many differences occur in the capitalization of labor and material overhead costs.

3.2.2 Historical cost on an IRS basis may be maintained in the ICC format or on an entirely different format depending on that particular road's data compatibility.

3.2.3 Regardless of the method a road chooses, the format must contain capitalized costs separated by year or group of years of installation and by method of depreciation.

3.2.4 Generally the IRS depreciation groupings of roadway property are as follows:

3.2.4.1 Original 1942 Submission

This provision applies to investment cost on assets placed in service from 1942 through 1955.

3.2.4.2 Section 94 (Technical Correction as of 1956)

This provision applies to investment cost on assets placed in service prior to 1962.

3.2.4.3 Guideline Depreciation

This provision applies to computing depreciation of investment cost of assets placed in service from 1962 through 1970. Depreciation was computed over a guideline life using either straight line, sum-of-the-years digits or declining balance method of depreciation. Open-end investment accounts were used until 1964; thereafter, vintage year costs were required. Investment costs were collected in Asset Guideline Class groupings.

A bridge placed in service in 1963 would be depreciated over a 30 year class life using S L, SYD or DB method.

3.2.4.4 Class Life System (effective 1-1-71)

This provision applies to computing depreciation of investment cost of assets placed in service prior to 1971. Depreciation is computed over a class life (Asset Guideline Period) using either straight line, sum-of-the- years digits or declining balance method of depreciation. Open-end investment accounts were used until 1964; thereafter, vintage year costs were required. Investment costs were collected in Asset Guideline Class groupings.

A bridge placed in service in 1945 would be depreciated under provision of the Original 1942 Submission. It was depreciated over a self determined economic life on a straight line depreciation basis until 1970. Starting in 1971 this bridge was depreciated on a straight line basis using an Asset Guideline Class group life that was standard for all railroads.

3.2.4.5 Class Life Asset Depreciation Range System (ADR)

This provision applies to investment costs on assets placed in service from 1971 through 1980. Vintage year costs are required with retirements deferred until assets are fully depreciated. Depreciation is computed over a life selected from a range of years using either the straight-line (SL), sum-of-the-years-digits (SYD), or declining balance (DB) methods of depreciation.

A bridge placed in service in 1972 was depreciated under provisions of ADR using a class 40.2 life ranging from 24 to 33 years (at the discretion of the railroad). Either SL, SYD, or DB depreciation methods were available for use.

3.2.4.6 Accelerated Cost Recovery System (ACRS)

3.2.4.6.1 This provision applies to investment costs on assets placed in service from 1981 thru 1986. ACRS combines all investment costs into four basic railroad groups that supersede Asset Guideline Classes:

(a) Group 1 is three year recovery property consisting of autos, light duty trucks and tractors.
(b) Group 2 is ten year recovery property containing railroad tank cars and mobile homes.
(c) Group 3 is 15, 18 or 19 year recovery property consisting of all real property such as buildings.
(d) Group 4 is five year recovery property that includes track structure and all remaining property including signals, communications, freight cars, and locomotives.

3.2.4.6.2 ACRS property is depreciated at a fixed, accelerated percentage for each elapsed year for each group. Recovery percentages are designed to approximate the effect of the use of the 150% declining balance method with a later-year switch to straight line recovery. Straight line depreciation over specified periods may be elected by the taxpayer.

A bridge placed in service in 1982 is depreciated over a five year period at the following rates:

First year	15%
Second year	22%
Third year	21%
Fourth year	21%
Fifth year	21%

3.2.4.7 The Tax Reform Act of 1986

3.2.4.7.1 This act modified the Accelerated Cost Recovery System (known by the acronym MACRS) for property placed in service after December 31, 1986, by changing the way assets are classified and depreciation computed. Generally, asset classification is based on the asset depreciation range (ADR) class lives. For railroads, the major portion of their assets fall into the 7 year property class, which would include railroad cars, locomotives and track structure expenditures. Depreciation is generally computed using the 200% declining balance method with a switch to the straight line method. The 200% declining balance method with a switch to the straight line method is used for the 3, 5, 7, and 10 year classes. The 150% declining balance method with a switch to the straight line method is used for the 15 and 20 year classes and only the straight line method is used for the 27.5 and 31.5 year classes of real property.

3.2.4.7.2 A bridge placed in service in 1987 is depreciated over 20 years at the following rates starting with the first year: 3.75%, 7.22%, 6.68%, 6.18%, 5.71%, 5.28%, 4.89%, 4.52%, 4.46% for the next 12 years and 2.25% for the last year. Note the first and last year includes the half year depreciation.

3.2.4.7.3 Assets are assigned the following classes:

(a) **3 year property** (ADR mid-point class life of 4 years or less) includes truck-tractors.
(b) **5 year property** (ADR mid-point class life of 5 - 9 years) includes autos, trucks, trailers, computers and office machines.
(c) **7 year property** (ADR mid-point class life of 10 - 15 years) includes locomotives, freight cars, track structure, signals, communications, and roadway machines.
(d) **10 year property** (ADR mid-point class life of 16 - 19 years) does not generally apply to railroads.
(e) **15 year property** (ADR mid-point class life of 20 - 24 years) includes wharves and docks.
(f) **20 year property** (ADR mid-point class life of 25 or more but not section 1250 real property) includes bridges, roadway and shop buildings, and TOFC terminal facilities.
(g) **27.6 year property** is section 1250 residential real property; does not generally apply to railroads.
(h) **31.5 year property** is for non-residential, section 1250 real property that includes office buildings and income producing (non operating) property.

3.2.4.7.4 Election may be made to claim depreciation on the straight line depreciation method over the recovery period or the ADR mid-point period (if the Alternative Depreciation System is elected).

3.2.5 Generally, values used in IRS submissions are derived from either of two sources:

(a) The first method accumulates cost directly from a road's current year accounting system to update accumulated running totals. This method frequently requires adjustments for actual values derived thru finalization of Completion Report used for IRS audit purposes.
(b) The second method combines BV 588 costs (financially complete data) with open AFE totals.

3.2.6 Gains and Losses

Gains and losses must be calculated for casualties, sales, or other abnormal dispositions of assets acquired prior to 1981. Gains and losses must calculated on all retirements of assets acquired subsequent to 1981 (except track structure on which a mass asset election was made). This calculation compares the tax depreciated values to the proceeds from disposition. For track structure on which a mass asset election was made, all proceeds are reported as ordinary income.

3.2.7 Retention of Documents

Records that establish the tax basis should be kept permanently. Other tax related records should be maintained at least until IRS audit is completed.

3.3 STATE INCOME TAX

3.3.1 Values provided for state income tax purposes generally follow federal guidelines. One notable exception is the requirement by some states for railroads to continue to report costs on a retirement - replacement - betterment (RRB) accounting basis even after the change in Federal law in 1981. In addition some states have adopted Federal ACRS rules, but with different effective dates for state purposes.

3.3.2 Each state provides its own income allocation factors to apportion the railroads total income to that particular state.

3.4 INVESTMENT TAX CREDIT (ITC)

3.4.1 ITC was enacted by the Revenue Tax Act of 1962, to provide tax relief for taxpayers with substantial capital investments. It was temporarily suspended on October 10, 1966 and reinstated on March 10, 1967. It was repealed on April 18, 1969, restored on April 1, 1971, and again repealed, for property placed in service after December 31, 1985 (except for property qualifying under transition rules).

3.4.2 Non track investment costs have been readily identified and reported for ITC purposes. However, due to the unique qualities of RRB Accounting, track costs have posed a greater challenge. RRB accounting has not been permitted for Tax accounting purposes since December 31, 1980.

3.4.2.1 Some track replacement costs, for the years prior to 1981, that were reported as operating expense under RRB accounting rules qualify for ITC as follows:

(a) Installations and not repairs (maintenance).
(b) Costs of removing facilities that are replaced are excluded. Some roads identify removal costs from direct field reporting, other roads use a percentage of reported replacement labor.
(c) Derailment or other casualty costs in excess of $50,000.
(d) Beginning in 1981, all capital projects and generally the former RRB replacement costs are depreciated for tax, including the track investment at December 30, 1980.

3.4.2.2 Property that qualified for ITC is required to remain in service for its assigned ITC life. Early dispositions must be reported for recomputation and recapture of ITC unless a Mass Asset Election is made. The Tax Reform Act of 1986 repealed ITC. Assigned ITC lives were 3, 5 or 7 years prior to 1981 and 3 or 5 years from 1981 through 1986.

3.4.2.3 Legislation passed in 1981 allowed roads to sell ITC and depreciation benefits. In 1983 sales were limited to 45% of investment base property.

3.5 PROPERTY TAX (AD VALOREM)

3.5.1 Reporting

3.5.1.1 All railroads are required by specific state laws, and under the threat of penalty, to file sworn tax reports which include a report enumerating all physical property, owned or used, to the appropriate state agency (e.g. State Board of Equalization in California, State Tax Commission in Utah, etc.). These reports vary in complexity from California where the report (Tangible Property List) is entirely computerized and includes a listing of all land, improvements, personal property and continuous property (track), to Nevada, where operating property is merely reported in track mileage.

3.5.1.2 These reports generally designate the property as operating or non-operating and indicate its placement within taxing district. In most states, the description of the land is by map and parcel numbers that refer to specific tax maps. These maps are submitted with the report in order to more clearly describe and locate the property with respect to established maps of record within each county of the state. In California a new map is submitted each tax year to supplement or replace the existing map only when a sale of previously reported property occurs, new property is acquired, or change in a taxing district causes a Parcel to be split between two different tax rate areas.

3.5.2 Assessment

3.5.2.1 Operating Property

The assessment of operating property for the railroads is on a unitary basis. A unit is defined as all property used for transportation purposes. Each state determines the value of this unit based on the railroad's entire system, then allocates a proportion of that value to that state, that state value is then apportioned to each county within that state. Any one of three "value indicators" are used by each state, in determining the unitary value. In most states the income approach is given priority. The Value Indicators are:

(a) Capitalized Earnings (Present Value of Future Income)
(b) Stock and Debt Indicator or Market Indicator
(c) Cost Indicator which could be based on either replacement or historical asset costs.

3.5.2.2 Non-Operating Property

Non-operating railroad property is assessed or valued separately from the operating unit. While in most states the operating unit is assessed at the state level, frequently the non-operating property is assessed locally. In most states the assessment is on situs basis where market value is the standard.

3.6 SALES AND USE TAX

3.6.1 Most states in which the railroads operate impose a sales and/or use tax. Generally, the sales tax is imposed upon retailers for the privilege of selling tangible personal property at retail. Although the tax is not levied directly on the consumer, it is ordinarily passed on to the consumer. The use tax enacted as a compliment to the sales tax, is imposed upon the storage, use or other consumption in a state of tangible personal property purchased from a retailer without being subjected to the sales tax.

3.6.2 In addition some of the states provide various exemptions from the sales and use tax for acquisition of certain railroad assets and all states are prohibited by federal law from imposing such taxes directly on interstate commerce.

Part 4

Planning, Budgeting And Control

1988

4.1 INTRODUCTION

4.1.1 In part 4 of this chapter, the planning and control process will be outlined, starting with the setting of corporate goals that deal with strategic issues and ending with the more specific long term plan and the quite specific annual budget. There will be discussion of the interrelationship of the various planning function, examples of common issues to be addressed, and suggestions of how railroad planning can be organized and accomplished.

4.1.2 The budgeting process, including the preparation of annual capital and maintenance budgets, selection of capital projects, authorization process, accounting for expenditures, and cost control for the projects, will be covered in detail. Lastly, a brief synopsis of the setting up of a permanent data base for the capturing of all details. Examples will be given for each part of the budgeting and control process as a guide for recommended practice.

4.2 STRATEGIC PLANNING

4.2.1 Corporate

4.2.1.1 Objective

The objective of corporate level strategic planning is to provide the Board of Directors and Management with a plan for the best utilization of corporate assets with a maximum return on investments consistent with safety, legal requirements, and maximum service standards.

4.2.1.2 Functions

The functions performed by the corporate level strategic planning group are:

(a) Analysis and evaluation of major trends and events impacting the railroad industry and the specific company.

(b) Provide senior management with strategic assessments of issues, options, and timing of specific corporate opportunities or potential danger areas, with a plan of positive or remedial actions as appropriate. Coordinate interdepartmental responses and communicate corporate positions and arguments.

(c) Evaluation of specific purchase, sale, or merger opportunities; assess the overall marketing, financial, and operational benefits; and make recommendations as to suggested courses of action.

(d) Develop long term corporate goals for review and approval of senior management and the Board of Directors.

(e) Monitor on an ongoing basis changes in the transportation industry structure and prepare reports for management and the Board of Directors as to the competitive implication for the company and its long term goals.

4.2.1.3 Organization

4.2.1.3.1 The Corporate Planning Group should report to the Chief Executive Officer or to a nonaligned corporate officer to provide impartial analysis and judgements across departmental lines. Staff should include personnel with varying backgrounds and areas of expertise.

4.2.1.3.2 The work of the Corporate Planning Group can be productively divided into the following separate responsibilities:

(a) Asset diversification outside the transportation industry
(b) Non-railroad asset diversification within the transportation industry: barge lines, trucking lines, steamship companies, airlines, warehousing, commodity storage, and ports.
(c) Railroad acquisitions and mergers
(d) Marketing issues-strategies and long-term planning
(e) Financial issues-strategies and long-term planning
(f) Operational issues-strategies and long-term planning
(g) Engineering issues-strategies and long-term planning

4.2.1.3.3 Departmental size probably should be limited and analysis of issues might best be accomplished on a task force basis utilizing key people from the Strategic Planning group and augmented by personnel from other affected departments.

4.2.1.4 Implementation

Implementation of strategic initiatives will requires use of special corporate planning techniques and effective coordination of several departments and/or companies.

4.2.2 Marketing

4.2.2.1 Objective

The object of marketing related strategic planning is to offer strategies to enhance the company's competitive position.

4.2.2.2 Functions

The functions performed by the marketing strategic planning groups are:

(a) Evaluate the market, including area served, size and nature of business, growth potential, vulnerability, and opportunity.
(b) Analyze the company's lines of business, evaluate each vs. all types of competition, and estimate the potential of each in the future.
(c) Develop a history of the company's shipper base, and determine those secured by access, service, freight, rates, equipment, special contracts, or for other reasons.
(d) Evaluate current and potential industrial development.
(e) Assess the areas of greatest competitive concern and greatest opportunity.

4.2.2.3 Implementation

Implementation of marketing oriented planning involves use of marketing planning techniques and coordination of one or more of the following departments:

(a) Sales
(b) Shipper relations
(c) Economic forecasting
(d) Industrial development
(e) Contracts
(f) Pricing

4.2.3 Engineering

4.2.3.1 Objective

The objective of engineering related strategic planning is to determine physical strengths and weaknesses in the property as they relate to future opportunities and develop a plan for correction and improvement.

4.2.3.2 Functions

The functions performed by the engineering strategic planning group are:

(a) Develop long-term route plan based on Marketing strategies. Plan should include a core route structure, light density line abandonments, multiple track rationalization, and associated yards, shops, and other infrastructures. In preparation of the plan consideration must be given to clearance requirements, bridge and track replacement/abandonment strategies and yard and shop expansion/consolidations/modernization and closings.

(b) Prepare criteria and establish long-term capital replacement and acquisition goals for track and structures, taking into consideration, service life expectancies, safety criteria, environmental requirements and return on investment.

(c) Develop long-term maintenance goals based on service requirements, taking into consideration, track standards for required speeds/tonnage, safety criteria, environmental requirements and productivity standards. Goals should be based on minimizing cost while meeting service requirements.

4.2.3.3 Implementation

Implementation involves use of engineering planning techniques and coordination of departments having responsibility for track, structures, signals, communications and roadway equipment.

4.2.4 Financial

4.2.4.1 Objective

The objective of financial strategic planning is to provide a financial plan for the future viability of the company and the specific actions necessary to accomplish the corporate objectives.

4.2.4.2 Functions

The functions performed by the financial strategic planning group are:

(a) Develop an overall long-term financial strategy including investment opportunities, divestitures, cash management, dividend policy, capital structure, and earnings requirements.

(b) Establish long-term goals by which all financial planning can be measured - both corporate and departmental. Applicable areas might include: cash flow, income and expense, capital programs, acquisitions and sales, debt and equity financing, earnings per share, return on capital investment and cost reduction.

(c) Monitor Corporate programs and investments against long-term financial goals.

4.2.4.3 Implementation

Implementation involves use of financial planning techniques and coordination of the Accounting, Treasury, Tax, and Insurance departments.

4.3 LONG-TERM PLANNING

4.3.1 Purpose

The purpose of long-term planning is to develop a long-term plan that meets strategic corporate goals.

4.3.2 Scope

The scope of the plan should include all expenditures (capital and expenses) related to improvement, construction, and maintenance of property and equipment.

4.3.3 Objectives

The objectives of preparing a long-term plan are to:

(a) Ensure that departmental objectives are synchronized with corporate goals (See section on Strategic Planning).

(b) Provide a first year plan which can serve as the basis for the next annual budget. (See section on Annual Budget).

(c) Provide a road map showing the most economical way to reach company's goals.
(d) Encourage innovation and new ideas based on sound economical premises. Time horizon should be from 3 to 5 years in duration. While reflecting projected expenditures for each year, the plan should focus on the entire period rather than on individual years.

4.3.4 Inventory of Property and Equipment

4.3.4.1 The first step in developing a plan is the detailed knowledge of the following information about the company's facilities and equipment:

(a) Their condition
(b) Remaining economic life
(c) Continued long term need for these assets
(d) Current value
(e) Adhere to prior years long term requirements in order to determine if any portions have been deferred

4.3.5 Departmental Responsibilities

The responsibilities of the departments involved are as follows:

4.3.5.1 Project Sponsoring Departments

(a) Develop inventory and requirements for facilities and equipment in which they are responsible.
(b) Submit projects for consideration.

4.3.5.2 Engineering/Mechanical Department

(a) Develop simple costing methodologies for construction/equipment repair projects; ensuring consistent costing of projects
(b) Ensure consistency with overall strategic plan

4.3.5.3 Finance Department

(a) Coordination of total operations plan
(b) Develop overall program timetable
(c) Final review of projects so all can be considered on equitable terms
(d) In conjunction with profit and loss and cash projections, determine available funding levels
(e) Develop financing (external/internal) plan for proposed expenditures
(f) Develop inflation rates for expenditures
(g) Develop format for project submission to ensure all required data is included.

4.3.6 Project Submissions

4.3.6.1 While specific details are not warranted since it is a long term plan and subject to many changes, project submissions should include the following:

(a) Description of project and its effect on current operations
(b) Cost of project (both investment and recurring)
(c) General benefits, if any

4.3.6.2 Projects should be submitted in one of the following categories:

(a) Programs (track rehabilitation, bridges, etc.)
(b) Individual major projects (over $1 million)
(c) All other based on historical spending (smaller projects in which details are unknown)

4.3.6.3 Projects should be classified as either of the following:

(a) Return on Investment (ROI)
(b) Mandatory (safety, environmental, etc.)
(c) Operating Necessity
(d) Replacement
(e) Discretionary

4.3.7 Comparison With Former Plans

4.3.7.1 It will be useful to compare previous year plans with current one to determine if they are consistent and to highlight any major variances in spending levels in program/projects.

4.3.7.2 After the final annual budget (see Section 4.4) is approved, a comparison should be made with the first year of the plan to highlight any major variances in spending levels by program/projects.

4.4 ANNUAL BUDGET

4.4.1 Purpose

The purpose of preparing an annual budget is to provide a quantitative expression of a plan of action and an aid to coordination and implementation. The annual budget should be formulated for the all Engineering functions which pyramid to the top operating officer.

4.4.2 Scope

The scope of the annual budget should include all expenditures (capital and expense) related to the improvement, construction, and maintenance of property and equipment.

4.4.3 Objectives

The objectives to be achieved by preparation of an annual budget are:

(a) Ensure a correct and quantitative assessment of the annual operating plan (initial year of long term plan) of the Engineering Department's objectives.
(b) Breakdown the annual plan into specific controllable sub-units (ie: tie programs, rail programs, curve programs, surfacing programs, etc.)
(c) Integrate both the operating and capital spending plans in order that all issues be culminated into one Engineering master budget.
(d) Provide the basis for carrying out a variety of functions such as planning, evaluating, performance, coordinating activities, implementing plans, communicating, monitoring, and authorizing actions.

4.4.4 Development of the Maintenance of Way Capital Budget

4.4.4.1 Tie Program

4.4.4.1.1 The designated individual (Roadmaster, Assistant Division Engineer, etc.) should review his assigned territory for needed maintenance and submit the appropriate reports to the Division Engineer with recommendations and assigned priorities.

4.4.4.1.2 The Division Engineer should review the submitted reports and makes inspections at key locations. He will summarize the annual program for the District or Regional Engineer with his recommendations and assign projects in priority order.

4.4.4.1.3 The District or Regional Engineer will review the summary reports from Division Engineers and make physical inspections with Division Engineers. He will then submit the annual program to Chief Engineer for his review and approval.

4.4.4.1.4 The Chief Engineer will review the summary reports received from District Engineers and also make physical inspection with District Engineers and Division Engineers at key points. They will then finalize the annual tie program and send to Estimating for costing. The Estimating Department furnishes costs to the budget centers for expense and capital budget preparation.

4.4.4.2 Rail Program (Mainline Relay)

4.4.4.2.1 The designated individual (Roadmaster, Assistant Division Engineer, etc.) should review his assigned territory for the current year maintenance program. In the review process he will examine projected gross tons over line segments. He will also review failure programs to highlight trouble areas. He will then submit annual budget report to the Division Engineer for his review.

4.4.4.2.2 The Division Engineer reviews these reports and makes inspections at key points. He will also review gross tons projections over line segments and failure programs. He then summarizes his annual budget program for the District or Regional Engineer.

4.4.4.2.3 The District or Regional Engineer reviews the summary reports from the Division Engineers and makes physical inspection with Division Engineers. He also reviews gross tons projections over line segments and reviews failure programs. He then submits his annual budget program to the Chief Engineer.

4.4.4.2.4 The Chief Engineer reviews the summary reports from the District or Regional Engineers and makes physical inspections at key points. He will also review gross tons projections over line segments and failure programs. He will then finalize the annual rail program and send to Estimating Department for costing. The Estimating Department furnishes costs to budget centers for expense and capital budget preparation.

4.4.4.3 Curve Program

4.4.4.3.1 The designated individual (Roadmaster, Assistant Division Engineer, etc.) should review his assigned territory for needed maintenance and reviews gross tons projections over line segments. He will then submit the appropriate reports to the Division Engineer with his recommendations and priorities.

4.4.4.3.2 The Division Engineer reviews the reports and makes inspections at key points. He summarizes the annual program for the District or Regional Engineer with recommendations and priorities.

4.4.4.3.3 The District or Regional Engineer reviews the summary reports from Division Engineers and makes physical inspections with the Division Engineer. He submits his annual program to the Chief Engineer with recommendations and priorities.

4.4.4.3.4 The Chief Engineer reviews the summary reports from the District or Regional Engineer and makes physical inspections of all curves at key points. He will finalize the annual curve program and send to Estimating Department for costing. The Estimating Department furnishes costs to the budget centers for expense and capital budget preparation.

4.4.4.4 Surfacing Program

4.4.4.4.1 The designated individual (Roadmaster, Assistant Division Engineer, etc.) should review the sub-grade problems and Geometry Car reports to determine maintenance needs which include tie and steel program locations. He submits his recommendations to Division Engineer with priorities.

4.4.4.4.2 The Division Engineer reviews these reports and makes inspections if needed. He summarizes and submits his report with recommendations and priorities to the District or Regional Engineer.

4.4.4.4.3 The District or Regional Engineer reviews these reports and makes inspections if needed. He summarizes and submits his report with recommendations and priorities to the Chief Engineer.

4.4.4.4.4 The Chief Engineer reviews the reports and makes inspections if needed. He finalizes the surfacing program and sends it to the Estimating Department for costing. The Estimating Department furnishes costs to budget centers for expense and capital budget preparation.

4.4.4.5 Other Maintenance and Additions

4.4.4.5.1 The designated individual (Roadmaster, Assistant Division Engineer, etc.) should review his assigned territory for maintenance needs and submits appropriate reports with recommendations and priorities to the Division Engineer.

4.4.4.5.2 The Division Engineer reviews the reports and inspects the assigned territory. He submits a report with recommendations and priorities to District or Regional Engineer.

4.4.4.5.3 The District or Regional Engineer reviews his territory needs and inspects his assigned territory. He sends his report to the Estimating Department for costing. The Estimating Department furnishes costs to budget centers for expense and capital budget preparation.

4.4.4.6 The general manager or other appropriate officer reviews and finalizes all programs.

4.4.5 Develop Maintenance of Way Annual Expense Budget

4.4.5.1 Unlike the capital budget, the expense budget (including expenses associated with capital programs) should be prepared by functions of labor, material, other and machinery rentals. The basic area of responsibilities in the Maintenance of Way Department are as follows:

4.4.5.2 Designated Individual (Roadmaster, Assistant Division Engineer, etc.)

(a) Labor -
  Foreman section
  Assistant Foreman section
  Miscellaneous operators
  Trackman
  Special Labor items
  Holiday pay
  Office staff
(b) Material -
  Gas - Oil - Service
  Tires - new cross
  Rail
  Small tools
  Office supplies
(c) Other -
  Travel expense
  Vehicle repair
  Auto and truck license
  Office expense
(d) Machine Rentals -
  Rail drill
  Rail puller
  Rail saw
  Motor car
  Loader
  Air Compressor

4.4.5.3 General Foreman Bridge and Building
(a) Labor -
  Foreman B&B Gang
  Bridge Inspector
  Carpenter
  Mechanical B&B
  B&B Helper
  Carpenter
  Office staff
(b) Material -
  Gas - Oil - Services
  Other work on bridges
  Fuel roadway machines
  Small tools
  Bridges, trestles, culverts
  Timber trestles

(c) Other -
- Meals and lodging
- Travel expense
- Other expense
- Vehicle repairs
- Auto and truck license
- Office expense

(d) Machine Rentals -
- Air compressor
- Generator
- Welder
- Water pump
- Loader
- Paint sprayer
- Sandblast machine
- Motor car

4.4.5.4 Signal Supervisor

(a) Labor -
- Signal Foreman
- Signalman
- Signal Supervisor
- Assistant Signal Supervisor
- Signal Inspector
- Signal Maintainer

(b) Material -
- Gas - Oil - Service
- Ordinary signal maintenance items
- Small tools
- Signal and interlocking
- Office supplies

(c) Other -
- Travel expense
- Repairs to small tools
- Vehicle repairs
- Auto and truck license
- Meals and lodging
- Removal snow and ice

(d) Machine rentals -
- Trencher
- Trailer
- Generator
- Track Scoot

4.4.5.5 Total Tie Gang

(a) Labor -
- Foreman Extra Gang
- Assistant Foreman Extra Gang
- Miscellaneous operator
- Assistant Operator
- Trackman
- Truck driver

(b) Material -
- Gas - Oil - Service
- Other track material
- Fuel roadway machines
- Small tools
- Office supplies

(c) Other -
- Other expenses
- Meals and lodging
- Vehicle repair
- Travel expenses

(d) Machine Rentals
- Anchor applicators
- Tie Handler
- Spike setter driver
- Tie knockout
- Spike puller
- Spike cleaner
- Rail lifter

4.4.5.6 Surfacing Gang

(a) Labor -
- Foreman Extra Gang
- Operators
- Trackman
- Truck driver

(b) Material -
- Gas - Oil - Service
- Fuel roadway machines
- Small tools
- Ballast
- Office supplies

(c) Other -
- Other expenses
- Meals and lodging
- Vehicle repair
- Auto and truck license

(d) Machine Rentals -
- Tie tamper
- Anchor squeezer
- Ballast regulator

4.4.5.7 Speciality Gangs
(Undercutter, Construction, Road Crossings, Pickup, Siding Relay, Jordan Spreader, Ballast Regulator, Weed Mowers, Burro Crane, Track Crane, Backhoe, Bolt Machine, PT Grinder, Dozer, Motor Graders, Dragline, Welders, and Others)

(a) Labor -
- Foreman Extra Gang
- Operators
- Trackman
- Truck driver
- Welder
- Timekeeper

(b) Material -
- Gas - Oil - Service
- Fuel roadway machines
- Small tools
- Ties
- Rail
- OTM
- Other Expenses

(c) Other -
- Other expenses
- Vehicle repairs
- Auto and truck license
- Meals and lodging
- Travel expense

(d) Machine Rentals -
- Tamping Power Jack
- Track Undercutter
- Track Liner
- Air Compressor
- Rail Drill
- Rail Saw
- Speed Swing
- Welder
- Tie Inserter
- Burro Crane
- Loader
- Spike Puller
- Tie Saver
- Cribber
- Adzer
- Gauging Machine
- Motor Car
- Rail Heater
- Rail Vibrator
- Anchor Applicator
- Rail Puller
- Spike Setter
- Other

4.4.5.8 Division Engineer

(a) Labor -
- Division Engineer
- Assistant Division Engineer
- Office Engineer
- Party Chief
- Engineering Technician
- Chief Clerk
- Maintenance Clerk
- Report Clerk
- Other

(b) Material -
    Gas - Oil - Service
    Office supplies
    Other
(c) Other -
    Utilities
    Travel expense
    Other expense
    Vehicle repairs
    Auto and truck license
    Contracts - various

4.4.5.9 Assistant General Manager - Engineering or Regional Engineer
(a) Labor -
    Gas - Oil - Service
    Office supplies
    Other
(b) Other -
    Utilities
    Travel expense
    Other expense
    Vehicle repairs
    Auto and truck license
    Contracts - various

4.4.5.10 Chief Engineer Office
(a) Labor -
    Chief Engineer
    Assistant Chief Engineer
    All other Engineering Office

4.5 AUTHORIZATION PROCESS

4.5.1 Purpose

The purpose of the authorization process is to develop a systematic approach to the authorization (approval) of short and long term plans corresponding budgets and individual projects or programs.

4.5.2 Scope

The scope of the authorization process should include all expenditures (capital and expense) related to improvements, construction, and maintenance of property and equipment.

4.5.3 Objectives

The objectives of the authorization process are:

(a) Assist the Engineering Department in justifying detailed plans
(b) Commit funds against fiscal year and/or long range plan
(c) Provide the ability for executive staff to review in depth, planned activities and weigh same against items of impending high priority.

4.5.4 Departmental Responsibilities

The responsibilities of the departments involved are as follows:

4.5.4.1 Engineering Department
(a) Develop functionary (C&S, Track, etc.) plans at lowest level
(b) Coordinate interrelated plans ensuring there is no duplication within content.
(c) Prepare necessary documentation for all project work ensuring that all appropriate designs, pricing and justifications needed are part of the package
(d) Submit total package to Corporate approving authority

4.5.4.2 Finance

(a) Coordinates overall planning/budgeting functions
(b) Review with executive staff any areas of concern
(c) Seek additional information from originating departments where prioritization is necessary

4.5.4.3 Corporate

(a) Review all overall project plans submitted by all departments
(b) Ensures that each meets Corporate guidelines and furthers Corporate goals
(c) Notify originating departments of status of each project

4.5.5 Plan/Budget Documentation

4.5.5.1 A document giving details of the would-be plans of the Engineering Department should be used. The designation should be decided by the Finance Department.

4.5.5.2 The documents should be used for all proposed capital and operating expense plans and should contain the following:

(a) Description of work to be performed
(b) Information as suggested in both the Long Term Plan and Annual Budget sections of this chapter
(c) Breakdown detail of all pertinent cost information

4.5.6 Project Documentation

4.5.6.1 A document giving details of the would-be commitments should be used by the organization. This document could be designated as any of the following:

(a) Authorization for Expenditures
(b) Commitment Approval Request
(c) Project Request

4.5.6.2 The document should be used for any major project either capital, expense or both and be a cover for a total package containing the following:

(a) Detailed breakdown of cost
    1. Contracted work
    2. Materials listing
    3. Work equipment needs
    4. Responsible sub-departments or divisions
(b) Description of project (Task)
(c) Breakdown of projected manpower utilization
(d) Incidental and ongoing costs. (Ongoing costs will benefit the planners in the development of future plans).
(e) Schedules
(f) Justification
(g) Consequence (if not approved)
    Summarizes all plans into overall presentation for executive union.

4.6 CONTROL FUNCTIONS

4.6.1 Purpose

The purpose of the control functions is to develop a systematic approach to the analysis of costs to ensure proper control over all project expenditures.

4.6.2 Scope

The scope of the control functions should include all expenditures (capital and expense) related to improvements, construction and maintenance of property and equipment.

4.6.3 Objectives

The objectives of the control functions are to:

(a) Ensure that all costs charged to a project belong to that project
(b) Ensure that the Engineering staff maintaining proper control on the progress of each project
(c) Ensure all costs chargeable to regular operating expenses are periodically reviewed and analyzed. Where deviations from plan (budget) occur, necessary changes should be made.

4.6.4 Responsibilities

The responsibilities of the departments involved are as follows:

4.6.4.1 Engineering Department

(a) Ensure that work performed is in accordance with specifications in AFE
(b) Forward all charges/accruals to Property Accounting
(c) Report the "percentage completed" for each project
(d) Report variances in schedule and/or spending
(e) Update each project schedule where necessary

4.6.4.2 Project Accounting

(a) Determine whether costs being assigned to the project are appropriate and reasonable.
(b) Publish monthly expenditure status report for each open AFE to include, for both capital and expenses incident:
    1. authorized amount
    2. amount expended to date
    3. amount overexpended, if any
    4. percentage of authorized amount spent to date
(c) Foreward, to project sponsor and Engineering, a report of projects for which 75% of authorized amount has been expended.

4.6.5 Variance Analysis

The project costs being incurred must be analyzed periodically to determine if project implementation is proceeding in accordance with plan. In general, the analysis will consist of the following steps:

4.6.5.1 Compare percentage of project completed and percentage of gross authorization expended to date.

4.6.5.2 Analyze any variances and identify any scope changes and/or possible project overruns.

4.6.5.3 Determine need for potential corrective action such as the possible need for a supplemental AFE if the anticipated cost to complete the project will exceed the authorized spending.

4.6.6 Impact on Operating Budget

It will be possible to identify, from most current project schedules, those projects whose anticipated/actual completion dates will provide benefits to be realized in the coming budget year. Incorporate benefits, to be realized from capital projects, into the development of the annual operating budget, e.g.,

(a) decrease in operating, repair costs
(b) incremental traffic and contribution

4.6.7 Capital Performance Reviews (Post Audit)

4.6.7.1 Purpose

The capital performance review has the following purposes:

(a) Improve capital budget administration and enhance future capital programs (improve management's forecasting, evaluation, and decision-making procedures)
(b) Review and evaluate the internal control system associated with capital expenditures

4.6.7.2 Objectives

The objectives of the performance review on:

(a) Determine whether the project objectives were realized

(b) Determine whether the actual project costs were in conformance with the estimated and authorized amount

(c) Identify the benefits achieved and determine (for ROI projects) whether the proposed ROI was realized

(d) Determine, to the extent possible, whether this was the best solution to the particular problem addressed in the AFE

4.6.7.3 Scheduling

To be effective, it is necessary to conduct the review within a reasonable amount of time after project completion so as to utilize findings in the evaluation and decision-making of similar projects. However, it is also necessary to permit necessary time to pass in order to accurately measure benefits realized (e.g., revenue enhancement projects)

4.7 PERMANENT DATA BASE

4.7.1 Purpose

The purpose of the permanent data base is to establish a direct access for the gathering of information pertaining to all Maintenance of Way functions entered into a data base for various reports and project status. The data base will have all Engineering expenditures readily available at all times in one location.

4.7.2 Scope

The scope of the permanent data base should include all expenditures (capital and expenses) related to improvement, construction, and maintenance of property and equipment.

4.7.3 Objectives

The objectives of the permanent data base are:

(a) To eliminate multi-handling of data for various reports

(b) To eliminate time lost by doing the reporting by hand

(c) Provide fast and efficient means of reporting

(d) To be able to review and make changes more rapidly

4.7.4. Departmental Responsibility

The responsibility of the departments involved are as follows:

4.7.4.1 Engineering Department

(a) Ensure that all possible units are defined and included into design of data base

(b) Ensure all pertinent cost and progress reporting is performed by appropriate divisional and functioning staffs

4.7.4.2 Property Accounting

(a). Ensure all Engineering input agrees to General Accounting reports in total

(b) Ensure all reports are prepared simultaneously with Finance Department accounting closings

4.7.5 Implementation

Implementation will require the availability of computer resources with a large amount of storage capacity. Using these resources, it is necessary to create a data base to store all the available information. Sufficient fields must be established to input each budgeted item and to contain the following:

4.7.5.1 Capital Budget Implementation

All budget items should be input by projects according to ICC Account Code order, by region, subdivision or district, etc. Output can be given in:

(a) Total dollars per region, subdivision or district
(b) ICC Account order
(c) Other reports as desired

4.7.5.2 Operating Budget Implementation

The available data should be input by:

(a) Gang numbers by project
(b) Gangs by Regions
(c) Regions by subdivisions or districts, etc.

The dollar amounts from the projects can be sorted, adjusted and changed throughout the year.

Proposed 1988 Manual Revisions
To Chapter 13 — Environmental Engineering

The following Section 4.2, "Noise Barrier Technology" is a proposed addition to Part 4 — Noise Pollution Control. Section 4.2 addresses the reduction and/or mitigation of noise received by employees and the general public from railroad sources through the effective design and installation of noise barriers.

Railroads can produce noise as a result of sundry operational functions at facilities and along the right-of-way. The United States Environmental Protection Agency has promulgated a number of noise standards applicable to the railroad industry. This is one of several methods which might be employed in order to control noise and comply with governmental regulations.

4.2 NOISE BARRIER TECHNOLOGY

4.2.1 Introduction

(a) Modern North American railroads provide service to a highly industrialized and technologically advanced society. As a result of these two aspects of modern society, North American countries produce materials, tools, and the means of progress for much of the world. An unfortunate by-product of this industrialization is the emission of pollutants. These pollutants come in the form of waste (solid, water and air), and the emission of noise. Railroads, like any industry, can emit these pollutants.

(b) The United States Environmental Protection Agency (EPA) has promulgated a number of noise standards for the railroad industry in an effort to protect the public environment. Most notably, standards have been set for sound levels from stationary and moving locomotives, moving railroad cars, locomotive load test stands, retarders, and car-coupling impacts. The Federal Railroad Administration (FRA) has promulgated compliance regulations to implement the EPA standards.

4.2.2 Solution of Noise Problems

(a) Railroads may produce noise pollution as a result of operational functions throughout facilities and along the right-of-way. In yard areas, the overall noise level is determined by noises associated with locomotive maintenance and operation and with the classification of railroad cars. Noise levels, both within the yard and around the perimeter of the yard, can vary significantly. A survey should be conducted by the railroad in order to determine sources of noise and the level of noise generated. Once a noise survey has been completed, a plan for mitigating excessive noise can be formulated, if necessary. There are a number of methods which may be employed for controlling noise.

(b) Protection can be used at the receiver. This protection might be in the form of ear plugs or noise attenuating ear muffs for employees or architectural modifications of residences, yards and commercial businesses.

(c) The problem of excessive noise can be eliminated at the source by a variety of means. Noise eliminating or suppressing devices might be utilized (e.g., quieter shoes on existing retarders and mufflers on refrigerator exhausts). Equipment might be redesigned with reduction of noise, an important criterion of the design. Addition of oils or metallic compounds to contact surfaces in order to reduce vibratory motion and noise might be employed. If noise reduction at the source is the objective, operating procedures of equipment or facilities might require modifications. Source noise control might be accomplished, where possible, by curtailing or ceasing noisy operations during noise sensitive periods. These techniques have varying degrees of feasibility and while feasible at one location, may not be equally feasible at the next.

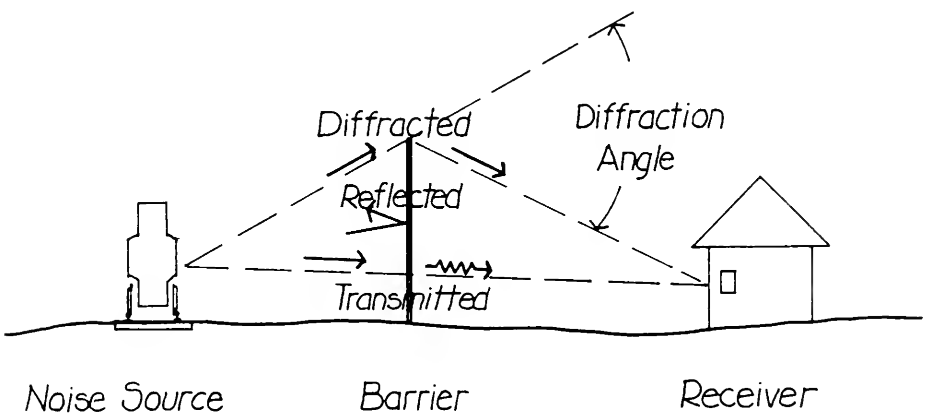
(d) Frequently, the most practical and economically feasible method of noise control involves effecting changes in the sound transmission path. This might be done by increasing the distance between source and receiver (e.g., moving ready tracks and similar areas where locomotives and switch engines idle to interior areas of the yard). Another means of increasing distance between source and receiver is to move the receiver, although this is rarely a viable option.

(e) A frequently used and effective method of altering the sound transmission path is the introduction of a barrier between the noise source and the noise receiver. By inserting a barrier between the source and the receiver, the amount of sound energy reaching the receiver is reduced. This reduction of the sound energy is referred to as "noise attenuation."

4.2.3 Noise Barrier Design

(a) The below information is offered, not as a design manual, but rather as an overview to provide information on available alternatives and benefits and drawbacks of barriers. Acoustical professionals or detailed reference material should be referred to in order to adequately design the optimum barrier.

(b) There are three components to the noise attenuation provided by a noise barrier (See Figure 1-1). These components are transmitted noise, diffracted noise, and reflected noise. Transmitted noise is sound which the barrier permits through the structure. Diffracted noise is that sound which is bent over or around the barrier. Reflected noise is that sound which reflects from the barrier. Reflected noise does not reach the receiver unless it reflects from another surface behind the barrier over the top of the barrier, thereby becoming diffracted noise.



Noise Attenuation Components

Figure 1-1

(c) The diffraction or bending of sound waves occurs in the "shadow zone." A straight line from the noise source over the top edge of the barrier defines the boundary of this zone. Any receiver in the shadow zone will benefit from some sound attentuation. The amount of sound attentuation is dependent on the size of the diffraction angle (the angle between the line from the source to the top of the barrier extended toward the receiver and a straight line from the top of the barrier to the receiver). The amount of sound attenuation as a result of diffraction increases as the diffraction angle increases. Therefore, the amount of noise attenuation attributable to diffraction is dependent upon the geometrical relationship between source, barrier and receiver and the wavelength of the sound.

(d) The sound attenuation provided by a barrier is critically dependent upon the height of the barrier relative to the line between the source and the receiver. Obviously, the greater the shadow zone area and the greater the diffraction angle, the greater noise attenuation can be achieved. Since the barrier height is so easily affected by the height of source and receiver, care should be taken in identifying source and receiver height. For this reason, optimum height will depend on several variables (height of receiver, height of source, and elevation of potential barrier locations) and will be different in each situation.

(e) The amount of transmitted noise, which travels through the barrier, is dependent upon barrier material parameters such as material weight, density and stiffness. The ability of the barrier material to decrease transmitted noise is also dependent upon the integrity of the barrier. If there should be holes or openings in the barrier surface, the reduction in transmitted noise will be greatly impaired.

(f) Sound refelcted from a barrier will not affect the receiver unless it reflects from a secondary surface redirecting the sound toward the receiver and thereby creating another sound source. (For example, this occurs when the squeal from a retarder is reflected between the retarder barrier and the side of a rail car). Therefore, in the event an installation has but one barrier and no surfaces capable of reflecting sound behind the barrier, no reflected noise will reach the receiver. Inasmuch as the above situation is idealized and rarely is achieved in reality, the effect of reflected noise upon the receiver must be considered.

(g) The barrier length required to attain a given degree of noise reduction is dependent upon the relative location of the receiver and the source. The barrier length must be long enough to ensure that the receiver is kept in the shadow zone of the barrier. Diffracted noise can be bent around the end of the barrier just as it is bent over the top of the barrier. An optimum length for the barrier would therefore be greatly influenced by the distance between the source, barrier and receiver and how far from perpendicular to the barrier longitudinal axis the receiver is located. The overall length can be modified by providing returns on the ends of the barrier to "wrap around" either the source or the reciever.

(h) Noise barriers can be built vertically or non-vertically (i.e. leaning toward the receiver or leaning toward the source). Angled barriers will eliminate multiple reflections and would be preferable in situations where barriers are installed on opposite sides of a noise source or where there might be reflective surfaces behind a single barrier (e.g., railcars on adjacent tracks and retarder barriers). A tilt of just a few degrees is usually sufficient to prevent the buildup of acoustical energy between two parallel surfaces.

(i) There is a wide variety of materials and combinations of materials which may be used in the construction of noise barriers. The basic structures have been constructed of masonry, concrete, steel, wood, earth, transite and combinations thereof. There are several variables which can affect the choice of material to be used for the basic barrier structure. The location of the barrier may require that the barrier be constructed of a material that is aesthetically pleasing and, as a result, somewhat more expensive. Space may prevent the use of an earthen structure, probably the least expensive of materials; however, an earthen berm has an added benefit of protecting the surrounding area in case of a derailment. Maintenance at the noise source may make it necessary for the barrier to be removable. The height of the proposed barrier can dictate the type of material to be used. If the barrier is to be of substantial height, steel or concrete will have to be used. Wood is often avoided because of its tendency to warp, thereby adversely affecting the integrity of the barrier and its ability to reduce transmitted sound.

(j) Another aspect concerning the choice of barrier construction materials is the source face of the barrier. This face can be covered with reflective or absorptive material. In general, absorptive surfaces will improve barrier effectiveness. Lower density materials will absorb more noise and reduce vibration of the barrier. Absorptive materials, however, are not considered necessary in situations where only one barrier is used because reflective surfaces can be just as effective in this instance and do not normally require replacement as often as absorptive materials. Therefore, maintenance costs would be smaller. Concrete, masonry blocks, fiberglass battes, open cell foam, and various acoustical tiles are materials with comparatively high absorptivity that have been used. Steel, aluminum and wood have significantly lower transmission loss values.[1]

(k) There are other factors which may require consideration in the design of noise barriers. Safety of workers around the noise barriers and the noise source is of utmost concern. This includes the areas such as master retarders where tower personnel should be able to see retarder and barrier maintainers while they work. Ease of maintenance of the noise source, noise barriers and any other adjacent equipment must be considered. Wherever possible, existing structures or land features should be utilized, thereby cutting installation costs. In some cases, an existing building can be used as an integral part of a noise barrier. In other cases, a hill might be employed as a barrier location in order to reduce barrier construction height.

4.2.4 Optimum Design for Specific Barriers

4.2.4.1 Physical Characteristics

(a) When confronted with the problem of reducing noise from individual sources or from a yard as a whole, there are several questions which must be answered:

1. Is a noise barrier the best solution to your noise problem?

All other avenues to the solution of your noise problem should be explored. This is especially true if the noise receiver is an isolated victim who could be easily moved or in the event that the noise source could be relocated so as to take advantage of the natural noise attenuation of distance.

2. Where should the noise barrier be located?

Obviously, the location of a noise barrier is dependent upon the noise source it is trying to treat; however, as a general rule, a barrier is most effective when placed as close as possible to the source.

3. How high should the barrier be?

The height of the barrier is dependent, as previously stated, upon the relative elevation of the noise source, the receiver and the ground at the proposed site of the noise barrier. A property line noise barrier should be of sufficient height to keep the "critical" receiver in the shadow zone of the barrier. A noise barrier installed for specific noise sources should also be constructed to a height great enough to place any potential noise receivers in the shadow zone. This is significantly affected by the elevation of the actual noise source (i.e., the top of standing locomotives, the bottom of rail cars at retarders and the top of refrigerator cars). Barriers designed to reduce car impact noise will often take on dimensions of property line barriers due to the inability to place the barrier in close proximity to the noise source.

4. How long should the barrier be?

Again, as in the height of a barrier, the length of the barrier is greatly dependent upon the nature of the noise source or sources. The length of the barrier should be sufficient to insure that the receiver or receivers are located well within the shadow zone.

5. What materials should be used?

As previously stated, the nature of the materials used will often be dictated by the three previous questions' answers (location, height and length). As a rule of thumb, it is preferable for the barrier to be constructed of material so that the transmission noise level is 10 db lower than the diffracted noise level. This insures that the contribution of the transmission noise level to the overall noise at the receiver is insignificant (i.e., less than 1 db).[2]

[1] Table #2-10, Reference #6
[2] See Figure #2-23, Reference #6

4.2.4.2 Functional Performance and Economics

(a) The above design questions regarding the physical characteristics of the barrier should be tempered with the answers to questions regarding functional performance and economics.

1. How expensive will the barrier be?

The cost of the barrier will be a function of its height, length and the nature of the materials of which it is constructed. Some "trade-off" may be necessary in materials or height of the barrier in order to make the barrier affordable.

2. Will the barrier create safety problems?

Every effort should be made so as not to compromise the safety of the workers or general public in the area of the barrier. Therefore, safety is an important parameter in the design of any barrier.

3. What maintenance or durability problems will arise?

The criticality of a noise barrier may dictate that materials requiring high maintenance or possessing low durability be incorporated in the barrier. Unless material makeup of the barrier is an overriding parameter, the most durable, low maintenance material should be employed in the barrier construction.

4. Is the barrier aesthetically pleasing?

This should be considered when barriers are near the property line as barrier builders have been sued for blocking breezes and reducing the amount of time sunlight reaches a yard. It is frequently claimed that a row of trees will act as anoise barrier; however, studies indicate that 100 ft. of dense woods will provide an attenuation of 8-10 decibels. Although a single row of trees offers no signficant noise reduction, they can (1) hide a noise barrier and (2) hide the noise source if no barrier is used. This increased feeling of privacy can reduce one's perception of the noise and its effect.

(b) Due to extreme variations in needs and conditions throughout the railroad industry, it is impossible to recommend a specific design for railroad noise barriers. One should define all reasonable alternatives (movement of receiver, movement of noise source, and potential barrier designs) which can possibly provide a solution to the individual noise problem under study and thereby insure that the most practical and economical solution to the noise problem is effected under the existing conditions.

REFERENCES

1. "Railroad Classification Yard Technology-Noise Control," U.S. Department of Transportation, Federal Railroad Administration, March 1981.
2. "Railroad Retarder Noise Reduction-Study of Acoustical Barrier Configurations," U.S. Department of Transportation, May 1979.
3. "Theoretical and Experimental Investigations of Selected Noise Barrier Acoustical Parameters," National Cooperative Highway Research Program Project 3.26, November 1980.
4. "Noise Barrier Design Handbook," U.S. Department of Transportation, FHWA-RD-76-58, February 1976.
5. "A Review of New Data Pertaining to Railroad Yard Noise Standards Made Available September 30, 1980," Wyle Research Report WR-80-50, November 1980.
6. "Handbook for the Measurement, Analysis, and Abatement of Railroad Noise," Wyle Research Report DOT/FRA/ORD 82/02-H, January 1982.

Proposed 1988 - Manual Revisions To Chapter 14 - Yards And Terminals

It is proposed that the following material on "Local Yard" will be placed under Paragraph 2.3.5, which has been left blank pending development of this information.

2.3.5 Local Yard - A local yard may be defined as one which handles cars to nearby destinations and from nearby origins. It generally acts as a sub-terminal and is often part of, or attached to, another Terminal Yard.

2.3.5.1 - Extra care must be taken in its design because insignificant changes in industry switching patterns, traffic volumes and through train scheduling may have considerable impact on the efficiency of its operation.

Proposed 1988 Manual Revisions To Chapter 28 - Clearances

Revisions include the addition of Article 3.7.4 on Methods of Measuring Clearances and a "Field Handbook of Recommended Practice for Measuring Excess Dimension Loads", which will be placed at the end of chapter 28. It is proposed to also have this handbook available as an individual publication.

Article 3.7.4 - A portable measuring instrument utilizing a calibrated, telescoping rod and vernier scale with an optical sighting device attached to an aluminum framework which is referenced to the centerline of the track to obtain a distance and an angle in a vertical plane. The combination of angle and distance from a known point to the obstruction is then converted from polar to rectangular coordinates and then plotted to attain a clearance diagram section. This method is very simple and can be performed by one person to achieve quick, accurate and inexpensive clearance data.

FIELD HANDBOOK OF RECOMMENDED PRACTICE FOR MEASURING EXCESS DIMENSION LOADS

NOTE:

This handbook was prepared by Committee 28 of the American Railway Engineering Association, and is to be used as a suggested guide for those employees who must measure, check or deal with high, wide or heavy loads in the course of their work duties.

GENERAL NOTES

1 - The load car or cars must be on level track when measured. Check cross level of track at each truck or load car or cars. If track is out of level at any truck, it will be necessary to arrange to either have the track made level or have the shipment moved to a level track.
All vertical measurements must be perpendicular to the plane of the tops of level rails. All horizontal measurements must be parallel to the plane of the tops of level rails, and taken from the longitudinal centerline of car.

2 - The heights "H" and the widths "W" must be given for both overhanging ends and also between the truck centers or bolster centers where the load is the maximum size. If there are changes in the size of the load on the overhang(s) or on the load between the truck centers or bolster centers, dimensions must be shown for these changes and their location defined with respect to truck centers or bolster centers.

3 - If idler car is used, Rule 8B of the AAR Open Top Loading Rules must be observed in order to maintain a 4 inch clearance below overhanging portion of load and above any part of idler car which load may contact. A 4 inch clearance must also be maintained between load and any part of bolster car. Deck on end idler cars equipped with conventional draft gears may be utilized for loading, provided that such materials are located not less than 2 feet from overhanging portions of load. When either one or all

GENERAL NOTES

3 - (Cont.)
end idler cars are equipped with sliding center sill or end-of-car cushioning devices, 6 feet of clearance must be maintained.

4 - Location of center of gravity of load must be furnished by shipper. If combined center of gravity exceeds 98 inches ATR, it must be reported to the Transportation Department Clearance Desk in order to obtain authority to move the load.

5 - Special attention should be taken if load appears to be unevenly distributed on car(s), as counter weights may be required.

6 - Never assume that a multiple axle can move unrestricted. The probable reason for the use of a multiple axle car would be excessive weight. Make sure that authority to move has been obtained for an individual load on a particular car.

7 - Take note that the net weight of shipment plus dunnage does not exceed the stenciled load limit (LD LMT) shown on the side of the carrying car. For bolstered loads, the load weight of each bolster must be determined from shipper for each car.
Also Rules 4(d) and (e) of the AAR Open Top Loading Rules must be observed.

8 - Should doubts arise regarding high, wide or heavy loads, help is available from your Transportation Department Clearance Desk or Clearance Engineer.
Shippers should obtain assistance from the originating carrier road.

INSTRUCTIONS FOR MEASURING

WIDTH

Locate longitudinal centerline of car. The longitudinal centerline is the line (from one end of the car or shipment to the opposite end) that is parallel to the sides of the car, and divides the width of the car into two equal parts (left side and right side).

Measure width from the longitudinal centerline of car (or from the vertical projection of this line) to all points on the load where the width changes and double (or multiply by two) each such measurement, so as to obtain the maximum equivalent width of the load.

HEIGHT

Use straightedge across rails and measure to top of car deck.

Measure height above deck of car to all points on the load where the width changes.

The height above top of rail is obtained by adding the height of the car deck above top of rail to the height or heights of the load where the width changes.

REPORTING MEASUREMENTS OF EXCESS WIDTH OR HEIGHT OF LOAD

All changes in width and height are to be reported.

When reporting dimensions of any load the following information must also be provided:

1 - Car initials and number.

2 - Overall length of load.

3 - Type of load:

Single, Double, Triple,
Single End Overhang, Double
End Overhang.

4 - Length of each overhang and complete dimensions of same. Length of each overhang must be measured from center of truck or bolster to end of load.

5 - Distance, center to center of trucks and bolsters.

6 - Distance from nearest truck center to the center of each load bolster.

7 - Center of gravity of lading and combined center of gravity of car and lading.

8 - Net weight of load.

9 - Weight of dunnage.

LEGEND

B - Distance, center to center of load bolsters.

C - Length of car, over end sills.

CL - Coupled length (between pulling faces).

D - Distance between truck centers or centers of bolsters.

H - Height above top of rail (ATR).

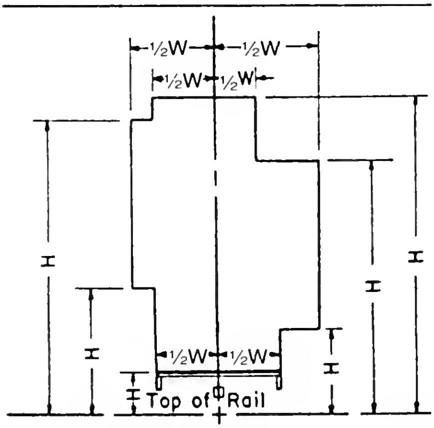
L - Length of load.

O - End overhang. (Measured from center of truck or center of bolster, to end of load.)

P - Longitudinal distance to centerline of projections on main body of load from truck or bolster center or end of load.

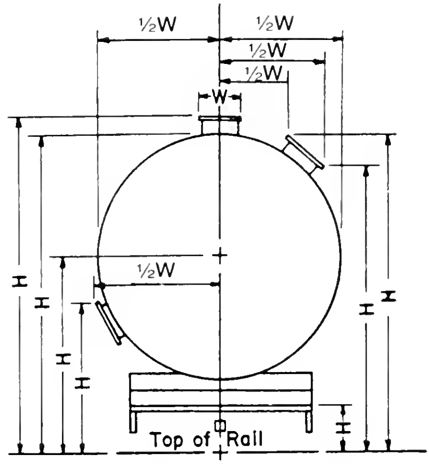
T - Distance from nearest truck center, to center of load bolster.

W - Width.



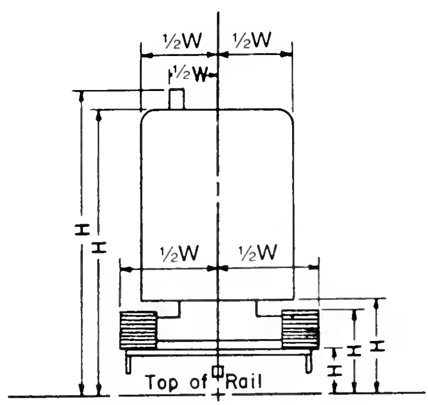
BOX TYPE LOAD

(End View)



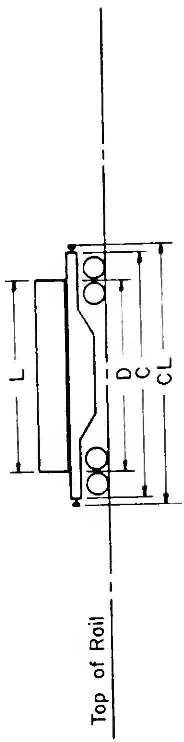
CYLINDRICAL TYPE LOAD

(End View)

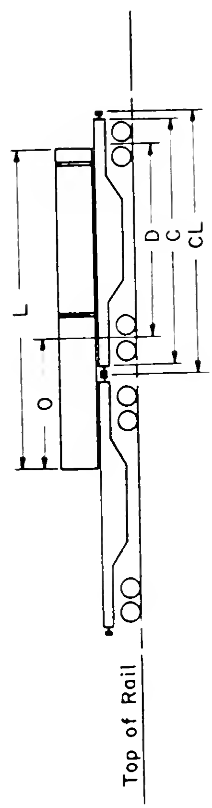


MACHINERY TYPE LOAD

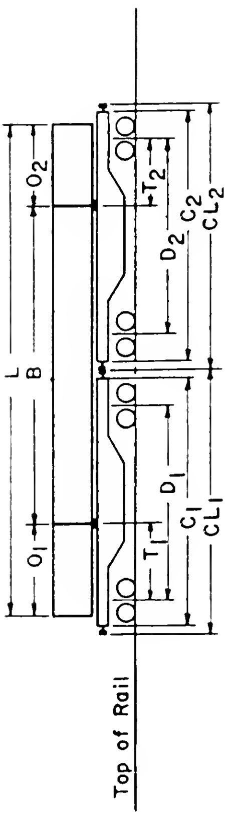
(End View)



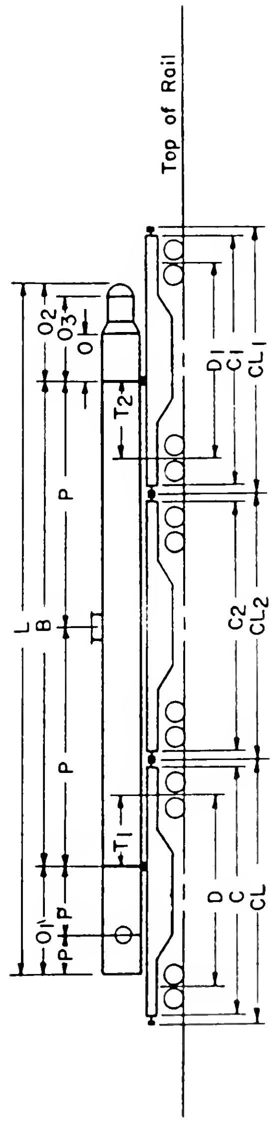
SINGLE LOAD DIAGRAM



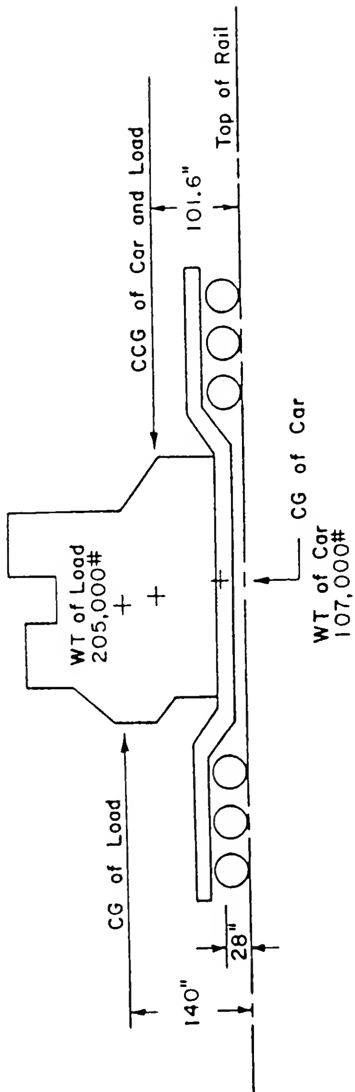
SINGLE END OVERHANG LOAD DIAGRAM



DOUBLE CAR LOADING DIAGRAM



TRIPLE CAR LOADING DIAGRAM



CENTER OF GRAVITY DIAGRAM

COMBINED CENTER OF GRAVITY FORMULA

CG - Center of Gravity, in inches Above Top of Rail

WT - Weight, in pounds

CCG - Combined Center of Gravity, Car and Load, in inches Above Top of Rail

$$CCG = \frac{(\text{CG Car}) \times (\text{WT Car}) + (\text{CG Load}) \times (\text{WT Load})}{\text{WT Car} + \text{WT Load}}$$

$$= \frac{28 \times 107{,}000 + 140 \times 205{,}000}{107{,}000 + 205{,}000}$$

$$= \frac{2{,}996{,}000 + 28{,}700{,}000}{312{,}000}$$

$$= 101.6 \text{ inches ATR}$$

NOTE:

If the combined center of gravity exceeds 98" ATR, authority must be obtained from the Transportation Department's Clearance Desk prior to movement.

GLOSSARY OF CAR AND LOADING TERMS

AAR OPEN TOP LOADING RULES

Standard procedures and specifications for loading and securing various types of loads to railroad freight cars, including excess dimension loads in both single or multiple car situations, as stated in *General Rules Governing the Loading of Commodities On Open Top Cars*, published by the Association of American Railroads, Mechanical Division. (May be found in the Mechanical Department of each railroad).

ABOVE TOP OF RAIL (ATR)

Distance from Top of Rail Line measured perpendicular to Top of Rail Line and parallel to Track Centerline (as viewed in an upright plane).

AXLE LOADING

Total weight on each axle expressed in pounds per Axle (or Thousands of Pounds, or "Kips", K per Axle). When load is not longitudinally centered on car, the axles of the truck closest to longitudinal center of gravity of load will be carrying a greater total load than the axles of the truck farthest from the longitudinal center of gravity is the load and their loading is *Maximum Axle Loading*, and is of more significance in most cases than *Average Axle Loading*.

AXLE SPACING

Distance between centers of adjacent axles of a single truck measured parallel to longitudinal centerline of car.

GLOSSARY OF CAR AND LOADING TERMS

BOLSTER

One of two pivots that support an extremely long load mounted on two flat cars called *Bolster Cars*. One bolster, the *Fixed Bolster*, can only rotate horizontally on its car, and the other bolster, the *Sliding Bolster*, can rotate horizontally and also slide longitudinally in a slot on its car as the entire consist of cars and load goes into or out of a curve. Sliding bolster also accomodates slack action of cars.

BOLSTER SPACING

Distance between bolster centers measured along longitudinal centerline of load.

CAPACITY (CAPY)

The nominal working load of a freight car expressed in pounds, gallons, or cubic feet which the car is designed to carry. This figure is stenciled on the car.

CENTER OF GRAVITY (CG)

Center of mass of an object. The point from which the component of gravity pulls downward. The weight would be perfectly balanced if a single support were placed at the Center of Gravity.

COMBINED CENTER OF GRAVITY (CCG)

Center of gravity of car, dunnage and load combined as one rigid unit. CCG is expressed in inches Above Top of Rail.

GLOSSARY OF
CAR AND LOADING TERMS

CONSIGNEE

Person, company, or entity receiving a shipment.

CONSIGNOR

Person, company, or entity sending a shipment.

COUPLED LENGTH

Length of a car measured between pulling faces of couplers. Maximum specified length of a car. This length is necessary in order to figure consist of bolster cars and idler cars. Also referred to as Outside Length.

CURVE

Track alinement having constant or variable radius (constant or variable curvature). Track alinement that is not tangent.

DOUBLE END OVERHANG

Load that extends longitudinally beyond truck or bolster centers at both ends.

DUNNAGE

Material used to secure load to car or balance load. Dunnage is not part of car and is not part of actual load proper.

EQUIVALENT WIDTH

When a load is not transversely symmetrical about the centerline of a car (the load protrudes out more on one side of the car than on the other side of the car), the greater of the two half widths is doubled to obtain the Equivalent Width.

GLOSSARY OF
CAR AND LOADING TERMS

GROSS WEIGHT

Total weight of car, net load, and dunnage.

HORIZONTAL

Parallel to horizon or level line, perpendicular to vertical or plumb line. On clearance diagrams Top of Rail Line should not be confused with Horizontal for obstructions next to curves where there is track superelevation.

IDLER CAR

Generally a non-load carrying flat car that is used in train consist for (1) Providing space for load end overhang that extends beyond striker.
(2) Providing connection between two bolster cars carrying an extremely long load.
(3) Providing space between loaded cars when loads are extremely heavy.

LADING

Net load or commodity being transported on a railroad freight car.

LIGHT WEIGHT (LT WT)

Weight of empty rail car expressed in pounds. This figure is stenciled on the car. Also referred to as Tare Weight.

LOAD LIMIT (LD LMT)

Absolute maximum allowable weight of load, expressed in pounds including both net weight and dunnage, that a freight car is authorized to carry. This figure is stenciled on the car.

GLOSSARY OF
CAR AND LOADING TERMS

LONGITUDINAL

Parallel to length of car.

MULTIPLE LOAD

Load supported by more than one car.

OUTSIDE DIAMETER

The outermost horizontal distance measured through the center of a cylindrical or spherical load.

OVER-ALL LENGTH (OAL)

(1) Length of a car over pulling faces of couplers.
(2) Total length of load.

OVERHANG (OH)

Distance between truck or bolster center and longitudinal extremity of load, always measured along prolongation of line between truck or bolster centers.

OVERLOADED

Condition that exists when:

(1) Weight of net load and dunnage exceed the Load Limit of a car.
(2) On a single load, overloading can happen if unequal distribution of lading (within Load Limit for total car) results in one truck being loaded greater than 50 percent of Load Limit of car.
(3) On a bolster car, having excess weight on one truck because of bolster being offset excessively from midpoint between truck centers.

GLOSSARY OF
CAR AND LOADING TERMS

(4) Weight (within Load Limit for total car and equally distributed between both trucks) is concentrated on too small an area of load platform of car body.

PULLING FACE

Inside face or coupler knuckles comprising principal surface of contact between couplers of coupled cars being pulled. Basic reference point for car length and figuring consist of cars and loading arrangement of a multiple load.

SINGLE END OVERHANG

Load that extends longitudinally beyond truck or bolster centers only at one end.

TANGENT

Straight track alinement that has no specified curvature.

TRUCK CENTERS

Distance between pivot points of the two trucks or span bolsters on one car.

VERTICAL

Parallel to plumb line, perpendicular to horizon or level line. Track Centerline, as viewed in upright plane, should not be confused with vertical for obstructions in curves where there is track superelevation.

File No.

EXCESSIVE DIMENSIONS LOAD REPORT

M ____________________ Phone ____________________

Of ____________________ Time ____________ Date ____________

Car Initials Number Type & Class of each Car	
LOAD CAR	IDLER CAR
LOAD CAR	IDLER CAR

Type of Lading	Value	Shipping Date

Shipper	Origin
Destination	Consignee, Address & Siding or Team Track

Normal Route (Show Junction & Carriers)

Tare Weight	Capacity or Stencilled Load Limit	Net Weight	Gross Weight	Transverse C of G of Lading	Combined C of G	Longitudinal C of G

DIMENSIONS

Height Above Top of Rail		Equivalent Width	
FT	IN	FT	IN

TYPE OF LOAD Single Load ☐ Bolster Load ☐ Single ☐ Double ☐ End Overhang Load

CAR NO. ____________ CAR NO. ____________

Over all Length of Lading Ft ______ In. ______

Base Length of Load Ft ______ In. ______

Bolster Spacing Ft ______ In. ______

Length of Car Over End Sills (C) Ft ______ In ______ Ft. ______ In ______

Coupled Length of Car Ft ______ In ______ Ft. ______ In ______

Distance from Bolster to Nearest Truck Center Ft ______ In. ______ Ft ______ In ______

OVERHANG INFORMATION

IDLER CAR NO. ____________ IDLER CAR NO. ____________

"A" END

LENGTH		HEIGHT		WIDTH	
FT.	IN	FT	IN	FT	IN

"B" END

LENGTH		HEIGHT		WIDTH	
FT	IN	FT	IN	FT	IN

OTHER CAR DATA

CAR NUMBER	"C"	Truck Centers	Axle Spacing	No Axles	Wheel Diameter	C of G of Car
LOAD CAR						
LOAD CAR						
IDLER CAR						
IDLER CAR						

DOES SHIPMENT CONFORM WITH A. A. R. LOADING RULES? YES ______ NO ______

COMMENTS or RESTRICTIONS:

REPORTED BY	TIME	DATE	MEASURED BY	TIME	DATE
FURNISHED TO	TIME	DATE	RECEIVED ENGR	TIME	DATE

CAR NO. ____________

DIMENSIONS

HEIGHT ABOVE TOP OF RAIL		EQUIVALENT WIDTH	
FT	IN	FT.	IN

CAR NO. ____________

DIMENSIONS

HEIGHT ABOVE TOP OF RAIL		EQUIVALENT WIDTH	
FT	IN	FT	IN

CAR NO. ____________

DIMENSIONS

HEIGHT ABOVE TOP OF RAIL		EQUIVALENT WIDTH	
FT	IN	FT	IN

CAR NO. ____________

DIMENSIONS

HEIGHT ABOVE TOP OF RAIL		EQUIVALENT WIDTH	
FT	IN	FT	IN

CAR NO. ____________

DIMENSIONS

HEIGHT ABOVE TOP OF RAIL		EQUIVALENT WIDTH	
FT.	IN	FT.	IN

CAR NO. ____________

DIMENSIONS

HEIGHT ABOVE TOP OF RAIL		EQUIVALENT WIDTH	
FT	IN	FT.	IN

Proposed 1988 Manual Revision
Chapter 29 — Waterproofing

The following two pages are proposed to replace in kind, pages 29-2-3 and 29-2-5 in Part 2. Substantive changes include revisions to requirements for butyl rubber and EPDM membranes.

2.3.4 Felt

A. Felts for use with an asphalt mopping shall meet the requirements of ASTM Specifications, designation D 226. This specification offers a choice of two weights of felt. The 15-lb. weight shall be used for construction of membranes on ballasted-deck railroad bridges.

B. Felt for use with coal-tar pitch moppings shall meet the requirements of ASTM Specifications, designation D227.

2.3.5 Butyl Rubber (butyl based IIR) or EPDM (ethylene-propylene-diene-monomers)

A. Membrane shall be .060 in., .090 in., or .120 in. thick at the engineer's option.

B. Membrane shall conform to ASTM D 3253:

Property	Type I (IIR)	Type II (EPDM)
Shore A hardness, points	60±10	60±10
Tensile strength, min.	1200 psi	1300 psi
Modulus at 300% elongation,min.	600 psi	900 psi
Elongation at break, min.%	300	300
Tear resistance, min. kN/m thickness	125 lbf/in.	125 lbf/in.
Weight change after 166 h at 158° F in water, max.%	±1	±1
Low-temperature brittleness temperature, max.	-40° F	-65° F
Ozone resistance, 166 h, 104, F 20% linear strain	no cracks (50 pphm)	no cracks (50 pphm)
Heating aging, air oven:		
Elongation retained, min. % of original	60, after 166 h at 240° F	50, after 166 h at 240° F
Tensile strength retained, min. % of original	60, after 166 h at 240° F	70, after 166 h at 240° F
Change in linear dimensions	±2% max.	±2% max.

2.3.6 Adhesive

Adhesive for securing membrane and the protective cover shall be compatible to the membrane waterproofing and with the materials to which it is bonded.

2.3.7 Cement

Cement for splicing either membrane shall be a self-vulcanizing butyl rubber compound conforming to the following requirements:

Viscosity @ 77° F. Brookfield Viscometer (#3 Spindle @ 10 rpm) 1700-3400 cps. Total Solids 30% (min.)

Applied to both mating surfaces @ 2 gal per 150 sq ft.

2.3.8 Butyl Gum Tape

Butyl gum tape for splicing either membrane shall be black, vulcanizable butyl rubber with an 8-mil polyethylene film backing. The tape shall be 30 mils (±4) thick, including the backing.

2.4 MEMBRANE PROTECTION

2.4.1 Premolded Asphalt Block

Premolded asphalt blocks shall meet the following requirements:

They shall be 1-1/4 in. thick. A deviation of 1/4 in. in length or 1/8 in. in width or thickness either way from these dimensions shall be cause for rejection.

These blocks shall be formed from a mixture of asphalt fiber and finely crushed aggregate placed in molds under a pressure of not less than 3300 psi of surface. An absorption test shall be made on blocks dried for 24 hrs at a temperature of 150° F., (65.5° C.), and then immersed in water 7 days. The absorption of moisture under this test shall not exceed one percent of the weight of the block.

2.4.2 Asphalt Plank

Asphalt plank shall meet the requirements of ASTM Specifications, designation D 517. Asphalt plank used for protection of waterproofing membranes shall be plain and have a minimum total thickness of 1 in. using one or more layers.

2.4.3 Brick

Brick protection shall meet the requirements of Type "M" industrial floor brick of ASTM Specifications, designation C 410 or paving brick, ASTM Specifications, designation C 7. The size of the brick shall be 2-1/2 in. x 4 in. x 8-1/2 in.

2.4.4 Portland Cement Concrete

Materials for portland cement concrete shall meet the requirements of Specifications for Concrete and Reinforced Concrete Railroad Bridges and Other Structures, Part 1, Chapter 8, of the AREA Manual. The concrete shall be air entrained, have a minimum cement content of 6 sacks per cubic yard and a maximum water content of 6 gal per sack. The maximum size of coarse aggregate shall be 3/4 in.

The concrete shall be reinforced with wire fabric which shall meet the requirements of ASTM Specification, designation A 185. The minimum gage of the wires shall be No. 12 and the wire shall have a maximum spacing of 6 in. in both directions.

2.4.5 Asphalt Mastic

Asphalt mastic shall be composed of asphalt mixed with mineral aggregates and mineral filler. The mastic shall be poured in place and mixed and proportioned in accordance with requirements of Section 2.9.4.2.

A. Asphalt shall meet the requirements of ASTM Specifications, designation D 449, Type 2.

B. Coarse mineral aggregate shall be well graded crushed stone, crushed air-cooled iron-blast-furnace slag, or washed gravel that will meet the requirements of ASTM Specifications, designation D 692 size 8 (3/8 in. to No. 8). It shall be free from soft particles, organic matter and other deleterious material.

C. Fine mineral aggregate shall be well graded washed sand that will meet the requirements of ASTM Specifications, designation C 33 for fine aggregate.

D. Mineral filler shall be portland cement, finely ground limestone or finely ground silica. The portland cement shall meet the requirements of Specification for Concrete and Reinforced Concrete Railroad Bridges and Other Structures, Part 1, Chapter 8, of AREA Manual. The finely ground limestone and silica shall meet the following requirements:

Passing a No. 200 (74 micron) sieve -- minimum 75 percent.

Passing a No. 30 (590 micron) sieve — minimum 100 percent.

Proposed 1988 Manual Revisions To Chapter 33 — Electrical Energy Utilization

It is proposed to add a new Section 4.1 — Railroad Electrification Systems to Part 4 — Catenary/Pantograph Systems. The present Section 4.1, "Contact Wire Ampacity" will be renumbered Section 4.4.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Part 4

Railroad Electrification Systems

1988

4.1 CATENARY DEFINITIONS, STANDARDS AND CONCEPTS

4.1.1 Catenary Support Options

A catenary system as utilized for traction power distribution on electric railroads is defined as a messenger wire with a contact wire suspended beneath it on hangers, mounted on fixed or hinged supports, sometimes with one or more auxiliary wires. There are numerous styles of existing systems, many of which reflect the historical requirements of originating organizations.

However, the widespread introduction of railroad electrification at 15, 25, or 50 kV with use of the local commercial frequency has encouraged greater uniformity of catenary styles and conductor choice, particularly since the early 1960's.

A considerable amount of standardization has occurred within national or regional railroad organizations and within the larger catenary system designer or supplier groups.

There are now a number of well-developed catenary styles for particular applications, with supporting concepts and standards as needed for design, installation and maintenance of catenary systems. These styles are illustrated in Figure 1.1.

4.1.1.1 Single Contact Wire System — applied where maximum train weight and speed are very low. Consists of a contact wire only, perhaps with a short bridle or stitch to the supports to permit use of longer span lengths.

4.1.1.2 Simple Catenary System — used for speeds up to 100 miles per hour where two wires are ample for the required current capacity. Consists of a messenger wire with a contact wire suspended beneath it on hangers.

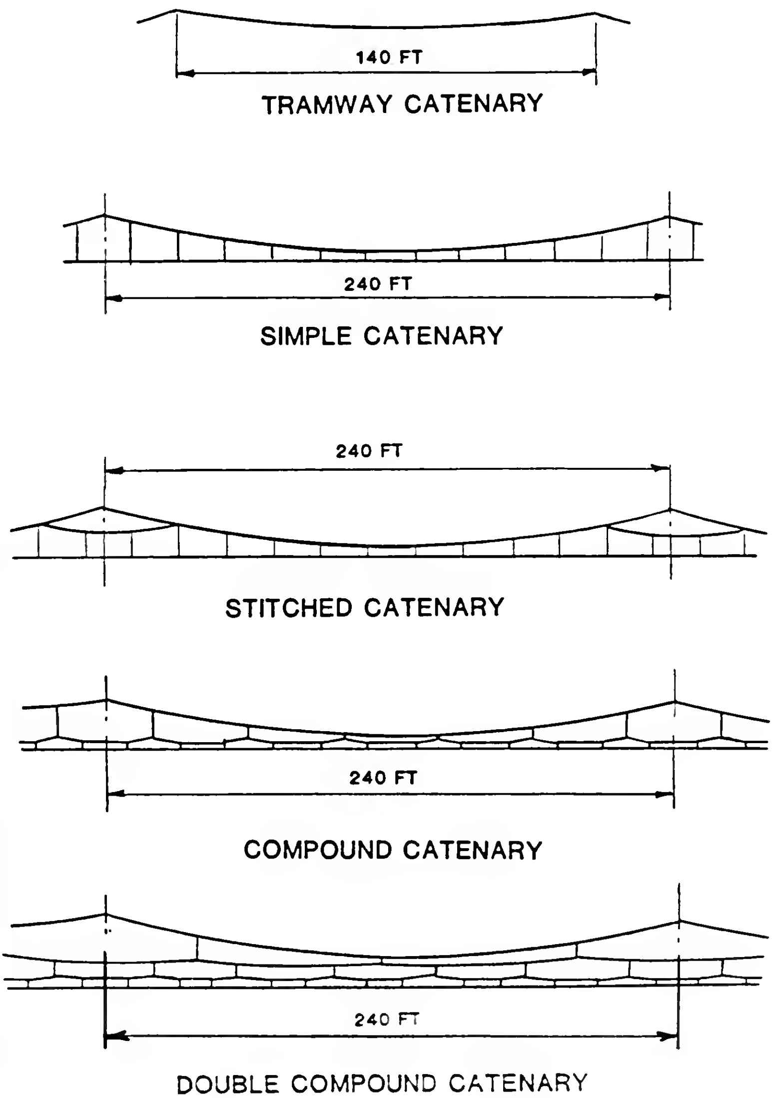
4.1.1.3 Stitched Catenary System — used for speeds up to 185 miles per hour with single pantographs where two wires are ample for the required current capacity. Is similar to simple catenary, but with a "stitch" or bridle included between the two main wires in the area of the supports.

4.1.1.4 Compound Catenary System — used for all speeds where the current capacity requires inclusion of a third wire and for medium and high speeds where progressively larger numbers of pantographs are operated on a single train. Consists of a main messenger with an auxiliary wire suspended beneath it on hangers, which in turn has a contact wire suspended on clamps or hangers beneath it.

4.1.1.5 Double Compound Catenary System — sometimes used for multiple pantograph operation on high speed lines. Consists of compound catenary with a second intermediate auxiliary wire. The styles are illustrated on Figure 1.1 attached.

4.1.2 Power Supply Equipment — includes substations and switching stations which bring the correct voltage to the distribution system from available power sources along the proposed route. The power system can be configured in either center or end-fed arrangements depending on the specific requirements. Most common secondaries used for these systems are 25 and 50 kV ac, 750, 1,500 and 3,000 Volts dc. These substations are spaced throughout the route depending on the load demand and voltage drop requirements for each system. Refer to other part of this chapter for additional details.

FIGURE 1.1


140 FT
TRAMWAY CATENARY
240 FT
SIMPLE CATENARY
240 FT
STITCHED CATENARY
240 FT
COMPOUND CATENARY
240 FT
DOUBLE COMPOUND CATENARY

4.1.3 Distribution System — is made up of all conductors which bring power from the wayside substations to the electric vehicles on the system. Depending on design requirements, each system can include:

4.1.3.1 Feed Cables — bring power from the substations to the catenary conductors on the rail route.

4.1.3.2 Catenary Conductors — can include any arrangements of messenger, auxiliary and contact conductors necessary to provide the current-carrying capacity to operate the vehicles at their required maximum speed and acceleration. In addition to current-carrying capacity, the make-up of the catenary conductors (size, material type) is determined based on maximum span lengths, tensions and climatic conditions for each specific application requirement.

4.1.3.3 Along Track Feeders — can be aerial at pole side or underground in dedicated cable-ways.

4.1.3.4 Equalizing Continuity Jumpers For Spans — provide paths either between messenger and contact wire, between parallel catenary equipments or a catenary and its along track feeder. All power can then be distributed evenly over the complex system of conductors which make up the catenary system.

4.1.3.5 Earth/Ground Conductor — maintains support structures at ground potential and provides a supplementary return path for traction current.

4.1.4 Support Equipment — includes all equipment utilized in putting a catenary system in its optimum place for maximum current collection and efficient mechanical operation.

4.1.4.1 Wayside Poles — have been supplied in many shapes and materials depending on route criteria, such as soil composition, climate, surroundings and load. The most universal has been a H section wayside pole with welded based plate which is bolted to a cast-in-place concrete footing. Support structures for specialized applications have taken the form of both tapered and fixed diameter tubular steel, wood and/or concrete poles, steel lattice type structures used along or as portal legs, and box-frame or octagonal steel forms. Support structures can be installed in a myriad of ways, also depending upon on-site criteria. In addition to bolted base poles mounted on cast footing, tubular poles can be directly embedded with native soil back fill or inserted into a concrete sleeve placed in a previously augured hole, which can then be sealed, back filled and guyed as situations merit.

4.1.4.2 Portal Structures — are used where the wire alignment is critical such as heavy wind conditions and curvy track or where multiple tracks are to be used in heavy congested areas such as New York City. Latest proposed designs incorporate fiberglass braced strut structures for bridge cross beams and poles to reduce weight and wind resistance.

4.1.4.3 Registration Assemblies — include cantilever brackets, cross-spans/head-spans, pull-off assemblies and bridge/tunnel steady assemblies.

Registration equipment in single or two-track areas is generally composed of single cantilever brackets attached to support poles positioned along side or between tracks depending upon the available clearance. Cantilevers are best constructed using standard round galvanized tubing for diagonal and top-tube members (in curve locations), assembled by means of U bolt-type clamps which allow quick, secure assembly and easy-on site adjustment during registration and commissioning. Cantilevered tubing can be affixed to the support structure through a series of H beam clamps of stainless steel strapping, which allows secure attachments which can be readily adjusted if necessary.

Electrical insulation, within the cantilever frame itself, can be either porcelain or non-ceramic. Non-ceramic insulators are a preferable choice if construction equipment has a space premium, track possession time is at a minimum, visual impact is a priority, or vandal activity is high. Messenger wire can be supported either at or from the diagonal or top tube, depending on specific load requirements of the project. Contact wire registration is performed by use of steady arms designed to accept the clearance envelope of the vehicle pantograph. Steady arms can be attached directly to diagonal cantilever tubing for tangent applications, and to a horizontal registration tube in most curve applications. Cantilevers designed for auto tensioned catenary are equipped with hinges at the pole face to allow the cantilever assembly to swing horizontally with temperature change, and with integral swivel fittings at the messenger and contact wire attachments.

4.1.4.4 Cross-Span/Head-Span Construction — is generally used where more than two tracks are present, usually in maintenance/marshalling yards. Construction is accomplished through stringing one or more stranded steel cables from one support pole to a companion pole on the opposite side. A single cable is referred to as a cross-span, while a multiple cable system, generally with the bottom cable suspended in a horizontal position, is called a head-span. The cable assembly, which is usually made up beforehand is insulated at each pole and at either side of each catenary with appropriate porcelain or non-ceramic insulation. Messenger suspension clamps and contact wire registration assemblies are attached to each head-span/cross-span with simple eye attachments to U-bolted clevis clamps, which can be placed anywhere along the cross-span wire.

4.1.4.5 Pull-Off Assemblies — provide horizontal registration, but not vertical support, to the catenary where sharply curved track is encountered. Pull-off assemblies are constructed from one or more stranded cable assemblies (also pre-prepared), one end of which has a steady arm to register the contact wire and a messenger clamp to position the messenger, with the other end attached to a pole or other structure. Connecting hardware is similar, if not identical, to that hardware used in cross-span and cantilever construction.

4.1.4.6 Tunnel/Bridge Registration Assemblies — can be as simple as flexible steady assemblies suspended from fabricated steel brackets at the face of bridges and tunnel/bridge deck, or as complex as support of an entire cantilever-type assembly from a roof-mounted steel bracket, depending on the clearances and track curvature existing at each tunnel/bridge location.

4.1.4.7 In-Span Catenary Supports — include catenary hangers, used to support auxiliary and/or contact wire from messenger. Crossing assemblies, used to allow cross over of intersecting catenaries, and spreader/knuckle assemblies, used to keep catenaries which are at close proximity to one another at their proper spacing and level.

4.1.4.8 Terminating Assemblies — which include guy anchors used to support poles, fixed deadend arrangements used where fixed catenary is applied, counter weight/cylinder arrangements used where auto tensioned catenary is applied, and midpoint arrangements used to firmly locate the center point of a constant tension catenary.

4.1.5 Sectionalization Equipment — is made up of three equipment areas:

4.1.5.1. Section Insulators — are elector-mechanical assemblies installed at various points of the catenary configuration to segment the entire catenary system, either for purposes of energization/de-energization for maintenance reasons or to designate "end points" for specific catenary feeding arrangements. These two types of applications are called bridging and non-bridging arrangements, both of which isolate one section of catenary from another by means of an insulating member at the same point in both the contact and messenger conductors. All hardware is designed to allow smooth pantograph underrun and a minumum of assembly oscillation and/or vibration. Non-bridging section insulators are fitted with arcing horns which draw and extinguish any arc created during the passage of the pantograph from the live contact wire to the dead insulating member. These arcing horns are present at both the leading and trailing edges of the section insulator assembly, and their lengths are such that passing pantographs cannot energize an adjacent catenary section which has been de-energized. Bridging section insulators are equipped with overlapping runners at both the trailing and leading edges of the section insulator in place of arcing horns which allow a vehicle pantograph to pass from one energized section of catenary to another without discontinuity of power supply.

4.1.5.2 Phase Brakes — are assemblies that separate catenaries of different voltage or phases from one another. This is required for substations using the same utility feed, but at opposing phases to one another, or on systems where multiple voltage levels or different feed sources are present. The phase break assembly uses similar components as those used in section insulators. In theory, most phase break assemblies are two non-bridging section insulator assemblies separated by a portion of catenary which has been grounded, which is also equipped with an arc trap arrangement to extinguish any electrical arcs created as the pantograph head traverses from the live catenary to the dead portion.

4.1.5.3 Isolation Switches — can be used in a variety of configurations, and are used in tandem with section insulators to isolate a section (or sections) of catenary to allow maintenance or inspection. Isolation switches can be non load-type or can be capable of opening under load conditions. Depending on their application, isolation switches can either be open air-type mounted on wayside poles, or in metallic or nonmetallic enclosures which can be attached to wayside poles, maintenance shop walls or in entirely free standing enclosures. Enclosed switches can be supplied with either internal or external operating handles with sundry features such as electrical and/or mechanical interlocks, padlocking features, switch mode viewing windows, weatherproof gasketing and louvering for venting purposes.

Notes

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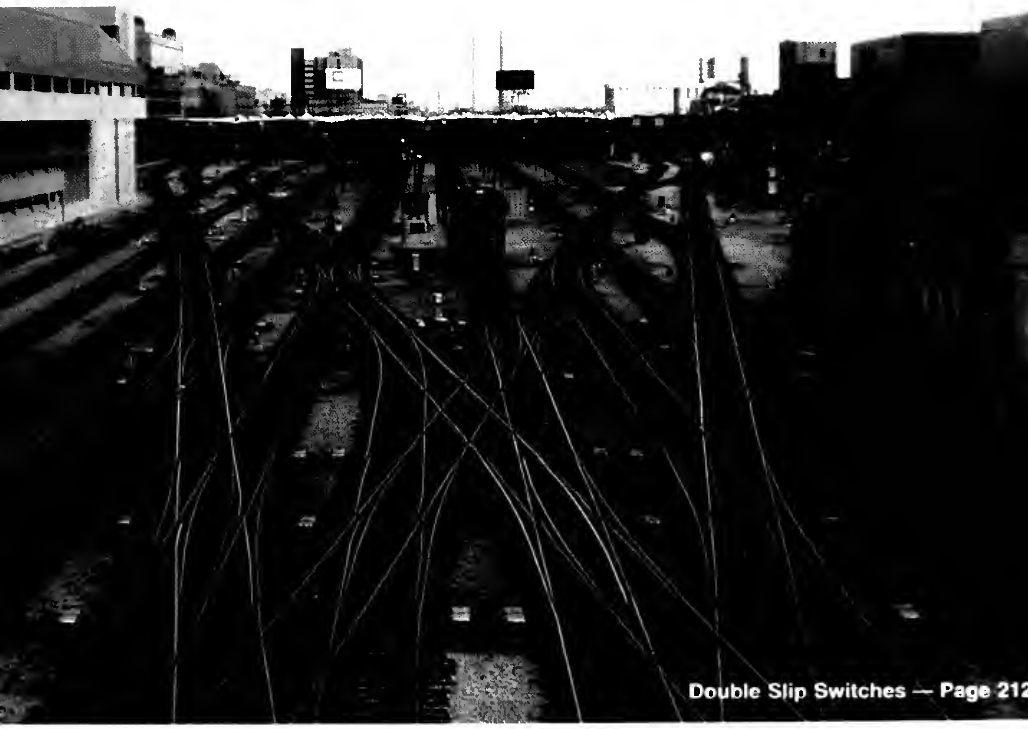

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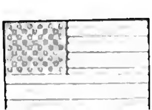

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Cover photo: Looking East towards main passenger station, Toronto, Ontario, Canada.
Photo by Peter Conlon

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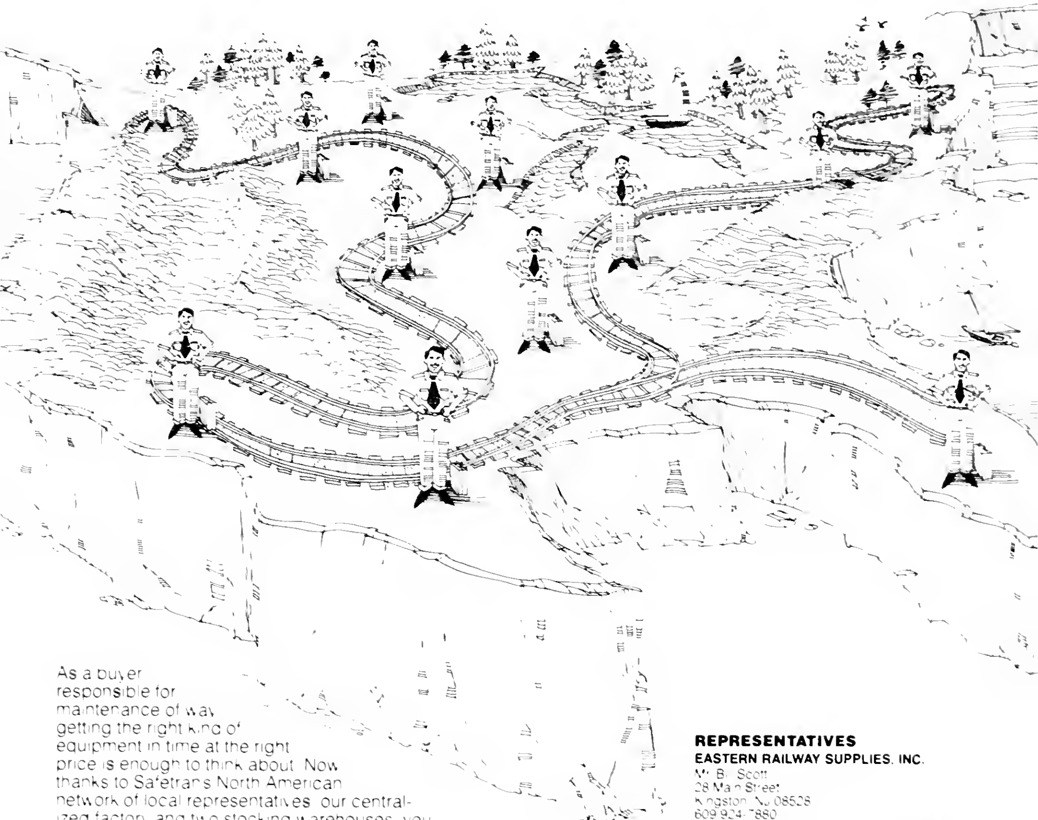

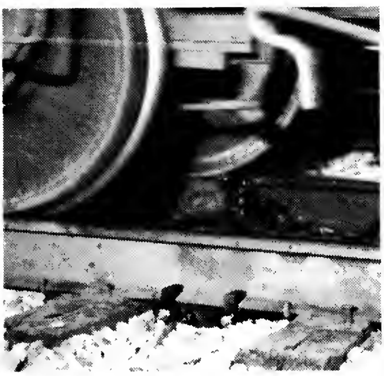

DOUBLE SLIP SWITCHES

Double slip switches are designed for places where the maximum operational flexibility between tracks is desired in the shortest possible longitudinal distance. For example, on a four track line with 14′ track centers, to give access in both directions from each track to all other tracks using only standard #10 turnouts, a longitudinal distance along the main track of about 960 ft. would be required. Using one diamond to form a double crossing between the two center tracks reduces this distance to about 640 ft. Using four double-slip switches, per AREA plan 814-55, in addition to four regular No. 10 turnouts and a diamond allows all moves to take place within a distance along the line of only 484 ft.

While the longer distance mentioned would not be a problem out in rural areas, such distance might not be available in yards and at approaches to multi-track terminals, or where junctions are congested, and there the double-slip switch provides a distinct advantage.

The advantages of the double-slip switch must be balanced against the additional moving parts they require and the need to keep an inventory of specialized parts. Using only conventional turnouts, the 960 ft. long arrangement between four tracks mentioned above requires 24 moving points. With double slip switches 40 moving switch points plus 16 movable center points must be maintained, as well as all the rods and signal apparatus needed to make sure the moveable components are in their proper location for the safe passage of a train. Because these double slip switch parts are in close proximity to each other, they are difficult to maintain, either in replacing components or for tamping. When the need to keep the moving parts of the double slip switches operating during snowfall is added, it can easily be seen why track layout designers require an exceptional set of circumstance before resorting to double-slip switches to save space.

Where double slip switches are common, such as around busy passenger terminals in the largest eastern cities, track forces skilled and experienced with double slip switches can routinely keep them operating without problems. Illustrated above, on the facing page, and on the cover, in photos take by Peter Conlon of the A.A.R. Research and Test Department, is such a location in Toronto, Ontario at the western end of the main passenger terminal, busy with VIA through trains and GO commuter trains as well as through freights.

Detailed drawings of A.R.E.A. recommended practices for double slip switches using No. 8 and No. 10 frog angles can be found in the A.R.E.A. Portfolio of Trackwork plans which is available from A.R.E.A. headquarters. The Portfolio is revised and kept current by A.R.E.A. Committee Five.


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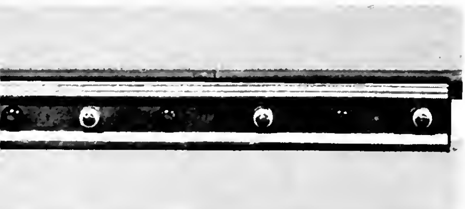

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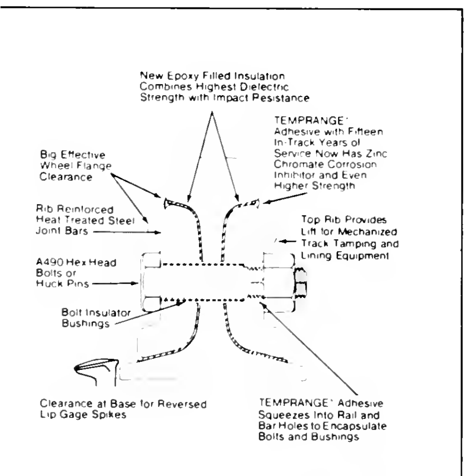

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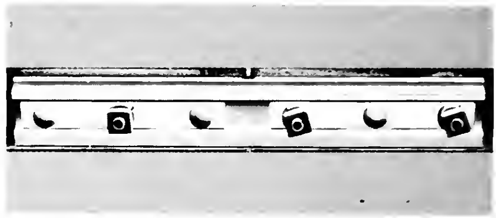

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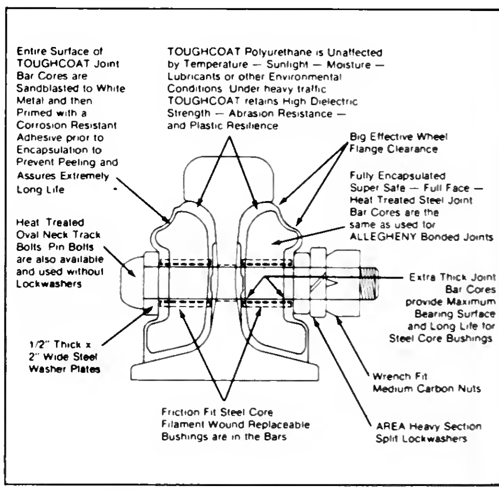

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PRESIDENTIAL ADDRESS

By: Warren B. Peterson*

Introduction

Officers, directors and members of the American Railway Engineering Association, special guests, ladies and gentlemen, welcome to the 1988 Annual AREA Technical Conference.

I am pleased and very honored to have the privilege of addressing you as president of the American Railway Engineering Association and to take this opportunity to briefly review the past year's activities and share with you some of the issues, concerns and opportunities we have before us.

Although the AREA is an organization of individual professionals, we have a very important relationship with the railroad industry and the associated equipment and supply industries. The work we do in meeting our objective for " . . . the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways"[1] can and must prove mutually beneficial to both the rail transportation industry, railroad construction and maintenance engineers and this organization's membership.

Railroad Operating Statistics[2]

In order to focus somewhat on the current status of the railroad industry and to establish a perspective of AREA's relationship, I would like first to highlight some key performance indicators to show changes or trends in railroad freight operations, revenues and productivity that have taken place in the last five years.

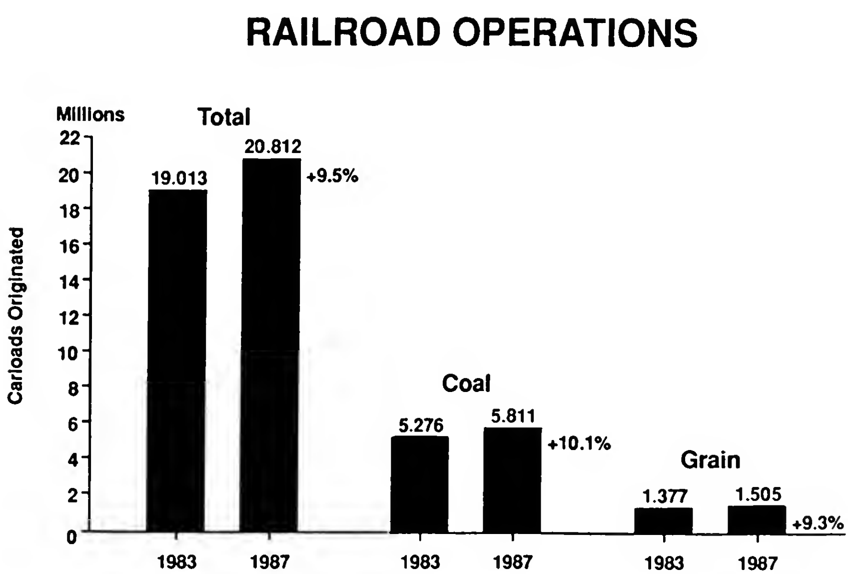

Figure 1 **Source: Association of American Railroads**

As indicated in Figure 1, railroad operations as measured by carloads originated have increased approximately 9.5 percent from 19.0 million in 1983 to a total of 20.8 million in 1987. Coal and grain have been two of the leading growth commodities with increases of 10.1 percent and 9.3 percent respectively in this same five-year period.

*President, American Railway Engineering Association, 1987-1988, Vice President Production, Soo Line Railroad

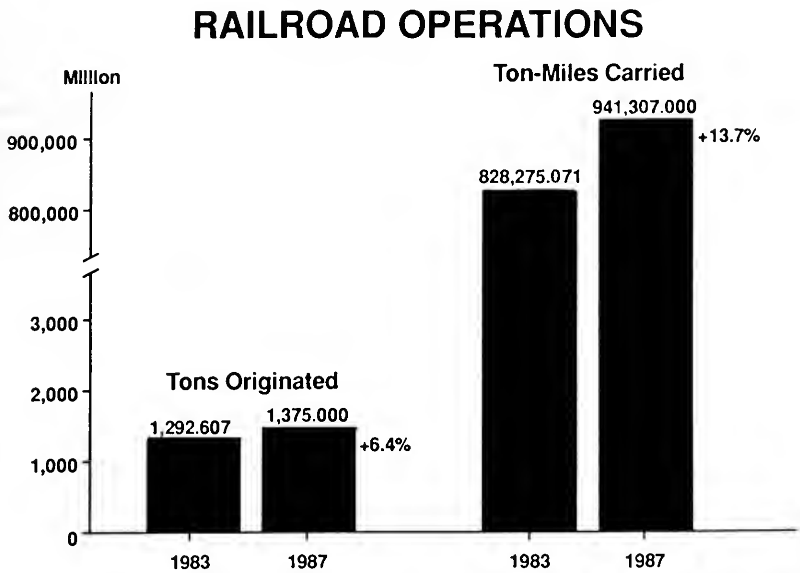

Figure 2

Source: Association of American Railroads

The related transportation service indicators, Figure 2, have increased as well but not quite in the same proportion. For example, total tonnage originated increased 6.4 percent from 1.3 billion to 1.4 billion even though corresponding carloads showed a 9.5 percent increase. The critically important measure of revenue ton-miles carried, however, moved up over 13 percent from 828.3 billion ton-miles

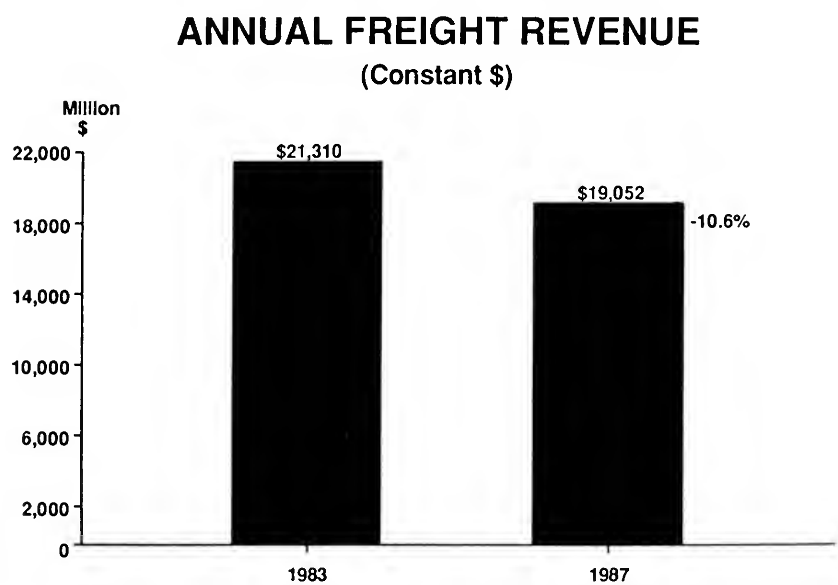

Figure 3

Source: Association of American Railroads in 1983 to 941.3 billion ton-miles in 1987. Increased tonnage combined with longer hauls produced a record 941 billion ton-miles of freight moved by major U.S. railroads in 1987.

Despite a very significant 13.7 percent increase in ton-miles carried, freight revenues, Figure 3, fell by 10.6 percent from $21.3 billion to $19.0 billion over this same five-year period. In spite of attaining a record level of freight movement, this decline in revenues clearly reflects the increasingly greater competitive pressures in the transportation marketplace.

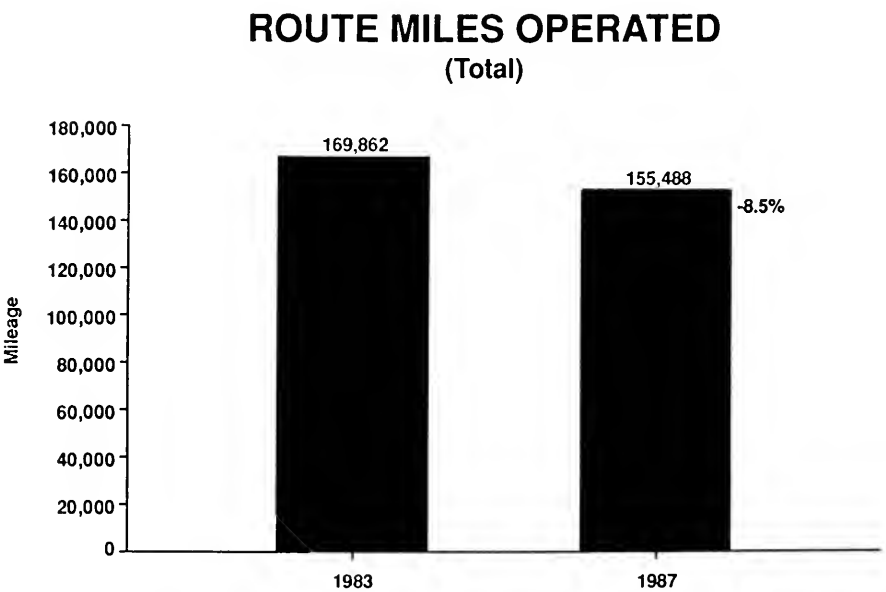

Figure 4 Source: Association of American Railroads

The railroad industry, including maintenance and construction engineers, have reacted to the resulting diminished profit margins in this five-year period. Route miles operated, Figure 4, were reduced from 169,862 miles to 155,488 miles or 8.5 percent. At the same time, total employment dropped nearly 23 percent from 322,000 in 1983 to 248,300 in 1987 as shown in Figure 5. A corresponding reduction in maintenance of way and structure employment was made equivalent to approximately 13,700 employees or 21.3 percent of the 1983 total.

Resulting cost reduction measures due in part to an 8 percent decrease in route miles and a 23 percent decline in total employment have produced major improvements in productivity, Figure 6, including a 24 percent increase in track density as measured by revenue ton miles (RTM) per mile of road and an impressive 47 percent increase in labor productivity as measured by the ratio of revenue ton miles per employee.

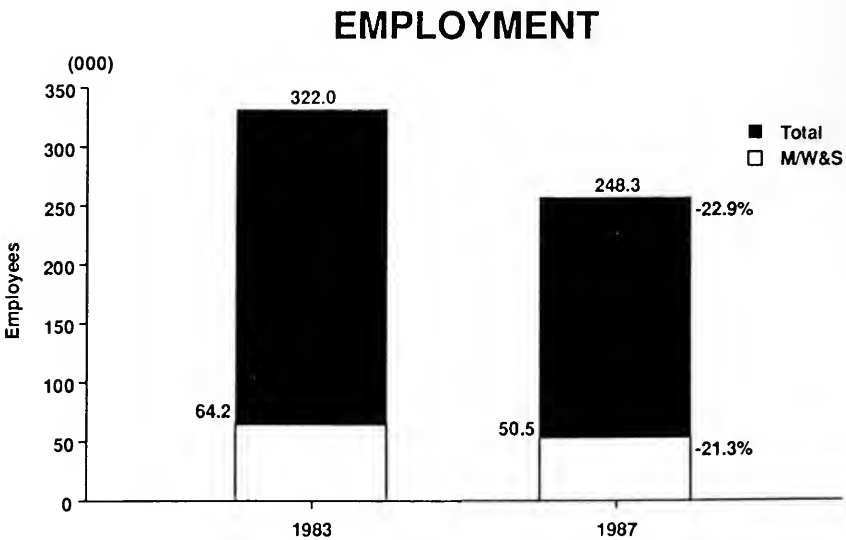

Figure 5 Source: Association of American Railroads

The fact is, however, that in view of anticipated minimal levels of economic growth, competitive pressures will continue to force reductions in profit margins making it mandatory that the railroad industry utilize all available resources to further advance productivity and continually increase and improve asset utilization.

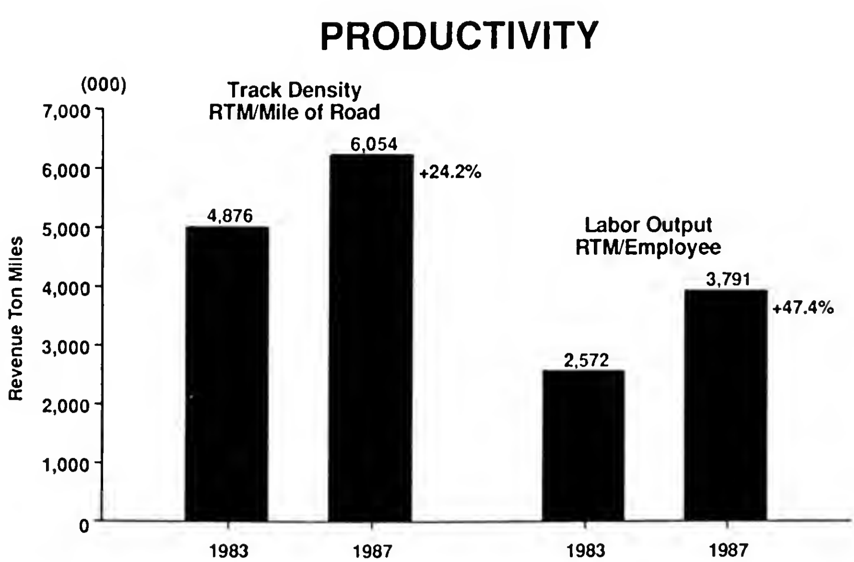

Figure 6 Source: Association of American Railroads

AREA Resource Potential

The American Railway Engineering Association presents what I believe to be a very significant industry resource affording a unique concentration of professional engineering experience and technical knowledge having the capability to study, analyze and define technical problems on an industry-wide basis and to establish recommendations that are both *economic* and *productive*.

The total membership of our Association, Figure 7, now stands at 4,248 members, a 6 percent increase over the 1983 level. This increase was attained in spite of a 21 percent reduction in maintenance of way & structures employment over the same five-year period. In addition, it is important to note that in this same time frame technical committee membership increased over 19 percent from a total of 1,333 members in 1983 to 1,590 in 1987 due in part to the addition of two new committees, 2—Track Measuring Systems and 12—Rail Transit.

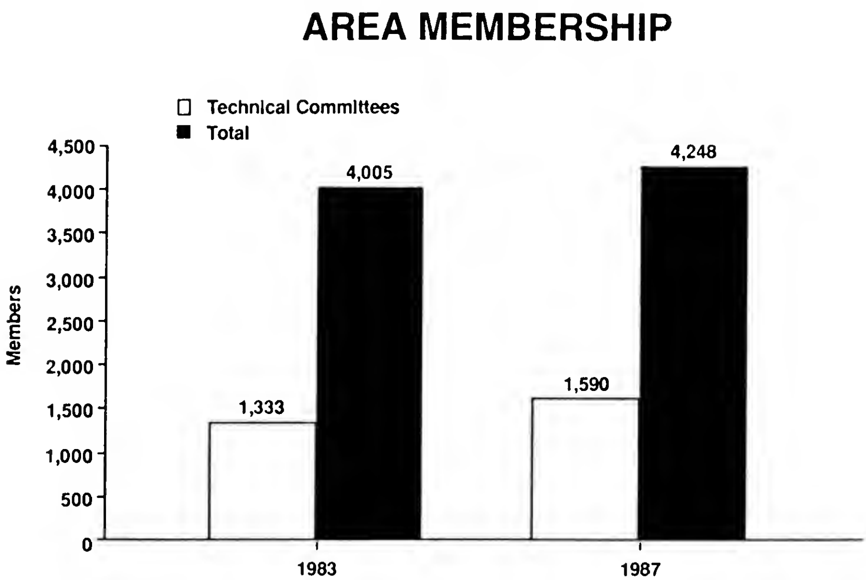

Figure 7

Not only have our Technical Committees shown growth in terms of real numbers but committee chairmen have taken significant steps to drop those not participating and to add new members having potential for greater committee contributions. Further, the Board of Direction this year implemented a new policy designed to expedite committee balloting procedures and, most importantly, to ensure appropriate committee member response and participation.

The net result should prove extremely beneficial in attaining a much higher level of membership participation in helping to achieve committee goals and objectives. For perspective, our current technical committee membership of 1,590 members committing only one percent of their time represents a potential resource of over 5,800 man-days annually.

The product of our committees, be it in the form of updated manual revisions, publications, presentations or reports, is the keystone to the effectiveness and success of AREA and most importantly the attainment of our stated objectives. We have, I believe, an excellent and highly qualified group of committee officers who have demonstrated a committment to achieving these results.

Technical Committees

AREA's 23 working committees all have important and timely assignments that will serve to advance both the scientific and economic knowledge of the railroad engineering profession. Time does not allow a review of all the major ongoing projects and accomplishments; however, the following will provide a sample of some of the excellent committee accomplishments attained this past year:

- Committee 1, Roadway and Ballast, developed a new recommended sub-ballast specification designed to improve track stability at a reduced cost. The Committee also completed a number of important manual revisions relating to roadbed instability and associated maintenance recommendations. In addition, the Committee helped produce a videotape on the installation of geotextiles and have sponsored a presentation concerning ballast degradation, both part of this year's Technical Conference.
- Committee 2, Track Measuring Systems, made its initial entry of Chapter 2 in the AREA manual only two years after the committee was formed. Further, the committee is sponsoring a symposium on automated track inspection following the completion of this Technical Conference.
- Committee 4, Rail, has developed new and improved specifications for testing new rails incorporating macro-etch standards in lieu of the current, and certainly outdated, drop test procedures. And, as with Committees 1 and 2, Committee 4 is the sponsor of a presentation at this conference relating to "Detection Methods for Harmful Inclusions in Rail Steels."
- A new manual specification concerning proper laying temperatures for continuous welded rail has been developed by Committee 5, Track, to provide critically important recommended practice guidelines that closely conform to overall industry practice. Further, Committee 5 is continually revising and updating the Portfolio of Trackwork Plans.
- Our bridge and structures committees including 7—Timber Structures, 8—Concrete Structures and Foundations and 15—Steel Structures, have all been very active in producing updated revisions to the manual relative to design, fabrication, erection and maintenance specifications. These three committees have also committed to participating in a Bridge Research Workshop being sponsored by the National Science Foundation and the AAR at the University of Illinois to help develop railway bridge research needs and recommendations relative to evaluation, rehabilitation and design. It is important to note that *active* participation as demonstrated in this case is an important AREA function.
- Committee 9, Highway-Railway Crossings, underwent a reorganization this year to more effectively evaluate and develop recommended practice regarding grade crossing surfaces, approaches and geometric design. The committee's new direction will include more emphasis on the development of new and more extensive manual specifications for highway-railroad grade crossings.
- An entirely new manual chapter was written by Committee 11, Engineering Records and Property Accounting, this year to complete a badly needed and long past due complete revision. By no means an easy task when one considers that the committee produced over 40 pages of new and/or revised manual material.
- Our newest Committee 12, Rail Transit, formed in 1986, is working on what will become the initial Chapter 12 manual material to be part of next year's supplement. Interest has been extremely good with membership already approaching the 125 member limit.
- Committee 13, Environmental Engineering, must keep abreast of the various environmental regulations affecting the railroad industry and, as a primary objective, disseminate information to help railroads achieve the most effective and economic compliance. The committee recently completed manual revisions relative to noise pollution control and is the sponsor of a

presentation at this Technical Conference regarding environmental cleanup procedures at a tie treating plant.

- Five undergraduate scholarships were awarded this past year under the sponsorship and direction of Committee 24, Engineering Education. The committee also provides speaker programs to interested student and professional groups and, in each of the last two years, the committee sponsored a very well received Railroad Track and Roadbed Engineering Seminar in conjunction with our annual technical conferences.
- Committee 32, Systems Engineering, achieves its mandate in part by sponsoring various symposiums, the most recent being a seminar on the use of personal computers held during last year's conference.

These examples of committee accomplishments provide at least some insight as to the importance of our committee activity and the results they have successfully attained. The list goes on to include a wide variety of equally important projects now underway as part of our working committee agendas. Thanks to the committee officers and those hardworking, contributing members, the committees have achieved objectives that afford the railroad industry opportunities for improvements in productivity, safety and related bottom line profitability.

AAR Research & Test

Speaking of opportunities, I would be remiss if I did not recognize the importance of the Research and Test programs currently underway by the Association of American Railroads and to emphasize the fact that our ability to continue to achieve technical committee objectives depends, to a great degree, on our ability to cooperatively participate in these research programs. Specifically, the projects included in AAR's Program 3, Track and Structures, and Program 4, Vehicle Track Systems, present very significant opportunities.

You will hear considerably more regarding AAR's activities in these important programs during the course of this Conference. I would, however, like to point out that the goal of Program 3, Track and Structures, is to develop means to reduce track and infrastructure costs by optimizing the performance of track and structure components, reducing related maintenance costs and improving maintenance of way and structure management techniques. Program 4, Vehicle Track Systems, emphasizes research relative to the interrelation of mechanical and track standards through a systems approach to improve both overall profitability and safety. The Heavy Axle Load Project (HAL) included in Program 4 is designed to evaluate the effect of 120 ton cars on track deterioration, equipment maintenance and operating costs. In my opinion, the HAL Project is critically important to this organization, the nation's railroads and the railroad supply industry.

As indicated in Figure 8, the Association of American Railroad's commitment to track and structure related research including vehicle track systems has substantially increased over the past five years.[3] In 1983, Programs 3 and 4 totalled $1.3 million or roughly 13 percent of the total $10.4 million budget. These two programs increased to $3.3 million or 21 percent of the $16.3 million budget in 1987. Programs 3 and 4 have been expanded to a total of $4.0 million this year due primarily to the HAL Project to the extent that both Programs 3 and 4 now constitute 26 percent of AAR's total 1988 research commitment.

This growth in track and structure related research is certainly beneficial to AREA. We have this year established procedures to attain necessary AAR Research & Test/AREA Technical Committee liaison to ensure our optimum participation in what now has become a $4.0 million effort. AAR liaison personnel have been assigned to appropriate Technical Committees with the responsibility to effectively communicate and establish interrelated participation. Hopefully our combined efforts will achieve mutually beneficial results.

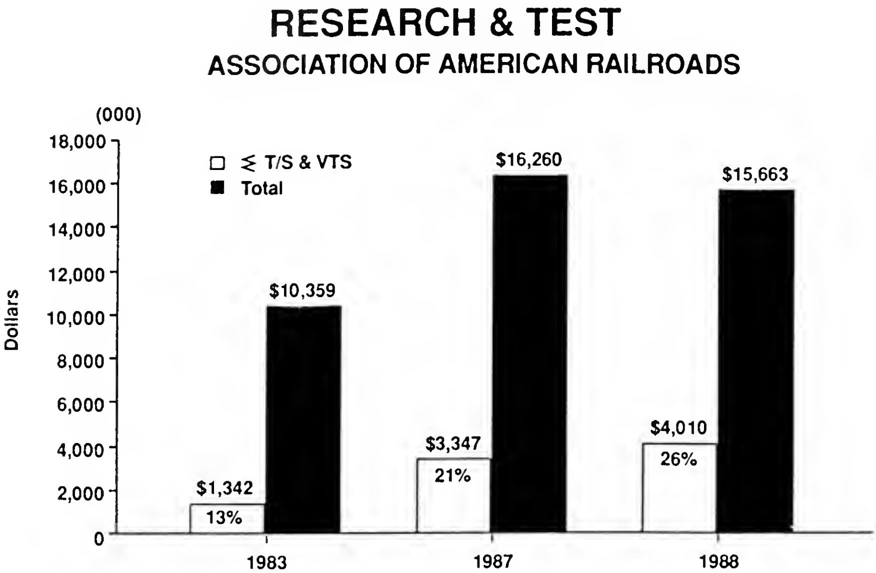

Figure 8

Challenges/Opportunities

We have major industry issues and concerns before us. The resulting challenges, or preferably opportunities, relate, at least in part, to the application of new technology, innovations in maintenance of way systems and procedures and continued research and development. It is my firm belief that the American Railway Engineering Association through its Technical Committees and support staff has the capability to properly and effectively study, analyze and define these technical problems on an *industry-wide* basis and to establish recommended practice that is both economic and productive. The AREA needs the railroad industry and most certainly the railroads of North America need our Association.

Active member participation is essential if we are to continue to meet our stated objectives with a convincing sense of direction and within a time frame that meets today's competitive demands.

In closing, I want to express my sincere appreciation and thanks to the members and officers of our Technical Committees for their generous contribution of time and effort, clearly your work is the driving force of our Association; to AREA's Board of Direction for their participation and critically important guidance; to our outstanding Washington staff for their highly professional management of our policies and procedures; and to this year's Conference Operating Committee for the commitment of their time and energy to ensure the success of this 1988 AREA Technical Conference. Please enjoy this conference; I am sure it will prove both beneficial and informative to all who have wisely taken the opportunity to attend.

This has been a year never to be forgotten, one that has given me an opportunity to be associated with outstanding individuals, second to none. I sincerely appreciate and thank you for the honor and privilege of serving you and your organization.

References

[1]American Railway Engineering Association, Constitution Article I, Section 2

[2]Source: Association of American Railroads, Economics and Finance Department. Note: 1987 Data—Estimated/Preliminary

[3]Source: Association of American Railroads, Research and Test Department

Detection Method for Harmful Inclusions in Rail Steels

By: K. Sugino*, H. Kageyama, H. W. Newell*****

Abstract

In order to confirm the correlation between non-metallic inclusions and transverse defects (T.D.) in rails, fourteen fatigue damaged rail samples in service and eleven new rail samples prepared for installation at Norfolk Southern railroad were metallurgically investigated.

Although we could not specify the inclusion which initiated the crack for the most part of the fatigue damaged rails, it was confirmed in case of two rail samples that a crack occurred from the long stringer-like Al_2O_3 cluster oxide. Based on this fact and a few references, a specific area of 10 × 20 mm in the rail heads where the crack occurs frequently was selected, and all the length and the number of Al_2O_3 and its compound cluster oxides of more than 100 μm on the specific specimen surface was measured by an optical microscope of the magnification of 100X. If the total length of 2000 μm is adopted as a threshold level, the fourteen fatigue damaged rail samples can be clearly distinguished from other new rail samples except for two rail samples from them which were found to show the total length of more than 2000μm.

These facts show that, by additional investigation for sample locations, hardness levels and installation conditions of rails, running conditions of wheels and so on, this method will be useful for pre-selection of anti-T.D. rails.

Introduction

The cyclic loading under the impact of running wheels causes various types of fatigue defects on rails. One type of fatigue crack occurs from a nucleus in the rail head, usually a few millimeters to more than ten millimeters beneath the running surface of the rail. Rails on heavy-haul railroads often break by this fatigue defect - transverse defect - and emphasize the importance of preventing the fatigue fracture. The transverse defect is usually classified into the transverse fissure (TF), detail fracture (DF) and compound fissure (CF) according to the apparent characteristics of the fracture surface[1].

When the initiation sites of these fatigue cracks are metallurgically investigated, the presence of relatively large complex non-metallic inclusions at the origins is reported [2-5]. Fracture mechanics has been employed as a principal approach to the determination of the relationship between rail life and non-metallic inclusions. Against this background, rail manufacturers have made efforts to reduce the non-metallic inclusion content of rail steel. The amount and size of inclusions have been steadily decreased by application of new steelmaking techniques[6]. Application of these techniques to a more than necessary degree, however, results in higher rail cost and lower economics. It is important in terms of economy to establish technology for quantifying the amount, size and composition of non-metallic inclusions that cause transverse defects in the rails and for decreasing such inclusions or rendering them harmless.

The method of quantitatively evaluating the non-metallic inclusions that cause the transverse defects was studied by the present work from the viewpoint of how to control the harmful inclusions. The quantitative evaluation of inclusions was performed by the following analytical procedure:

(1) Cut the specimen from a rail damaged in service by the transverse defect, metallurgically analyze the specimen and identify the non-metallic inclusion that directly caused the fatigue crack.

(2) On the basis of the finding obtained as described in (1) above, analyze fatigue damaged rails and new rails by the same method and study a method that can at least select the fatigue damaged rails or distinguish such new rails that contain non-metallic inclusions similar to those present in the fatigue damaged rails.

*Chief Researcher, Yawata R & D Laboratory, Central R & D Bureau, Nippon Steel Corp

**Researcher, Yawata R & D Laboratory, Central R & D Bureau, Nippon Steel Corp.

***Senior Metallurgical Engineer, Norfolk Southern Corp

Experimental Procedure

1. Rail Samples

Norfolk Southern selected and sent twenty-five 132-RE rail samples to Nippon Steel in three installments. Therefore they were investigated and analyzed as three experiments. The rail samples were designated A to Y. Fourteen of them were from fatigue damaged rails and were labeled F, G, H, J, N, P, Q, R, U, V, V′, W, X, and Y (V and V′ were taken from the same rail). The remaining eleven rail samples were from new rails not yet installed. The rail samples had been made by multiple rail manufacturers and they were analyzed without any knowledge of the names of the manufacturers and production history of the rails.

2. Experimental Method

The fatigue damaged rail samples were investigated for their correlation with non-metallic inclusions by a metallurgical technique. The metallurgical technique involved confirming the origin of the fatigue defect from the fracture surface pattern of the fatigue damaged rail sample, cutting a specimen containing the origin at right angles to the fracture surface or in the longitudinal direction of the rail, polishing the specimen in steps and examining the specimen for any inclusions that may be present.

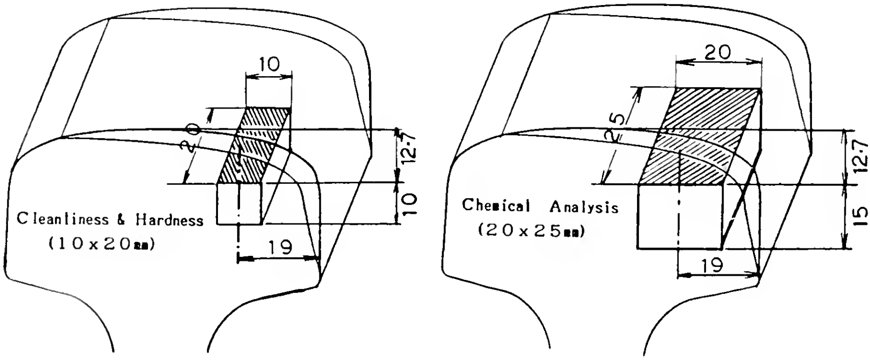

Figure 1. Test samples in rail head

Figure 1 shows the typical locations where a chemical analysis specimen and a cleanliness and hardness specimen (Fig. 1) are taken from a rail sample. Given the high density of crack origins, it was decided to analyze an area ½ in. (about 12.7 mm) deep from the running surface and ¾ in. (about 19 mm) from the side of the rail head by referring to the new 132-RE rail section. The fatigue damaged rail sample was worn into a profile different from the new rail section. Therefore, the profile of the rail sample was superimposed on the new 132-RE rail section and the positions explained above were confirmed before the two specimens were cut from each rail sample. The specimens were polished by a conventional metallographic technique while taking care that the inclusions should not be lost.

In order to confirm the effectiveness of the newly developed method of non-metallic inclusion determination, inclusions in ten rail samples in the first experiment were evaluated by three different methods currently in wide use. The methods employed were the ASTM method (E45 Method A), the JIS method (Japanese Industrial Standards, G 0555) and automatic Image Analyzer method using an optical microscope. Under the last method, the inclusions detected are classified into Type A (sulfide), Type B (cluster oxide) and Type C (globular oxide) according to the JIS method and also are classified according to their size.

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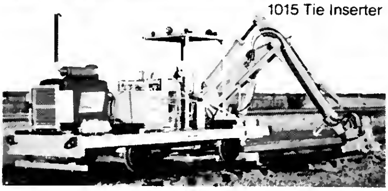

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Nobody builds it tougher.
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Table 1. Chemical compositions and average hardness values of rail samples

	C	Si	Mn	P	S	Aℓ	N	O	Hv
A	0.79	0.26	1.17	0.014	0.015	0.003	0.0042	—	281
B	0.78	0.40	0.99	0.006	0.033	0.005	0.0039	—	273
C	0.80	0.41	1.11	0.016	0.009	0.030	0.0028	—	283
D	0.74	0.39	1.17	0.019	0.017	0.051	0.0065	—	298
E	0.79	0.24	1.19	0.018	0.009	0.010	0.0069	—	297
(F)	0.76	0.14	0.82	0.015	0.015	0.004	0.0030	0.0061	318
(G)	0.75	0.15	0.85	0.022	0.011	0.004	0.0077	0.0035	359
(H)	0.82	0.15	0.82	0.015	0.016	0.008	0.0061	0.0018	321
(J)	0.82	0.23	0.84	0.020	0.007	0.004	0.0056	0.0015	266
K	0.72	0.16	0.78	0.025	0.011	0.013	0.0023	—	372

	C	Si	Mn	P	S	Aℓ	N	O	Hv
L	0.78	0.39	1.11	0.013	0.010	0.004	0.0060	0.0016	290
M	0.79	0.25	0.98	0.014	0.008	0.000	0.0076	0.0017	290
(N)	0.77	0.18	0.90	0.014	0.012	0.021	0.0095	0.0026	261
O	0.76	0.22	0.85	0.012	0.002	0.001	0.0030	0.0023	316
(P)	0.76	0.15	0.76	0.010	0.016	0.004	0.0066	0.0052	278
(Q)	0.75	0.15	0.76	0.014	0.011	0.003	0.0054	0.0045	257
(R)	0.74	0.19	0.95	0.012	0.012	0.010	0.0044	0.0032	273
S	0.74	0.33	0.89	0.012	0.010	0.010	0.0101	0.0022	279
T	0.75	0.40	1.01	0.004	0.018	0.001	0.0033	0.0063	272

	C	Si	Mn	P	S	Aℓ	N	O	Hv
[U]	0.80	0.18	0.91	0.007	0.021	0.005	0.0024	0.0020	262
[V]	0.74	0.24	0.99	0.016	0.011	0.004	0.0087	0.0038	276
[W]	0.76	0.16	0.92	0.014	0.014	0.001	0.0040	0.0017	263
[X]	0.76	0.12	0.96	0.020	0.009	0.002	0.0080	0.0036	347
[Y]	0.71	0.12	0.93	0.016	0.009	0.003	0.0078	0.0039	329

○ Fractured rails ☐ Fatigue defective rails

METALLURGICAL ANALYSIS OF FATIGUE DAMAGED RAILS

1. Effect of Chemical Composition and Hardness on Rail Fatigue Damage.

The chemical compositions and the mean hardness of the analysis surface of the rail samples are summarized in Table 1. The eight rail samples enclosed in a circle were from fractured rails and the six rails enclosed in a square were (Tab.1) rails that were not fractured in service but contained fatigue crack in the head. The eight fractured rail samples received from Norfolk Southern were each one half of a rail completely fractured in service. Judging from the composition and hardness values, all of the rails investigated are either standard carbon rails or head-hardened rails and none are alloy rails.

The content of manganese, sulfur, aluminum and oxygen, responsible for the formation of non-metallic inclusion, in the rail samples are shown in Figure 2 relating to the fatigue damaged rail samples. As far as these compositional distributions are concerned, some rails that contained small amounts of such elements are damaged. This means that the (Fig. 2) fatigue damaged rails cannot be distinguished by the chemical composition alone. This is true for hardness level of rails investigated.

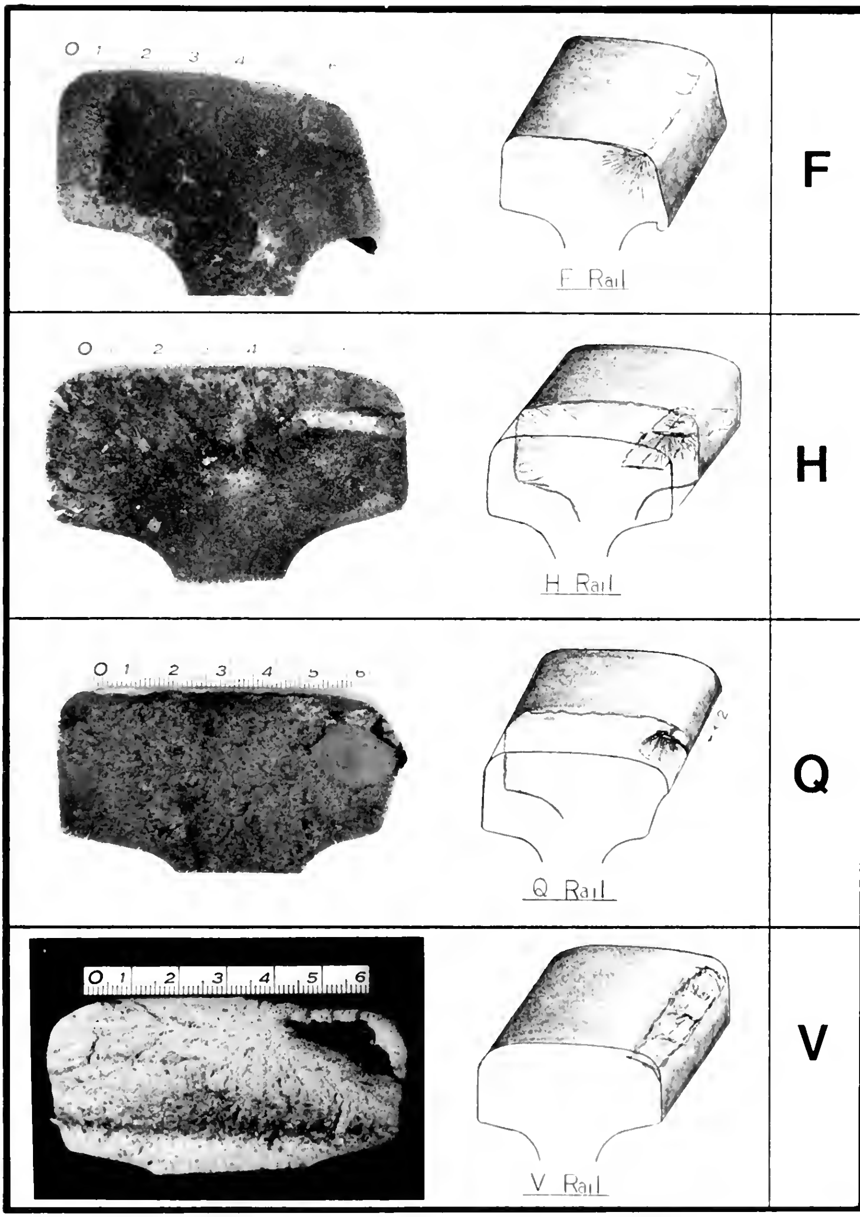

Photo 1. Photographs and Schematics of fracture surface of typical fatigue damaged rail samples

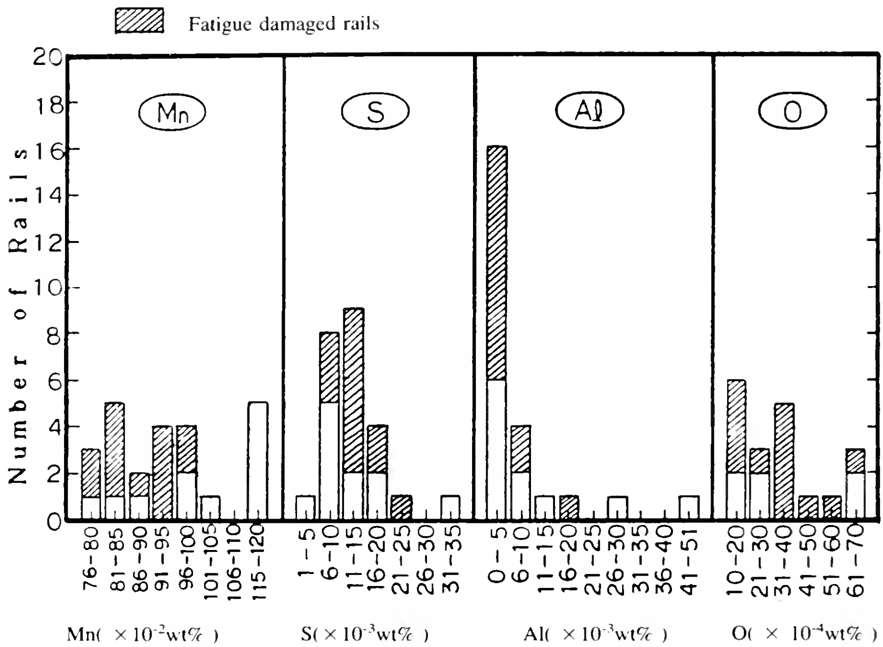

Figure 2. Relationship between contents of manganese, aluminum, sulfur and oxygen and fatigue damaged rail samples

2. Fractographic Examination

The photographs of the fracture surface of four typical types of fatigue damaged rails or rail samples F,H, Q and V among fourteen damaged rail samples investigated in three experiments are shown in Photo 1. Since the fracture surfaces are completely oxidized, their schematics are also given. (Photo 1)

The characteristics of the fracture surfaces of the fatigue damaged rails are summarized in Table 2. The defects detected in the rail samples were classified as described in the Rail Defect Manual of Sperry Rail Service. From the Table 1, it can be seen that each crack started from the internal area of the rail head except rail sample F and grew into a shell or transverse defect. When the area where this type of crack initiated was observed in detail, the crack originated and grew directly on the transverse plane in a few of the rails investigated, but the transverse defects from longitudinal internal shelling were recognized in most of the rails. This finding is unrelated to whether the rail is a standard carbon rail or head hardened (HH) rail as is evident with the fatigue damaged rail samples H and J in Table 2. Locating the cause of the cracks thus basically involves identifying the origin of shelling and analyzing the area concerned.

The crack origins of the fatigue damaged rails are shown on the 132-RE rail section in Figure 3. These origins are all confined in a 10 x 10 mm area which is located at approximately 17 mm beneath the head surface and 13 mm inside of the head side, irrespective of whether the rails (Fig. 3) are heat treated or not.

The non-metallic inclusion measuring position adopted in the present study corresponds to the upper side of the region that transverse defects begin to occur frequently.

Table 2. Characteristics of 14 rail samples with fatigue failure

NO.	Rail	Initiation Depth from Gauge Corner Surface	Crack Mode	Classification	Angle
F	HH	Gauge Corner Surface	(Flaking) ⇨TD	DF	—
G	HH	10 mm	(Shelling) ⇨TD	TF or CF	90°
H	HH	12 mm	Shelling ⇨TD	TF or CF	90°
J	Std. C	12 mm	Shelling ⇨TD	TF or CF	90°
N	Std. C	5 mm	Shelling ⇨TD	DF	70°
P	Std. C	5 mm	Shelling ⇨TD	DF	70°
Q	Std. C	5 mm	—— TD	TF	70°
R	Std. C	10 mm	—— TD	TF	—
U	Std. C	10 mm	Shelling ——	Shelling	70°
V	Std. C	8 mm	Shelling ——	Shelling	60°
V'	Std. C	5 mm	Shelling ⇨TD	DF	65°
W	Std. C	9 mm	—— TD	TF	—
X	HH	9 mm	Shelling ——	Shelling	78°
Y	HH	13 mm	Shelling ——	Shelling	70°

· HH : Head Hardened · Std. C : Standerd Carbon · TD : Transverse Defect
· Classification ; Based on the Sperry Rail Defect Manual
(TF : Transverse Fissure. CF : Compound Fissure. DF : Detail Fracture)
· Angle ; Shell growth angle to the vertical plane

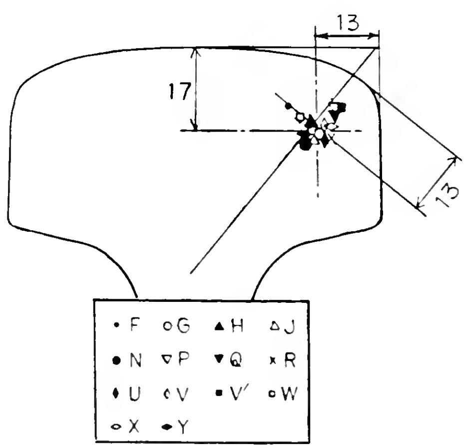

Figure 3. Distribution of crack origins on cross section of 132RE rail

3. Metallurgical Analysis of Fatigue Fracture Origins

The fatigue crack origins in the fourteen fatigue damaged rail samples discussed above were metallurgically investigated. As a result, a very long streak or non-metallic inclusion extending in the longitudinal direction of the rail was located at the center of the horizontal fractured surface of the rail samples H and J. they are shown in Photo 2 and 3. When analyzed with an electron probe (Photo 2) micro-analyzer (EPMA), the streak was identified as mainly (Photo 3) an alumina cluster measuring as much as 10 mm or more in length. Typical example of rail sample H is shown in Photo 4. When the cross sections through the crack origins in the (Photo 4) remaining twelve damaged rails were examined in detail, no such non-metallic inclusions or any other harmful substances were recognized at the origin, but relatively large dispersions of alumina clusters were observed near the origin.

The following inferences can be drawn from these findings:

(1) Elongated streak-like alumina clusters or oxide inclusions compounded with them are the most harmful non-metallic inclusions for shelling or transverse defects. This finding agrees with the results of Marich et al.[3] or other researchers.[4,5]

(2) A probable reason that a well-defined cause was identified for only two of the fourteen damaged rail samples is that inclusions of the two rails were of significant size. On the contrary, no inclusions were detected at the crack origins in the remaining twelve rail samples, presumably because any inclusions that may have initiated the crack were lost when the fracture surfaces rubbed against each other as the crack propagated.

This also suggests that it is very difficult to identify inclusions directly from the analysis of crack origins and another method must be devised for this purpose.

New Method for Quantitatively Evaluating Non-Metallic Inclusions

1. Development of New Method

The method of quantitatively evaluating non-metallic inclusions with particular emphasis placed on alumina clusters were studied based on the above-mentioned results of analysis. A 10 x 20 mm specimen was taken from the location illustrated in Figure 1 and all the number and length of alumina clusters present in specific surface of the specimen were measured under an optical microscope with a magnification of 100X. This measurement was taken on all of the twenty-five rail samples investigated.

The concrete measuring method is as described below:

1) Magnification: 100X (Optical microscope)
2) Area: 10 mm wide x 20 mm long = 200 mm^2
3) Criteria of measurement
   (1) Inclusions mainly composed of alumina oxide (Al_2O_3)
   (2) Inclusions 100 μm or more in length
   (3) Length between ends of three or more globular inclusions that are located disconnectedly on a line and are apart 100 μm or less

Alumina cluster of 100 μm or more in length were selected as the non-metallic inclusions to be measured, because 100 μm is the minimum length at which inclusions can be distinguished as clusters and because it is often observed that fatigue cracks occur from inclusions measuring 300 μm or more.[3-5] Therefore, selection of the value of 100 μm does not always mean that fatigue defects initiate at such small alumina cluster. Typical examples of measuring alumina cluster are shown in Photo 5. The results of measurement are given in Table 3. The rails that were fractured in service are enclosed in a circle and (Photo 5) the rails that were not fractured in service but contained (Table 3) transverse defects or shelling in the head are enclosed in a square.

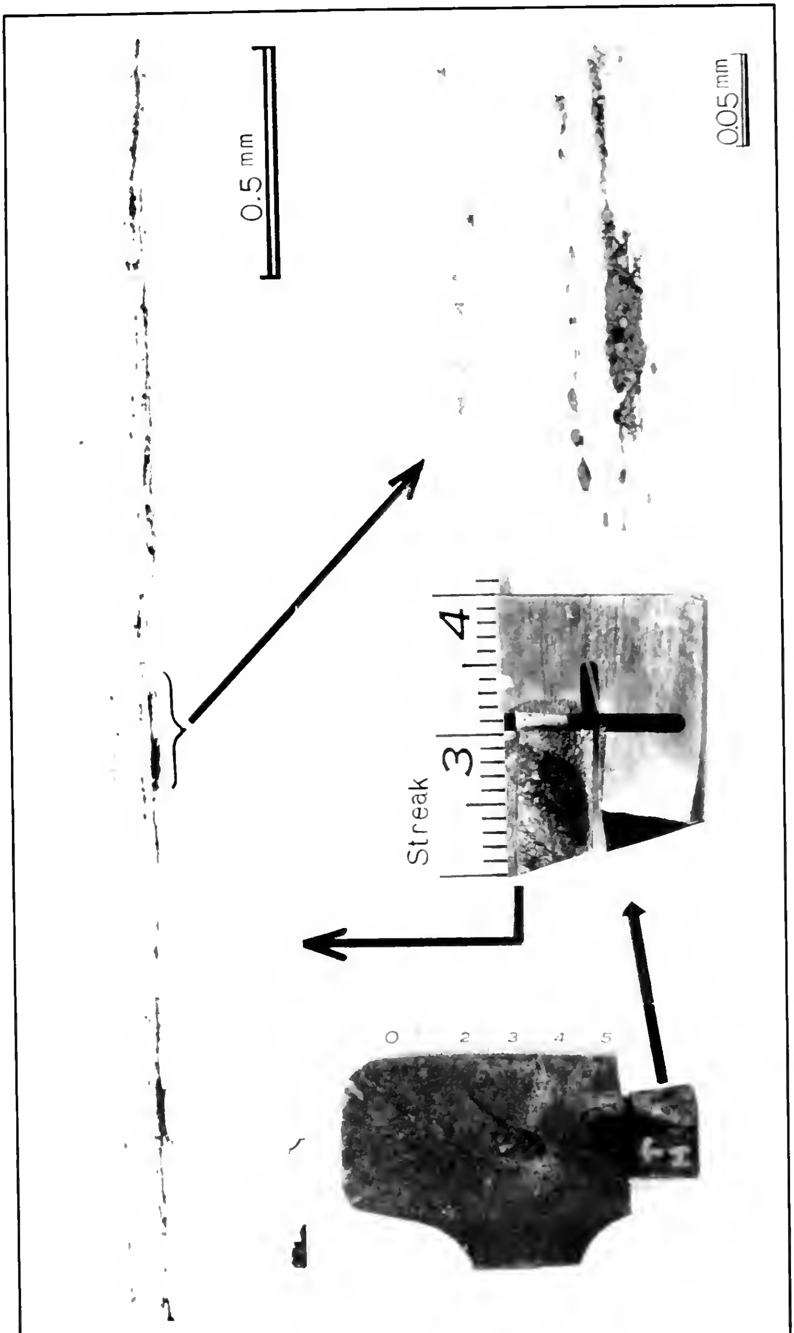

Photo 2. Appearance of horizontal crack and long alumina cluster at initiation site in rail sample H

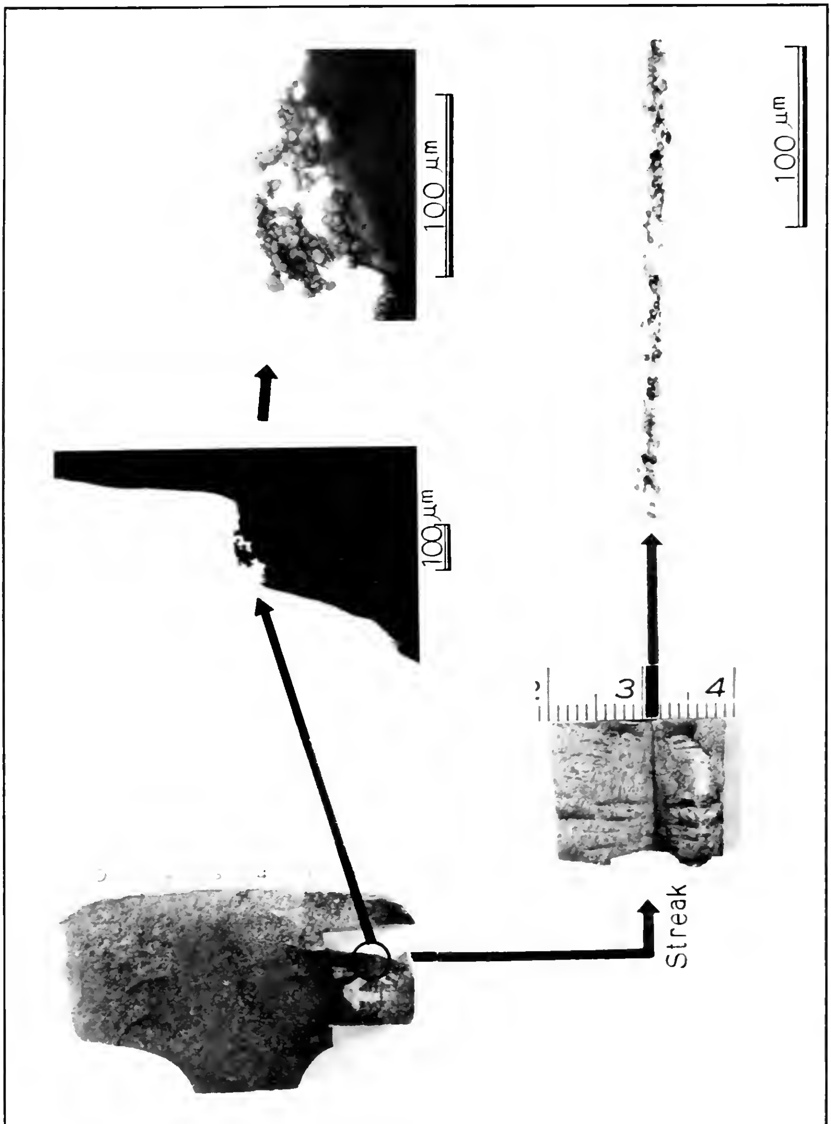

Photo 3. Appearance of horizontal crack and long alumina cluster at initiation site in rail sample J

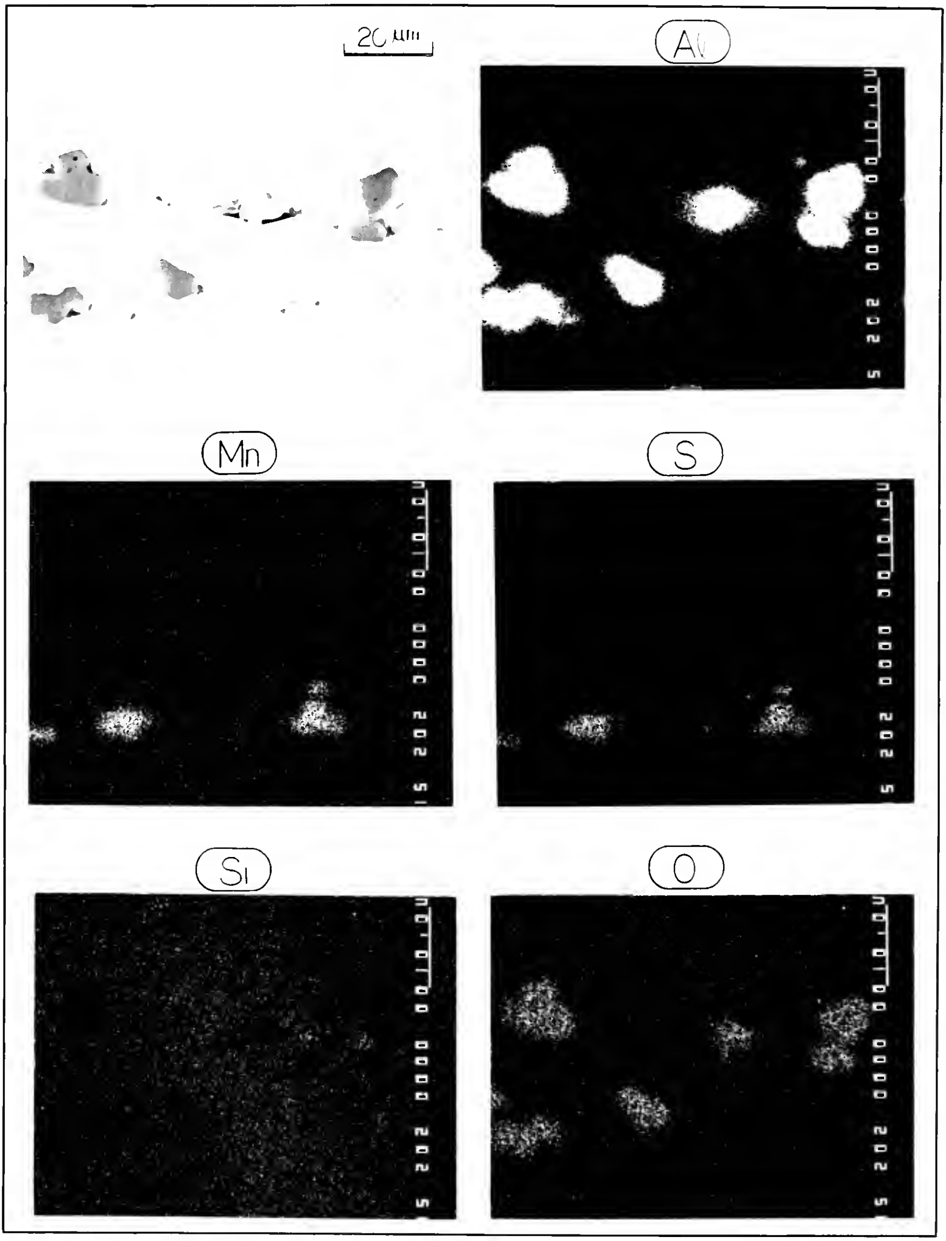

Photo 4. Electron probe microanalysis of inclusions observed at initiation site in rail sample H

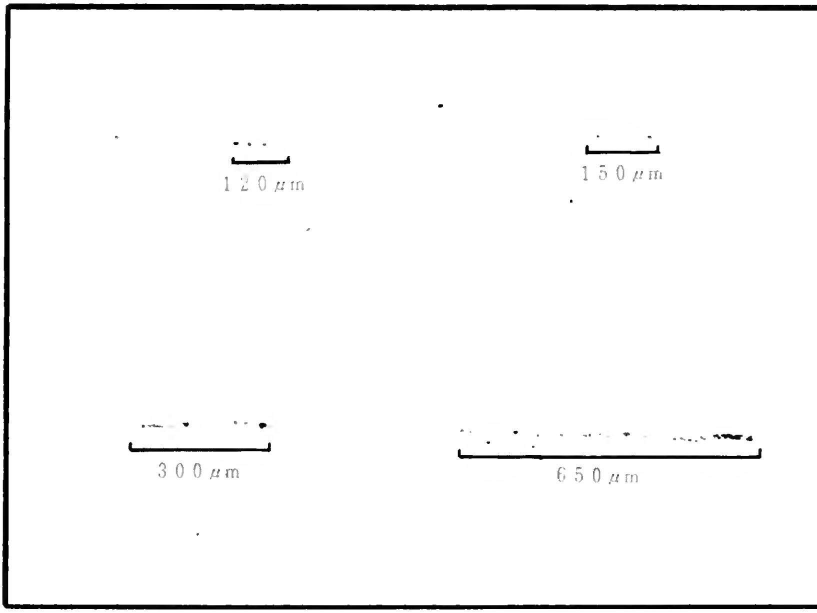

Photo 5. Typical examples of measuring alumina cluster

It is known from the results of measurement that many alumina clusters with a length of 100 μm or more are present in the eight fractured rail samples F, G, H, J, N, P, Q and R and in the six fatigue defective rail samples U, V, V', W, X and Y. Of the unused rail samples, two rail samples E and S contain relatively many non-metallic inclusions.

The total number and total length of alumina clusters determined are shown in Figure 4. There exists an almost linear relationship between the total number and total (Fig. 4) length of oxide inclusions as represented by alumina clusters. The fourteeen fatigue damaged rail samples signified by solid circles and squares (● and ■) can be distinguished as defective rails according to a criterion that a rail should be classified as a defective one if alumina clusters, present in a 10 x 20 mm area of the specimen and measuring 100 μm or more in length, exceed 2,000 μm in total length. The unused rail samples E and S are included in the defective rail group or they may develop transverse defects when laid and used in the track. The total length of alumina clusters detected is, however, less than 2,000 μm for most of the unused rail samples investigated. Since the unused rails should be those manufactured recently, this may be taken to reflect the result of latest steelmaking techniques introduced to reduce the non-metallic inclusion content of rail steels.

Figure 5 shows the total number of alumina clusters at depths of 5 to 30 mm in the head of the rail samples in the third experiment. The alumina cluster content tends to increase with increasing depth, and also its distribution considerably varies with the rail investigated or production method employed. Although the alumina cluster content of the defective rails is relatively low at depths smaller than 10 mm except for some rail samples, the threshold level of 2,000 μm holds true at the measuring position of 12.7 mm beneath the rail head for all the defective rail samples investigated.

Table 3. Measurement of alumina cluster in rail samples

	Alumina Cluster Length (μm)	n	Total Length (μm)
A	0	0	0
B	550, 450, 100, 200	4	1,300
C	250, 100, 150, 100	4	600
D	200	1	200
E	200, 220, 240, 150, 100, 150, 150, 100, 150, 100, 100, 100, 100, 120, 150, 100, 100, 350, 100, 100, 100, 100, 150, 150, 100, 100, 380, 100, 160, 150, 100, 140, 100, 200	34	4,910
Ⓕ	240, 100, 150, 100, 200, 100, 150, 100, 100, 230, 350, 200, 100, 330, 200, 130, 130	17	2,910
Ⓖ	220, 100, 120, 100, 500, 200, 200, 420, 100, 100, 600, 100, 800, 300, 100, 100, 100, 100, 500, 550, 550, 130, 150, 200, 100, 160, 200, 130, 250, 150, 130, 100, 230, 250, 100, 100, 280, 150, 350, 200, 530, 150, 200	43	10,100
Ⓗ	350, 500, 100, 100, 350, 550, 300, 230, 180, 150, 150, 400, 100, 350, 150, 100, 250, 100, 100, 150, 150, 100, 200, 700	24	5,810
Ⓙ	100, 330, 500, 200, 200, 120, 110, 150, 800, 380, 320, 150, 600, 200, 300, 150, 120, 100, 100, 750, 100, 100, 430, 150, 220, 200, 100, 150, 270, 250, 100, 200, 100, 100, 150, 170, 150, 200, 130, 220, 250, 130, 150, 100, 200, 250, 160, 230, 500, 650, 280, 100, 200, 250, 100, 100, 400, 100	58	13,220
K	150, 100, 100	3	350

	Alumina Cluster Length (μm)	n	Total Length (μm)
L	0	0	0
M	0	0	0
Ⓝ	100, 220, 110, 150, 220, 550, 320, 250, 250, 110	10	2,280
O	100, 100	2	200
Ⓟ	800, 600, 350, 750, 100, 350, 200, 100, 180, 250, 130, 160, 200, 170, 150, 530, 300, 140, 200, 100	20	5,760
Ⓠ	320, 170, 220, 160, 150, 220, 140, 110, 100, 120, 350, 200, 190	13	2,450
Ⓡ	270, 260, 150, 180, 320, 540, 120, 400, 480, 220, 250, 130	12	3,320
S	100, 270, 180, 160, 250, 180, 210, 300, 350, 430, 120, 300, 100, 140, 110, 160, 200, 200, 100	19	3,860
T	330	1	330

	Alumina Cluster Length (μm)	n	Total Length (μm)
☐U	200, 250, 250, 190, 180, 100, 180, 300, 190, 350, 170, 280, 230, 200, 180, 230	16	3,480
☐V	180, 700, 240, 200, 180, 200, 300, 260, 300, 240, 300, 150, 200, 200, 250	15	3,900
☐V'	180, 200, 300, 240, 420, 870, 150, 170, 200, 320, 570	11	3,620
☐W	270, 280, 120, 430, 120, 400, 150, 200, 200, 290, 560, 150, 100, 450, 300, 280, 300, 120, 260	19	5,080
☐X	150, 200, 180, 200, 150, 150, 250, 150, 800, 1000, 150, 950, 180, 300, 150, 370	16	5,330
☐Y	300, 140, 180, 250, 150, 360, 170, 440, 150, 160, 120, 150, 150, 110, 100, 200, 120, 150, 250, 650, 120, 230, 310, 160, 130, 500, 330, 210, 100, 150, 420, 150, 360	33	7,470

○ Fractured rails ☐ Fatigue defective rails

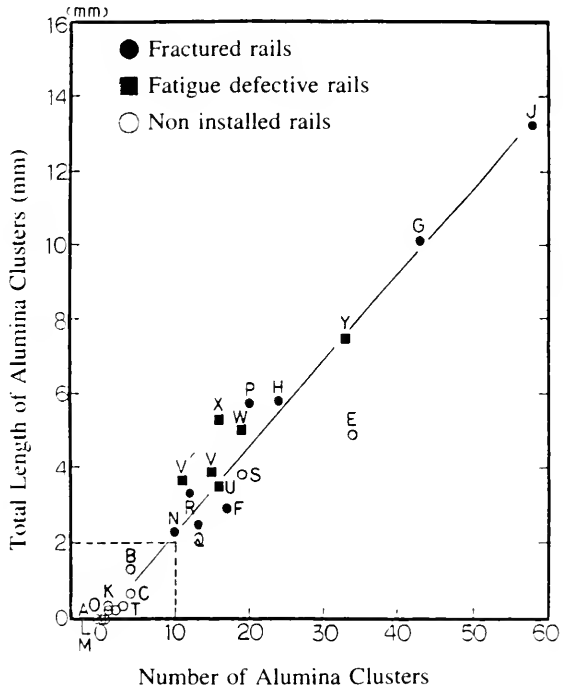

Figure 4. Relationship between total number and total length of alumina cluster

2. Comparison of Standard Carbon Rails and Head-Hardened Rails

Standard carbon rails and head-hardened rails are generally considered to be different in sensitivity to transverse defects.[7,8] Of the fourteen fatigue damaged rail samples, five rail samples F, G, H, X and Y are from head-hardened rails. Table 4 shows the relationship of the types of transverse defects, depth of defect origins and the total number and length of alumina clusters determined in the head-hardened rail samples.

The rail sample F was fractured in service from flaking at the running surface on the gage corner side. Therefore if sample F is excepted, the total length of alumina clusters is 5,000 μm or more for all of the head-hardened rails. The total alumina cluster length of approximately 5,000 μm may be thus taken as the harmful inclusion threshold level for head-hardened rails. But the rails examined are too small in sample number to apply this threshold value in general. Many more head-hardened rails will have to be analyzed to develop such a threshold level.

Analysis by General Non-Metallic Inclusion Evaluation Methods

The rail samples were analyzed by conventional non-metallic inclusion evaluation method in comparison with the new non-metallic inclusion evaluation method that focused on alumina clusters alone.

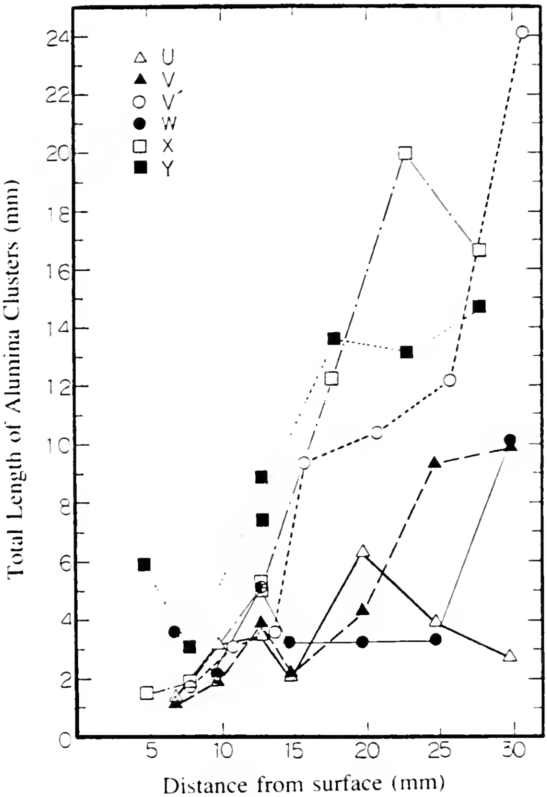

Figure 5. Total length distribution of alumina clusters in depth direction of rail head

Table 4. Relationship of type and origin depth of fatigue failure with alumina clusters in fatigue damaged HH rail samples.

Rail	Classification	Depth from Surface	Alumina Cluster n	Alumina Cluster Length(μm)
F	DF	0 mm	17	2,910
G	TF or CF	10 mm	43	10,100
H	TF or CF	12 mm	24	5,810
X	Shelling	9 mm	16	5,330
Y	Shelling	13 mm	33	7,470

The analysis was performed on the ten rail samples in the first experiment. The conventional methods were investigated to see if they could commonly distinguish at least four fractured rail samples from other rail samples.

1. ASTM Method (E 45 method A)

Non-metallic inclusions are classified into four types—Type A to D—by the ASTM method. Type A mainly corresponds to sulfide, Type B to disconnected row of oxides, Type C to silicate and Type D to globular oxide. The distributions of Types A to D inclusions are expressed in comparison with a five-step standard distribution chart prepared by the ASTM. Table 5 gives the average values of inclusion rating numbers on three fields of view for ten rail samples. The (Table 5) larger the number, the greater the inclusion content in the field of view.

When attention is focused on the results of the fractured rail samples F, G, H and J, it is characteristically found that the inclusion rating numbers for Type B (alumina) inclusions in the thin series are 0.3 for the rail samples G, H and J. For the rail sample F, the content of Type B inclusion is very low but Type C (silicate) inclusions exhibit rating numbers of 0.7 in both the thin and heavy series. Rating numbers for Type A (sulfide) inclusions differ fairly among the fractured rail samples alone. That is, the rail sample J has relatively small inclusion rating numbers for Type A but is fractured. All of the rail samples tabulated in Table 5 do not show any significant differences in rating numbers for Type D (globular oxide) inclusions.

Table 5. Inclusion rating number of rail samples (1st Ex.) as determined by ASTM method

	Type A		Type B		Type C		Type D	
	Thin	Heavy	Thin	Heavy	Thin	Heavy	Thin	Heavy
A	2.0	1.0	0	0	0	0.7	1.0	0
B	4.3	0	0	0	0	0	0.7	0
C	2.0	0	0	0	0	0	0.7	0
D	2.7	0	0	0	0	0	1.0	0
E	2.0	0	0.7	0	0	0	1.0	0
(F)	3.3	2.0	0	0	0.7	0.7	1.0	0
(G)	2.7	0	0.3	0	0	0	1:7	0
(H)	3.0	0.7	0.3	0	0	0	1.0	0
(J)	2.0	0	0.3	0	0	0	1.0	0
K	2.0	0	0	0	0	0	0.7	0

○ Fractured rails

2. JIS Method (G 0555)

The JIS method classifies non-metallic inclusions into Type A (inclusions of sulfide, silicate, etc., elongated in the rolling direction), Type B (cluster inclusions of alumina, etc.) and Type C (globular inclusions of oxide, etc.).

The above-mentioned types of non-metallic inclusions located at 20 x 20 grid points are counted in 60 fields of view under an optical microscope with a magnification of 400X. The cleanliness index of the specimen is expressed as the percent ratio of the number of grid points that fall on inclusions to the total number of the grid points.

The results of non-metallic inclusion evaluation by the JIS method are summarized in Table 6. These results are similar to those obtained by the ASTM method, although they (Table 6) are different from the latter in the method of expression employed.

Three of the four fractured rail samples exhibit Type B (alumina cluster) inclusions although the contents of them are very small as compared with Type A. Like the ASTM method, Type B inclusions are not detected in the rail sample F. The fractured rail samples show no particularly characteristic differences in the contents of Types A and C inclusions as is the case with the results of determination by the ASTM method.

Table 6. Cleanliness index of rail samples (1st Ex.) as determined by JIS method

	Type A	Type B	Type C	Total
A	0.096	0	0.008	0.104
B	0.221	0	0.004	0.225
C	0.050	0	0.008	0.058
D	0.083	0	0.004	0.087
E	0.067	0.008	0.008	0.083
Ⓕ	0.208	0	0.004	0.212
Ⓖ	0.154	0.004	0.008	0.166
Ⓗ	0.154	0.004	0.004	0.162
Ⓙ	0.075	0.012	0.004	0.091
K	0.058	0	0.004	0.062

○ Fractured rails

3. Classification Method Using Image Analyzer (LUZEX)

The non-metallic inclusions that existed in an area of 61 mm^2, equivalent to the area investigated by the JIS Method, were measured using an image analyzer (LUZEX). The results of inclusion number and size are shown in Figure 6. The non-metallic inclusions were classified in the same way as done (Fig. 6) by the JIS method. According to the results of Figure 6, the four fractured rail samples F, G, H and J are not appreciably different from the unused rail samples in the distribution of inclusions.

Type B inclusions were detected in the fractured rail sample J but not in the fractured rail samples F, G and H. This probably means that Type B inclusions which are present disconnectedly are not clearly distinguished from Type C inclusions.

4. Comparison with the New Method

According to the results obtained by two conventional ASTM and JIS methods in wide use, the characteristics of inclusions contained in the fractured rail samples appear to lie mainly in Type B inclusions based on alumina clusters. The contents of Type D (ASTM) or Type C (JIS), which are the

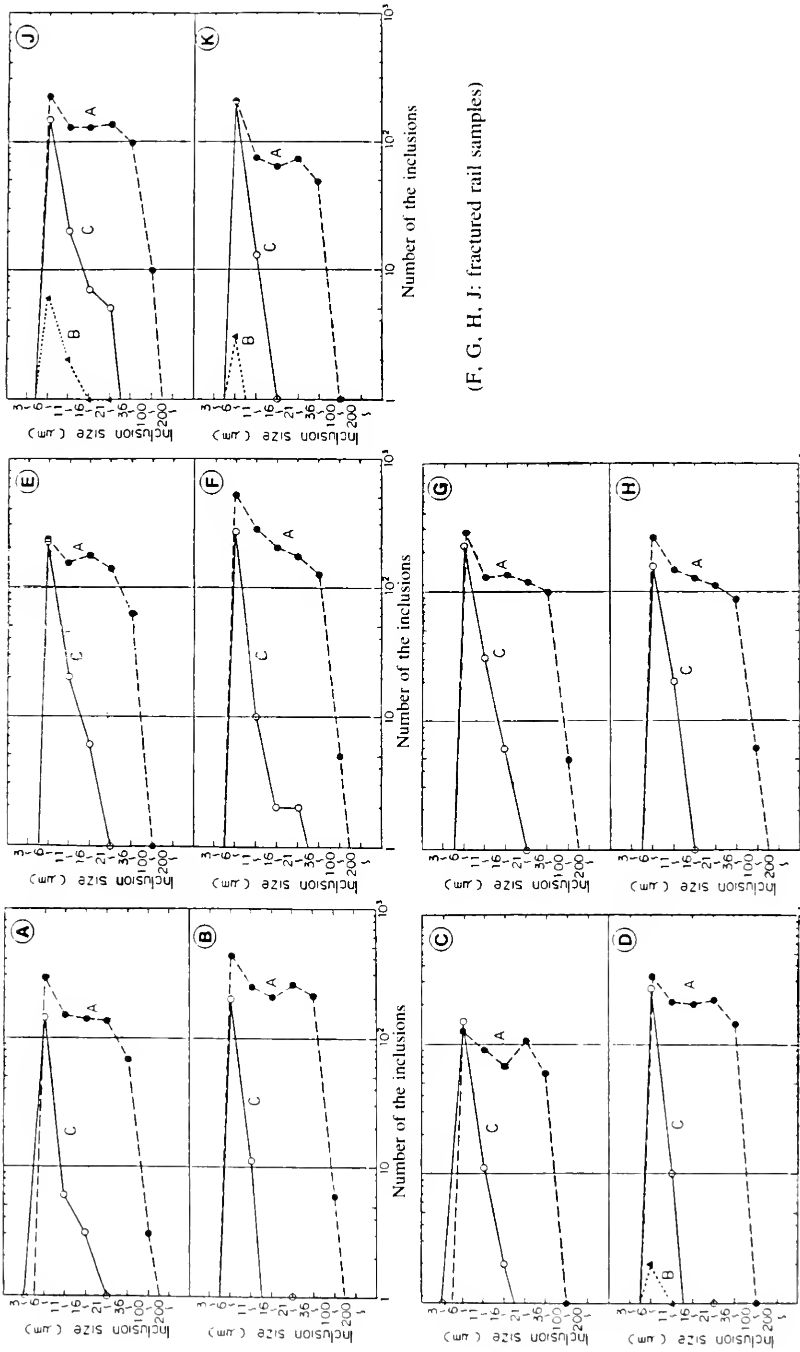

Figure 6. Results of inclusion counting by image analyzer method.

same oxide inclusions as Type B but are distributed scattered, are almost the same among the four fractured rail samples and also among all of the ten rail samples investigated.

The new method is compared with the two conventional methods in terms of Type B inclusions in Table 7. The data of Table 7 show that Type B inclusions are detected by the ASTM and JIS methods with relative clarity. But the two methods are somewhat inadequate to quantitatively evaluate Type B inclusions as shown in the fractured rail sample F. The method of measuring the non-metallic inclusions by different size classifications using the image analyzer was less effective in detecting inclusion characteristics common to the fractured rails than the two conventional methods discussed above. Further study must be done to establish the criteria for detecting Type B inclusions by the image analyzer method because the determination of inclusions by this method was obstructed by predominantly present globular oxide inclusions.

The content of non-metallic inclusions that are identified as Type A is generally higher than that of Types B and C inclusions. Some of the rails had fractured, although they had a relatively low content of Type A inclusion, and there was no evidence of Type A inclusions in the region around the crack origin of the fatigue damaged rails. Given these findings, sensitivity to damage by Type A inclusions seems to be lower than that by Type B inclusions. This is recognized as a fact in the rolling-contact fatigue phenomenon of bearings[9,10].

Table 7. Comparison of type B inclusion with total length of alumina cluster

Rail	(ASTM) Type B	(JIS) Type B	Cluster Length	n
E	0. 7	0. 008	4, 910	34
F	0	0	2, 910	17
G	0. 3	0. 004	10, 100	43
H	0. 3	0. 004	5, 810	24
J	0. 3	0. 012	13, 220	58

Future Problem

Rails with shelling and/or transverse defects while in service at Norfolk Southern railroad were analyzed and based on the results of analysis, a new method was proposed for evaluating the non-metallic inclusion content of rail steels with attention focused on alumina clusters or Type B non-metallic inclusions. The threshold level of 2,000 μm for the total length of alumina clusters, however, is a result of measurements taken on a limited number of rail samples and should be taken as a preliminary value. The total length distribution of alumina clusters in the depth direction of the rail head greatly varies among several rail samples, as shown in Figure 5. To enhance the reliability of the alumina cluster threshold level found out by the new method, it is necessary to study the existing state and content of non-metallic inclusions in long-life rails. Both rail users and rail manufacturers should survey many rails and develop rational threshold levels for the total length of alumina clusters, so that they can commonly utilize the new method.

The passing tonnage (MGT) to fatigue failure and installation condition (degree of curve) were known for the six rail samples investigated in the third experiment, but it was impossible to correlate these conditions to the fatigue failure of rails in a clear-cut manner. Further study will be necessary to establish the threshold level of alumina clusters for each installation and train operating condition. Such statistical results should be of much help in the fracture mechanics study of transverse defects in the rail head.

Conclusions

Norfolk Southern and Nippon Steel jointly investigated the relationship between non-metallic inclusions and in-service fatigue damage in the head of twenty-five rail samples, including eleven new rail samples and fourteen fatigue damaged rail samples.

The findings obtained are as follows:

(1) When the origins of fatigue failure in the fourteen rail samples with shelling and/or transverse defect were analyzed, cracks were clearly found to have started from long Type B non-metallic inclusions (mainly alumina clusters) in two of the samples. The origins were not clearly correlated with any inclusions in the remaining twelve rail samples, but comparatively many alumina clusters were observed around the origins.

(2) Based on the above finding, a new method was devised for evaluating non-metallic inclusions with attention focused on Type B inclusions. The method determines the total length of alumina clusters present in a 10 x 20 mm surface of the specimen cut from a specified location in the head of the rail sample. All of the fourteen fatigue damaged rail samples were shown to contain alumina clusters with a total length of 2,000 μm or more by the new method. Two of the new rail samples were found to satisfy the threshold level, too.

(3) It was difficult to establish national criteria to distinguish the fourteen fatigue damaged rail samples from the sound rail samples by ASTM or JIS cleanliness evaluation methods.

(4) The amount and size of non-metallic inclusions were not particularly correlated with chemical compositions of rail themselves.

(5) To utilize the new method in evaluating the non-metallic inclusion content of rails, it is necessary to establish rational threshold levels by investigating many more rails using the new method.

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THE CONSTRUCTION OF THE CHANNEL TUNNEL LINKING THE UNITED KINGDOM AND FRANCE

By: Winn B. Frank*

The first known serious plan for a channel tunnel is thought to have originated in 1802. Napoleon had given sober consideration to the construction of such a tunnel. Boring for a channel tunnel commenced in 1882 utilizing a Beaumont Boring machine which had a diameter of seven feet. In the early 1970's, there were renewed efforts and a service shaft 820 feet long was drilled before the project was abandoned.

THE FOUNDATION

A natural first question to ask is why this latest effort will succeed while the others have not. The answer is the fact that so much progress has been made. For example, both Houses of Parliament in France have unanimously approved the laws permitting the ratification of the Treaty and approving the concession to Eurotunnel. (The Treaty is the basic document authorizing and regulating the system)

The Channel Tunnel Bill has been passed by both Houses of Parliament in the UK. Construction of the access shafts and delivery of tunnel boring machines has already begun. Financing is in place. With limited exceptions, the governments will pay compensation if they interrupt or terminate Eurotunnel's rights.

It should be understood that the channel tunnel is a private sector undertaking. Eurotunnel is a private Anglo-

* Advisor—Railroad Operations, Parsons-Deleuw, Cather, Lahmeyer International; Technical Advisor, Eurotunnel Project Financing

French group that has been granted a 55 year concession by the governments to develop, finance, construct and operate the tunnel system. With certain qualifications, this concession grants to Eurotunnel the right of first refusal through the year 2020 for the construction of additional tunnels that may be required because of increased demand. Concession privileges run through to July 28, 2042.

IMPLEMENTATION ORGANIZATION

The construction of the tunnel involves three principal organizations: (1) Eurotunnel; (2) Maitre d'Oeuvre; (3) the Contractor, who is referred to as "Transmanche Link." The Maitre d'Oeuvre functions in a monitoring role and includes some activities similar to that of a construction manager within the United States context. The principal contractors within the Maitre d'Oeuvre include W. S. Atkins & Partners of the U.K., and Societe' d' Etudes Techniques et Economiques of France.

The Contractor, Transmanche Link (TML), is a venture made up of two principal divisions: Translink of the U.K. & Transmanche Construction of France. These organizations are made up of ten principal contractors as listed below:

Balfour Beatty Construction Limited
Bouygues S.A.
Costain Civil Engieering Limited
Dumez S.A.
Socie'te' Auxiliaire d'Entreprises S.A.
Socie'te' Ge'ne'rale d'Entreprises S.A.
Spie Batignolles S.A.
Tarmac Construction Limited
Taylor Woodrow Construction Limited
Wimpey Major Projects Limited

TUNNEL DESIGN AND CONSTRUCTION

The tunnel system will consist of two running tunnels, each 25 feet in diameter and accomodating one standard gauge track structure. In addition, there will be a 15' 9" diameter service tunnel located between the running tunnels. Cross passages connecting the service tunnel to the running tunnels will be located at 1,230 foot intervals. The service tunnel network will serve as a ventilation conduit, provide access for tunnel and track maintenance, and serve as a refuge and escape path in case of an emergency in the running tunnel/s. A general cross section of the tunnel configuration is provided in Figure 1.

COMPARISON OF ROLLING STOCK

CROSS-SECTION OF TUNNELS

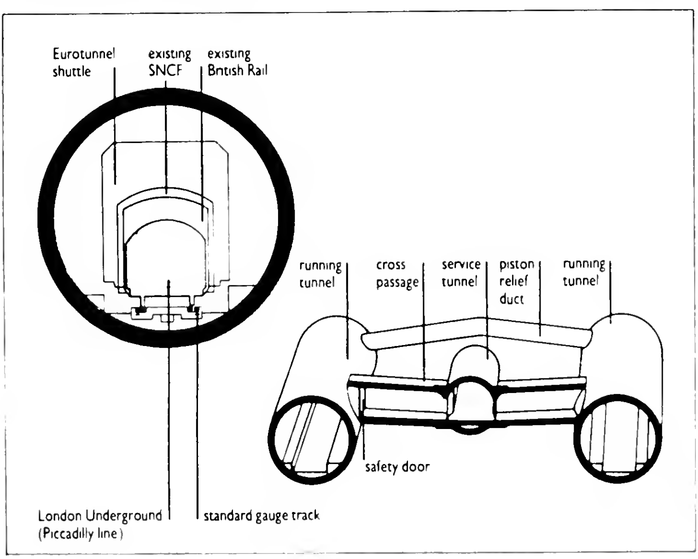


Figure 1.

Extending between Forkstone, near Dover in the UK, and Coquelles, near Calais in France, the tunnel network will be almost 31 miles long. Approximately 23 miles will actually be under the channel, while 4.9 miles will be under the UK mainland and 2.6 miles under the French mainland. Tunnel lining will be pre-cast concrete on cast iron segmental rings. 265 million cubic feet of material will be excavated before the project is completed.

Construction will require a total of eleven tunnel boring machines (TBMs), six on the British side and five on the French side. A TBM for the pilot tunnel on the British side has been delivered from James Howden of Glasgow, and assembled on site. The first French side TBM is enroute from the Robbins Company, Portland, Oregon.

Design criteria stipulates that the tunnel system will accommodate trains or shuttles on three-minute headways. Shuttles are to operate through the tunnel at approximately 100 miles per hour, while TGV-type trains will be able to travel at speeds up to 150 miles per hour.

Accommodating movements at these speeds and headways, make this tunnel unique among the world's longer tunnels. In particular, one of the more fascinating aspects of the design is that involving the relief of the "piston effect". It is conceivable that during high density operations, a total of 18 trains could be within the tunnel network. The resultant air pressure differentials created by these passages require special mitigation design techniques. To relieve these pressure differentials, additional cross passages, referred to as "piston relief ducts", will be constructed between the two main bores but not intersecting the service tunnel. These ducts will be constructed at 820 foot intervals and will be open, allowing the free passage of air. Thus, as a train travels through the tunnel, the

resulting block of air that forms at its front will dissipate through these piston relief ducts. Similarly, the vacuum created at the end of the train will suck available air through these ducts from the other bore. The piston effect is the subject of extensive simulations. Piston relief ducts are illustrated in Figure 1.

Boring for the main tunnels is to begin this year and will continue through 1991. Breakthrough for the service tunnel is scheduled for autumn of 1990, and for the main tunnels in the summer of 1991. 1990 thru 1992 will see the fitting out of the total tunnel network. Operations are scheduled to begin in 1993.

CONSTRUCTION CONTRACT

The construction contract has been divided into three principal categories: 1) the target works; 2) lump sum works; and 3) procurement items. The target works include the tunneling aspects, and are covered by the equivalent of a cost-plus fixed fee contract. In US dollars its cost is estimated at $2.4 billion. Lump sum works include stations, track, signals, and other similar type items. Their cost is estimated at $2.0 billion. Procurement items refer principally to rolling stock. They are estimated at $.4 billion. Total project costs including construction, corporate, inflation, and financing costs equal $8.5 billion. These costs reflect 1987 prices and an exchange rate of $1.75 US dollars to the British Pound.

GEOLOGY

The underchannel portion of the tunnel will average about 325 feet below the water surface. Boring has been designed to take advantage of a chalk marl layer which is approximately 65 to 118 feet thick. This chalk marl is considered an excellent medium for boring. On the French side, some layers of upper and middle chalk will be encountered. It is anticipated that water will be found in fissures within this strata. TBMs used in this region will be pressure-balancing. It is also anticipated that the cast iron ring tunnel lining will be utilized through this region. Distance from the top of the tunnel to the bottom of the channel will vary between 120 and 55 feet.

The tunnel geology has been a subject of very detailed investigations over long time periods. Confidence in the geologic data is further enhanced by the fact that the tunnel begun on the U.K. side in the 1880s has retained its structural integrity.

THE "FIXED LINK"

The tunnel is commonly referred to as the "fixed link". The philosophy behind this title is that the tunnel is to serve as the connection for the rail and highway networks between the continent and the U.K.

Eurotunnel is to provide frequent shuttle service from special terminals to be constructed at Coquelles and Folkstone. In addition, British Railway (BR) & French Railway (SNCF) trains will operate through the tunnel. Passenger services from Paris and Brussels to London will be utilizing purpose-built TGV-style high speed trains, thus enabling a Paris/London trip of approximately three hours. Because of clearance differences between BR and the continental trail works, the new trains will be made to fit BR clearance specifications.

Railways are making infrastructure investments to support this service. SNCF is proceeding with design of the TGV-Nord route to Brussels and connecting with the tunnel. The British will make modifications at Waterloo station, London, will construct a new international station at Ashford, and will make improvements to enable 100 MPH running between the tunnel and London. Facilities will be constructed so that conventional freight trains operated by railways may pass through the tunnel.

Design of rolling stock and operations will be unique among world railways. Two classes of shuttles are planned: 1) Passenger; and 2) Freight. Passenger carrying shuttles will be of two types: (1) Double-deck; and (2) Single-deck. It is planned that automobiles will be driven directly onto the shuttle carrier wagons by their drivers, and all automobile occupants will normally remain with their vehicles for the journey. The loading operations are illustrated in Figure 2.

A shuttle may consist of one or two rakes. Each rake may consist of single or double-deck wagons and loading/ unloading wagons. One rake of double-deck wagons will carry up to 100 cars. A single deck rake will carry 12 buses or a mixture of buses, cars, and high dimension vehicles. Total length of two rakes will be approximately 2,500 feet. Locomotive/s will be placed at each end of a shuttle. Should one fail, the remaining locomotive/s will have the power to continue the trip. Terminal-to-terminal time is scheduled for 33 minutes. The initial service frequency will have a departure every 12 minutes during peak periods.

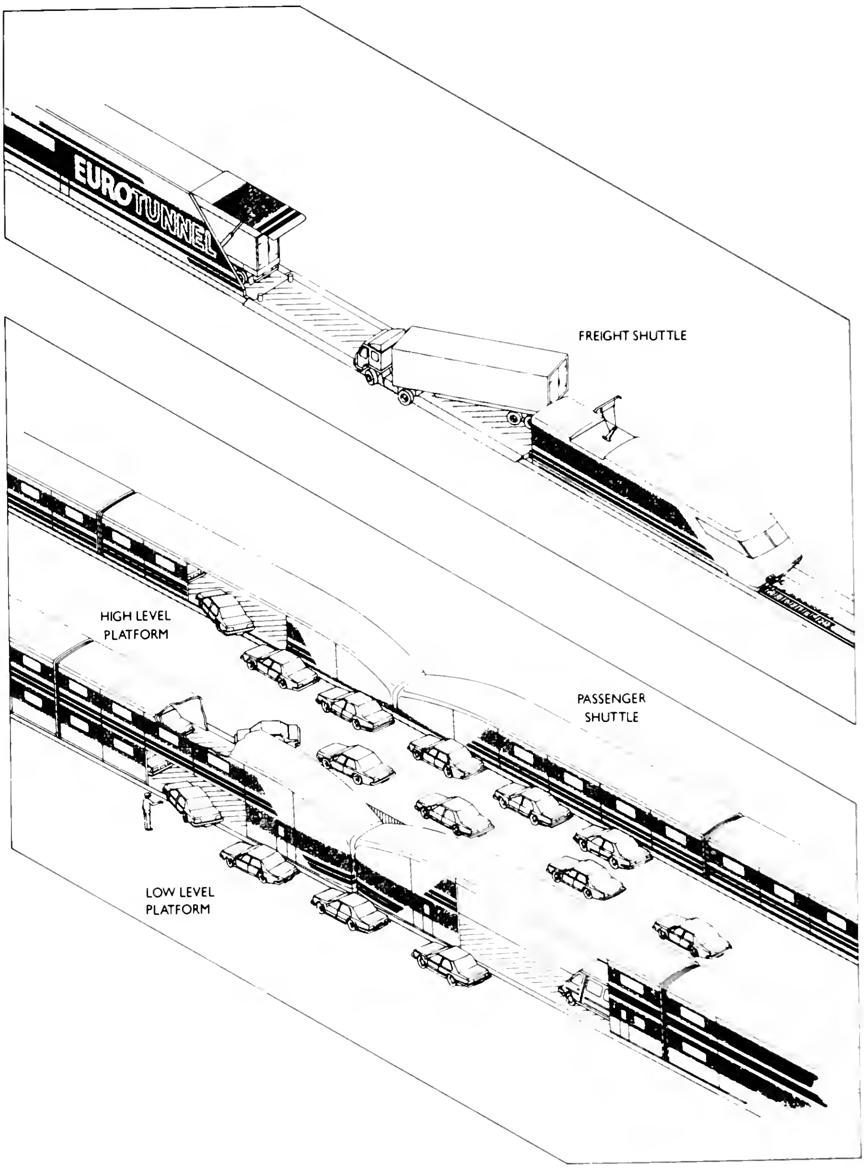


Figure 2.

Freight shuttles will consist of single deck carrier wagons having the capacity of 44 tons. Trucks will be driven directly onto these wagons in an operation similar to

that of the shuttle passenger service; however, freight terminals will be separate from passenger terminals.

TRACK CONFIGURATION

The basic track layout of the tunnel system is a loop which virtually eliminates opposing movements. In addition, a flyover is provided so that a figure "8" operation is accomplished which equalizes wheel wear. Two crossovers are to be constructed in the under channel portion of the tunnel in concert with crossovers outside each end of the tunnel.

Because of anticipated heavy traffic, it is conceivable that rail change-out could be required in a 7 - 12 year time frame. Thus, during the reduced passage periods of the evening hours, single track operation is required between crossovers in order to accomplish track and system maintenance.

CONCLUDING REMARKS

The channel tunnel is a unique undertaking. It is unique from the design aspects of piston effect relief, and the specialized shuttle carrier wagons. It is unique in that it is a private undertaking involving a major transportation infrastructure project, which is usually the domain of the governments. However, by far the most profound impact this tunnel may have is through the linking of the European and U.K. transportation networks. This event brings one step closer the achievement of the European Community objective of a unified Europe, as exemplified by the title "Eurotunnel."

CONCRETE TIE EXPERIENCE ON THE BURLINGTON NORTHERN

By: M. N. Armstrong*

Good morning. I am pleased to be able to talk to you this morning about Burlington Northern's experience with concrete ties. As you may or may not be aware of, Burlington Northern has made a substantial committment toward the use of concrete ties through 1992. In fact, we are aggressively working toward the installation of 3.5 million concrete ties which will cover over 1,300 track miles of main line railroad. This sounds like alot of ties and, in fact, it is. However, to put things into proper perspective one must realize that the 3.5 million concrete ties will represent little more than 4% of our total tie population. Needless to say, wood ties have and will continue to play an important role on the Burlington Northern in the foreseeable future.

Photo 1

Why the decision to utilize concrete ties? The answer is simply "it makes good economical sense." When wood ties are lasting only 5-6 years in certain high degree, high tonnage curves due to severe spike kill and heavy mechanical wear, you begin to look for long term solutions that will reduce annual maintenance costs. On the Burlington Northern, concrete ties were the cost effective solution. We cannot afford to install concrete ties everywhere on our railroad. The economics of the concrete ties are such that we have limited their installation to areas of high tonnage and generally high degree of curvature. (Photo 1). These areas give us the quickest payback. Burlington Northern's decision to utilize concrete ties is by no means a test but rather a committment toward reducing the maintenance costs on certain segments of our railroad. I believe that it is fair to say that the successful concrete tie programs that have been experienced by the Europeans as well as the Hamersley Iron in Australia and the Canadian National Railroad certainly have had a positive impact on our decision to go with concrete ties.

*Chief Engineer-Maintenance, Burlington Northern Railroad

Various fastening systems were analyzed during the formulation of our concrete tie program. The McKay system was chosen due to it's design features, it's use on other heavy haul railroads and because of the price tag associated with it. The McKay fasteners have proven to be successful by giving us the security and toe load that we need in the severe operating environments where we are placing them. A variety of tie pads are available for use with the concrete ties and we have found the EVA pad to perform well. However, we believe that the rubber pad and the polyurethane pad have definite advantages including better attenuating properties and longer lives for certain applications such as areas with higher train speeds and heavy locomotive sanding. Although the rubber and polyurethane pads cost more, there are locations where their use is justified.

Two manufacturers are producing the BN 100 concrete ties for Burlington Northern. Lone Star-Monier located in Denver, Colorado and CXT located in Spokane, Washington. Lone Star is casting the BN 100 tie with 28 prestressing strands arranged in 4 layers. On the other hand, CXT is utilizing 28 prestressing strands arranged in 3 layers. The tie weighs approximately 630 pounds and is 8′-3″ long.

Production of the concrete ties begins by pulling the prestressing strands off their spools and threading them through the tie molds. The wire is then given an initial pre-set loading prior to the final set loading. Properly mixed concrete is then cast and vibrated and the bottom of the tie is finished to a rough condition or indented with a pattern to aid in ballast interlock and to improve the lateral resistance of the tie. The beds of ties are then covered and allowed to cure for approximately 8 hours and the temperature of the concrete cannot exceed 175 degrees Fahrenheit through controlled heating. Test cylinders must achieve a minimum of 4,500 psi compressive strength prior to the prestressing strands being cut. Since the ties are cast upside down they are then flipped over and transported out of the plant to either the storage yard or for loading onto BN's flat cars for shipment to a jobsite. The tie plants are capable of producing about 1450 ties during each casting.

Quality of the concrete tie is controlled through specifications, quality control, auditing and independent consultant analysis. Random tie samples are taken to test for proper wire bonding and to test for bending strengths. Burlington Northern employs an inspector at each of the concrete tie plants to ensure that the ties are manufactured according to our specifications. The inspectors look for a number of things such as proper positioning of the shoulders and any problems with the prestressing wire. They look closely at the ends of the ties to ensure that the prestressing strands do not protrude excessively and that the concrete has bonded with the strands at the ends. In addition, they review plant testing activities and plant records to monitor the mix design. Acceptable ties are shipped to the jobsite utilizing our fleet of 224 custom built flat cars. Each flat car is designed to carry 220 concrete ties. When the flats are emptied at the installation site, they are re-loaded with wood ties which are shipped back to either Spokane or Denver to be rehabilitated.

Through 1987, 392,000 concrete ties have been installed. 125,000 of these were installed in 1986 with a Mannix sled and tie inserters followed up by undercutters/cleaners. These particular ties were cast with Pandrol fasteners. The remaining 267,000 were installed with Tamper's P-811S track laying machine in 1987. (Photo 2). This year, we will install 722,000 concrete ties with two Tamper P-811S track laying machines. Currently, one P-811S is working between Spokane with Pasco, Washington. The other track laying machine recently began installing ties near Birmingham, Alabama. Installation with the Tamper equipment has been very successful. We have found the Tamper track laying machine to be a cost effective and efficient method for concrete tie placement. Production with the P-811S has been as expected with from 500 to 600 or more concrete ties placed per hour of work time. We have installed as many as 3,425 ties in a given day.

In 1987 we were able to successfully negotiate a unique agreement with the Brotherhood of Maintenance of Way Employees which provides for several BMWE people to work on the P-811S track laying machine at several locations on the BN. Although Tamper retains control of the operation of the track laying machine, 13 BMWE employees perform various functions including spike pulling,

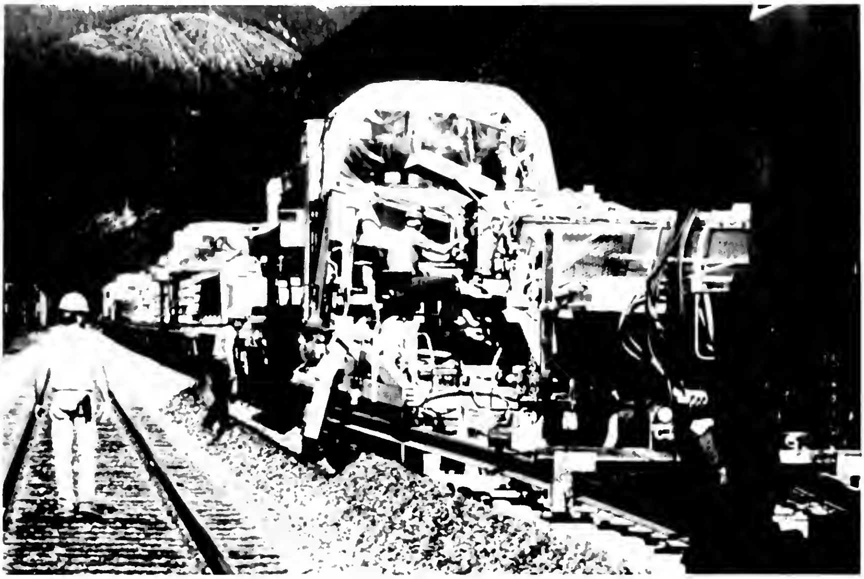


Photo 2

gantry crane operation and rail lining. This agreement is a good example of a win-win type arrangement where both the BN and the BMWE can realize the benefits. Essentially, BMWE personnel assigned to the track laying machine have system work rights, non-bumpable positions, tool box headquarters, flexible starting times and a reasonable per diem allowance. This arrangement has worked very well and daily production has been good.

A typical workday with the P-811S starts with the cut in of the sled at the worksite. The field side spikes are pulled and the rail is then threaded out and around the working area. The wood ties are picked up and conveyed to the collection area and the plow is positioned to prepare a bed for the concrete ties which is level yet slightly depressed in the center to eliminate any potential center binding conditions. Once the concrete ties are set onto the grade, they are then spaced automatically at 24″ centers. Pads are then placed at the rail seat and the rail is threaded back onto the ties. During this process, the gantry cranes are busy shuffling concrete ties to the P-811S and carrying the wood ties back to the empty flat cars. Ballast deck bridges do not present any special problems for the P-811S; however, it is critical that there is sufficient ballast placed between the concrete tie and the ballast deck itself to properly hold the ties in position.

Behind the P-811S, insulators and clips are distributed and then set into position. A tamper ensures that the rail is snug in the rail seat area prior to automatic clip application. Crews do the clean up work at this time including installation of the special McKay clips at insulated joint plug locations. A regulator brings up the rear by pulling in the ballast which was previously plowed out by the P-811S. At the completion of the workday, the sled is removed from the track and the rail is buttoned up in preparation for traffic. All joints are field welded as soon as possible. We have determined that the installation of 11 each 10′ wood switch ties provides a good transition from the stiffer concrete tie track structure onto the more resilient wood tie track structure.

Once the concrete ties are in place, we follow up with a ballast undercutting/cleaning process and unload enough additional crushed rock to ensure that there are 12″ of clean ballast underneath the ties.

n a 2,000 locomotive fleet, COBRA* High Friction Composition Brake Shoes can probably save you $250,000 or e over the course of one year. If you doubt e savings, give us a chance to prove them!

In field test after field test—f them closely monitored—COBRA Brake es lasted 20% to 50% longer than the shoes were tested against. With average loco-ive brake shoe and labor costs estimated 290 per year, this kind of increased shoe wear life can provide savings of $58 to $145 a year for each locomotive in the fleet—savings directly related to the use of COBRA Brake Shoes. Better wear means reduced shoe costs—reduced labor costs. And the ability to go that one more inspection.

For complete data on these field tests, or for more on how your railroad can strike gold with red COBRA Brake Shoes, contact your Railroad Friction Products Representative.

Without a doubt, ballast quality, gradation and proper depth under the tie are absolutely essential toward maximizing the life of the ties and providing for a stable track structure. We are surfacing the concrete tie track with a variety of tamping equipment including Jackson 6700's, Tamper Mark III's and Plasser 09 Continuous Action Tampers. We currently have one Plasser 09-32 Continuous Action Tamper which has the capacity of tamping two ties at a time. With the consistent tie spacing that the concrete tie affords, this machine can be utilized to maximize production and reduce overall surfacing costs as well as reduce train delay.

After the track is undercut and surfaced, we bring in a destressing gang, if necessary, in order to equalize the rail and eliminate any potential for a track buckle. Since the entire track structure is disturbed during the concrete tie installation process and because the rail neutral temperature is constantly changing due to the undercutting and surfacing, it does not pay to attempt to equalize the rail until all work has been completed. The destressing gang is comprised of 15 people who cut the welded rail, remove the clips and pull the rail with hydraulic expanders. After destressing, clips are reapplied and joints are field welded immediately.

Behind the destressing gang, we are left with a safe, consistent and reliable track structure over which to move our customer's goods.

I would like to shift gears and talk briefly about the second hand wood tie rehabilitation process that is taking place at Spokane and Denver. There are two organizations which are rehabilitating the ties released from the concrete tie installations. Atlas Construction is located near Lone Star-Monier's plant in Denver and Mid-West Pacific Resources Corp. is situated near CXT's plant at Spokane. These two companies receive the second hand wood ties on flat cars at their plants. The wood ties are sold to these two companies and are rehabilitated by them. They unload the ties, pull the spikes, retrieve the tie plates, liquid plug the spike holes, adz the ties, treat the rail seat area, and grade the ties. Any approved ties are purchased by the BN, much like our concrete ties are, at which time they are banded and loaded into cars for shipping to wood tie projects on our system. Atlas Construction and Mid-West Pacific sell any rejected ties to landscapers or any other interested parties. Both of these companies are performing this service for other railroads. To date, approximately 65%-70% of the wood ties removed from track are rehabilitated, repurchased and reused. As our program progresses this percentage is expected to decline slightly each year. The second hand rehabilitated ties are used only on lower tonnage lines. In 1988, we plan to install about 600,000 second hand ties on our system.

In addition to reusing the second hand ties, we utilize the anchors, tie plates and spikes that are released from the concrete tie installations. This material is forwarded to other projects as needed.

Overall experience with the concrete tie program up to this point has been very good. We realize that it will be essential for us to maintain a clean ballast section around and under the concrete ties if we expect them to perform as designed. Shoulder ballast cleaning and undercutting/cleaning operations will have to be performed on regular cycles in order to keep the ballast section draining properly. Currently, we believe that we are realizing reduced rail wear and reduced surfacing cycles through better control of the alignment and surface. The elimination of gauging in high degree curves is resulting in savings which we are beginning to see. Rail grinding is performed to keep the rail head clean and to reduce any vibration and impacts on the concrete ties. In some of our very heavy tonnage locations we have noticed a rapid development of shatter cracking in higher degree curves, particularly on the low rail. However, light, frequent grinding cycles are cleaning up these locations and appear to be giving us very good results.

In addition to keeping the rail surface smooth by grinding, it is necessary to keep all joints eliminated from the concrete tie track structure. Again, vibrations and impacts should be kept to a minimum. We make every effort to field weld any joints on concrete tie track immediately.

Cracking of the concrete ties due to negative bending at the center of the tie and high wheel impacts at the rail seat area has not been a problem. We currently have one wheel impact load detector installed near Glendo, Wyoming and we anticipate the installation of additional units in 1988. These detectors will ultimately assist us in identifying bad acting wheels that can impart high impact loads into the track structure. High wheel impacts can potentially damage not only concrete ties but they can also cause potential damage to the conventional wood tie track structure as well as to the equipment and lading. We believe that the wheel impact load detectors will provide information which will be applicable to both the concrete and wood tie track structures.

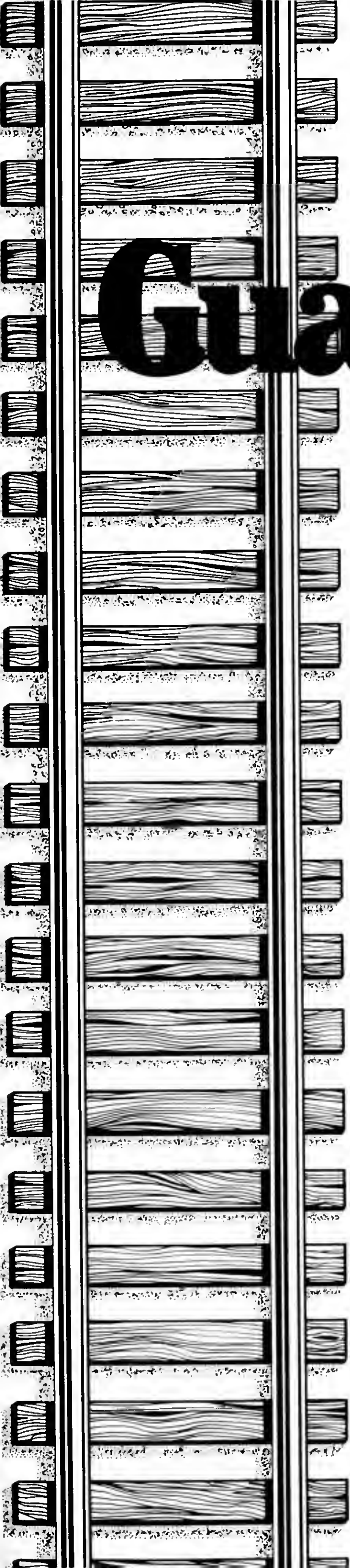
We have experienced some one car derailments on concrete ties and damage has been relatively minor. The majority of the damage has been limited to the fasteners and in addition there has been some shoulder damage. The concrete ties have performed very well in these derailment situations. We have had to replace a few concrete ties in some cases just as you would have to do with wood tie track. Also, we have experienced one major derailment on concrete ties which destroyed a total of 165 ties. It appears from this incident, and others like it on other properties, that a major derailment on concrete ties may generally take place over a shorter section of track since the train seems to break into two quicker than it would on a conventional wood tie track.

We are currently working with some manufacturers to come up with a grade crossing design that will not require the use of a special concrete track tie. Koppers Company, Inc., was the first manufacturer to come up with an acceptable design and they have a timber crossing which is available for testing in 1988. Wilson Concrete Company has a prototype precast concrete crossing panel that we plan to test which will set into place right on top of our concrete ties. The bottom of the panel is cast to conform to the shape of the BN 100 tie. Once the panel is set, it's shear weight will hold it down. The flangeways on both sides of the rail are then filled with asphalt to maintain alignment. Asphalt is also placed at the ends of the crossing to prevent any longitudinal shifting of the crossing panels.

Omni Products, Inc. has developed a prototype rubber crossing for testing which will adapt to the BN 100 concrete tie without any necessary modifications. Rubber shims are attached to the concrete tie with a high strength epoxy. The rubber shims provide a stable, flat surface for the full depth rubber crossing panels to sit on. A locking bar that fits underneath the edge of the rubber shim actually holds the panel from moving up and down, laterally or longitudinally. Burlington Northern intends to install a few of these crossings in 1988 in order to observe their performance and provide feedback to the manufacturers.

In addition to our concrete track tie program, we are also beginning to install concrete tie turnouts at selected locations on our system. (Photo 3) We have one such turnout installed at Anselmo, Nebraska and we will install 21 more this year. The concrete switch ties are being produced for us by CXT at Spokane, Washington. We will utilize a #20 swing nose frog on 17 of the turnouts and we will use a #11 Rail Bound Manganese frog on the remaining 4 turnouts. The concrete tie turnouts will be installed with the Geismar Panel Renewal System more commonly known as P.U.M.S. This system will allow us to install the concrete tie turnouts in one complete panel rather than a series of sections. Hopefully, this will provide a more consistent quality switch and require less track time to install. It is very important that no twisting or torque be introduced into the concrete tie turnout since this can result in tie damage. Depending upon our experience with this undertaking, we intend to expand the installation of concrete tie turnouts in 1989 and beyond.

What lies ahead for concrete ties on the Burlington Northern? We fully intend to look at other manufacturers of concrete ties beyond those that we are currently using. Although our current concrete tie committment only extends through 1992, we could very well install more concrete ties beyond that if the economics dictate that it is feasible. We are interested in looking at the dual block tie and observing how well it performs in a heavy tonnage environment. The alleged greater lateral resistance associated with the dual block tie is a feature that we are particularly interested in.



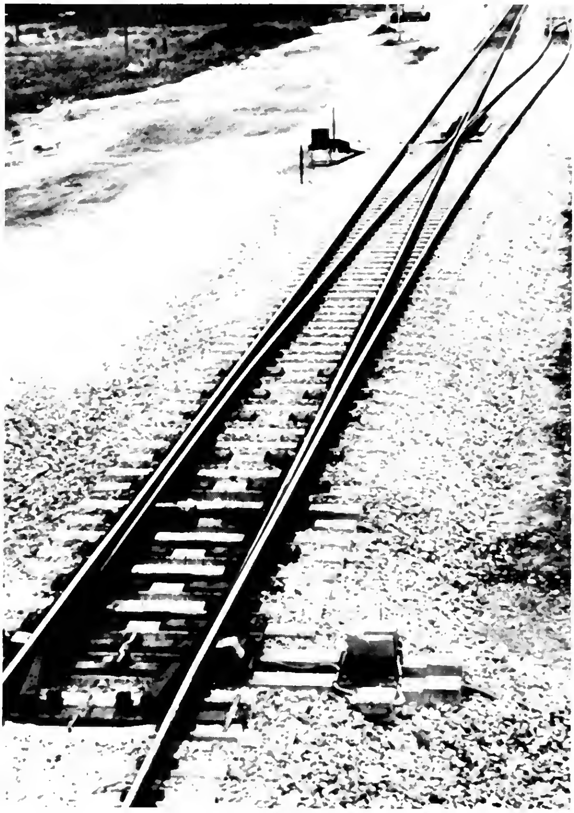


Photo 3

Only the future will tell us how successful we have been or ultimately will be with our concrete tie program. As for today, we know that we had to do something in order to improve the quality of the track structure and reduce the annual maintenance costs on certain select line segments through the installation of concrete ties.

In summary, our experience to date has been very good and we are pleased with the performance of the concrete tie, to say the least. We still have alot to learn about concrete ties. However, anything that we can do to improve their performance and prolong their life at a reasonable cost will be worth doing. For now, we are realizing reduced maintenance costs in the areas where we have installed the concrete ties through improved alignment, reduced surfacing cycles and elimination of gauging. The greatly improved track structure is allowing us to provide the customer with goods which are delivered safely and reliably at the least possible cost.

Thank you very much for your attention.

RECENT RESULTS IN TRACK BUCKLING RESEARCH

By: A. Kish*

1.0 INTRODUCTION

The increased utilization of continuous welded rail (CWR) tracks in the United States has resulted in a large number of accidents attributable to train derailments induced by thermal buckling of railroad tracks. In an effort to improve the safety of CWR tracks, experimental and analytic investigations are being conducted by the Transportation Systems Center (TSC) supporting the safety mission of the Federal Railroad Administration (FRA). This paper endeavors to highlight some of the recent results of those investigations. These include results of dynamic buckling tests, track resistivity studies, rail neutral temperature and force measurements, and some basic considerations for buckling prevention.

2.0 BACKGROUND

Track buckling is the formation of large lateral misalignments caused by a combination of high compressive forces, weakened track conditions and vehicle loads. Compressive forces are generated by stresses due to thermal and mechanical loads. Weakened track conditions are most typically due to:

(i) inadequate track lateral resistance
(ii) alignment deviations
(iii) low or "decreased" rail neutral temperature.

Vehicle loads entail both vertical and lateral wheel forces causing "dynamic uplift" (i.e., the lifting of rails/ties vertically out of the ballast resulting in a loss of ballast resistance under the ties), and L/V type loads due to curving, wheel flats and truck hunting.

Track buckling is a serious problem because incipient buckles are difficult to predict and detect, and most often buckles occur under dynamic conditions, (i.e., under the train) which can cause, serious derailments. Based on FRA's accident statistics, the past ten years' average was 103 derailments a year causing damage in excess of 9 million dollars per year. Of equal importance is the fact that there are 10 times as many incidents as derailments, which heavily impact track maintenance activities, budgets, and schedules.

Because of the severe safety aspects of track buckling, the Transportation Systems Center has been conducting research to improve the buckling safety of CWR tracks. The three major program activities of this research effort are:

- o Analytic and experimental prediction of buckling forces and temperatures
- o Measurement and characterization of the critical parameters influencing buckling
- o Development of nondestructive techniques of rail longitudinal force measurement.

* U.S. DOT, Transportation Systems Center

In the following, some critical elements and results of this research will be briefly outlined.

3.0 EXPERIMENTAL INVESTIGATION OF DYNAMIC BUCKLING BEHAVIOR OF CWR TRACKS

The most recent set of buckling tests was conducted in October of 1987 at the Transportation Test Center in Pueblo, CO with the objective of evaluating buckling strength of higher degree curvature tracks.

As summarized in Figure 1, the 1000 ft., 7.5° curve test zone consisted of 136# CWR on wood ties in slag ballast with 12"-16" shoulder. The test zone

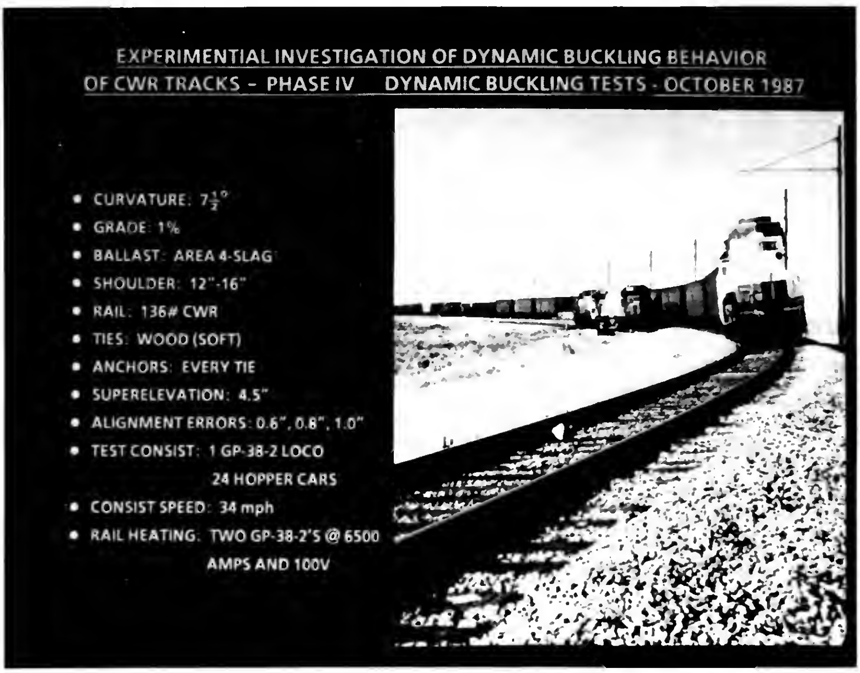


FIGURE 1. DYNAMIC BUCKLING TEST ZONE DESCRIPTION

contained three naturally occuring lateral line defects of 0.6", 0.8" and 1.0" amplitudes. Dynamic (train action) conditions were simulated by a test train consisting of a GP-38-2 locomotive and 24 loaded hopper cars operating at 34 mph. Rail compressive forces were generated by electric resistance rail heating. Segments of the test zone were instrumented to measure rail forces and temperatures, lateral and longitudinal deflections, and vertical and lateral wheel loads. Other parameters such as track resistance and alignment errors were also measured prior to the tests.

One of the major results of the test is presented in Figure 2, where its shown that buckles occured under the train at each of the three initial line defects resulting in the derailment of 6 cars. Three buckles occured at force levels corresponding to temperature increase values (above neutral) of 62°-74°F indicating that:

- 7.5° CWR curved tracks with relatively low lateral resistance and typical line defects exhibit moderately weak dynamic buckling behavior

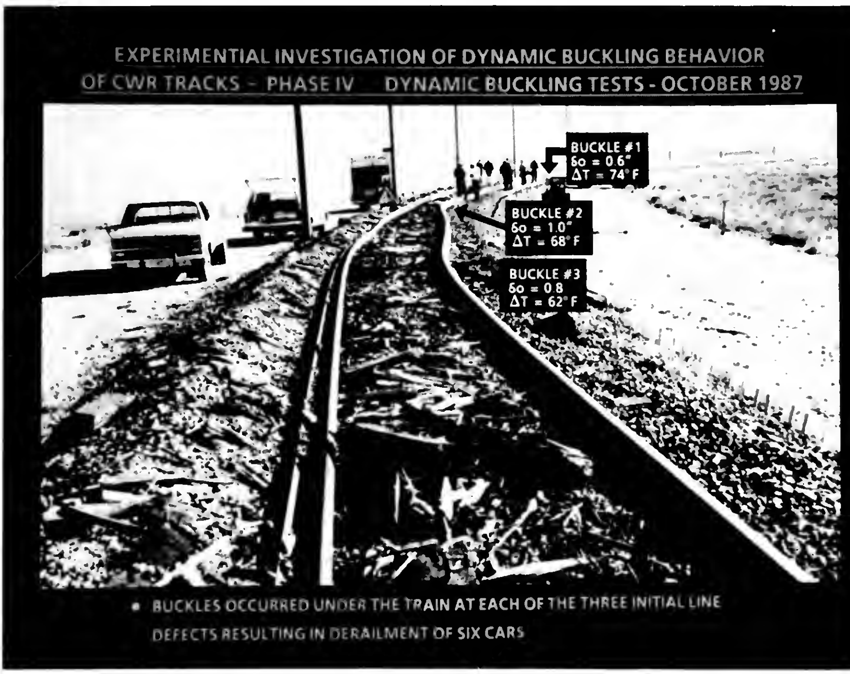


FIGURE 2. TRACK BUCKLING TEST ZONE AFTER DERAILMENT

The test results also furthered buckling analysis development, and re-emphasized the importance of track resistance, line defects and dynamic influences as major factors in track buckling.

4.0 TRACK LATERAL RESISTANCE

Track lateral resistance is the reaction offered by the ballast to the rail tie structure against lateral movement. As indicated in Figure 3 lateral resistance has three contributing components, f_s, f_b and f_e corresponding to the tie side, tie bottom and tie ends respectively.

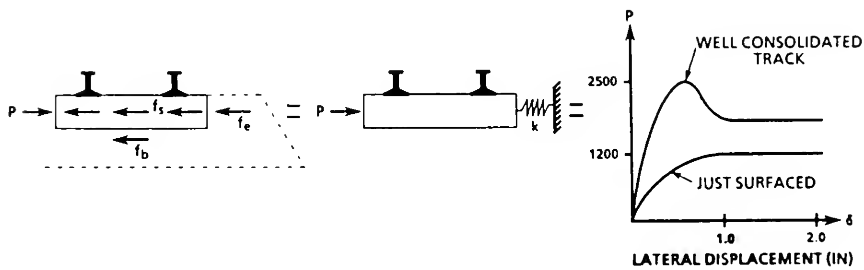


FIGURE 3. TRACK LATERAL RESISTANCE CONCEPTS

The measurement of track lateral resistance is by a single tie push test (STPT) which basically entails mobilizing a tie laterally through the ballast and determining its load deflection behavior as shown in Figure 3. Typical values of lateral resistance can be expressed in terms of the peak values on these response curves, and typical ranges are 900-1200 lbs for weak, recently maintained tracks, to 2500-3500 lbs for good, well consolidated tracks. The measurement of track resistance is very important for:

(i) the analytic determination of "safe" allowable temperature increase limits, and for:

(ii) monitoring lateral resistance recovery after maintenance to aid in the determination of slow-order requirements

Recent research results on track resistance characterization conducted by TSC on the CSX are shown in Figure 4.

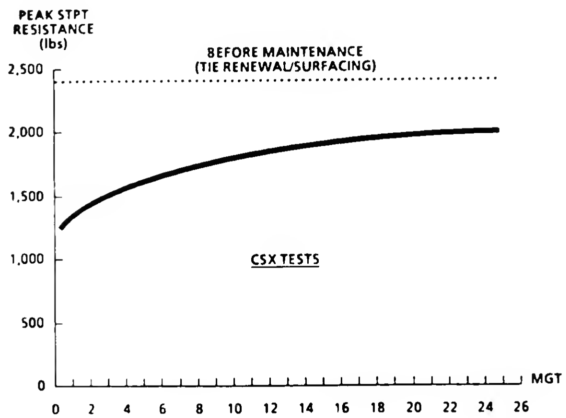


FIGURE 4. TRACK LATERAL RESISTANCE RECOVERY VS. TONNAGE

As can be seen from the figure, maintenance (tie renewal and surfacing) reduced track lateral resistance by about 50 percent, and in 25 MGTs about 80 percent of the original resistance was recovered. These tests were conducted on timber tie-tangent track with good quality granite ballast.

More recent studies on quantifying track lateral resistance behavior from FAST at AAR/TTC show the approximate percentage resistance contributions f_s, f_b and f_e in one test zone as indicated in Figure 5.

It is important to note that although the shoulder contribution is only 20 percent, during dynamic uplift when all or part of the tie bottom resistance is lost, this 20 percent becomes critical in providing adequate lateral resistance for buckling prevention.

5.0 RAIL NEUTRAL TEMPERATURE VARIATION

Rail neutral temperature is defined as the temperature at which the net longitudinal force in the rail is zero. Initially, it is the rail laying or anchoring temperature. However, as recent test data indicate, 20°-40°F shifts in neutral temperatures are not uncommon. Variations in the rail's neutral temperature are important because they directly influence the longitudinal force in the rail. For example, for a typical 132 lb. rail, a 40°F change in the rail's neutral temperature changes the force level by about 100,000 lbs. A downward change (e.g., from 80°F to 40°F) could lead to buckling, while an upward change (e.g., from 80°F to 120°F) could lead to pull-aparts.

The major causes of neutral temperature change are:

(i) unconstrained rail or track movement

(ii) maintenance actions

(iii) CWR installation in cold temperatures

Unconstrained rail/track movement is usually manifested by rail longitudinal movement (creep), curve shift ("breathing"), and vertical settlement (subsidence). Maintenance actions influencing neutral temperature changes include replacing broken rail and lifting and lining the track. CWR installation in cold temperatures could result in an incorrect neutral temperature due to non-uniform rail heating and from improper subsequent adjustment of the rail. Figure 6 shows some recent results in monitoring rail neutral temperature behavior on a tangent, revenue service track on the CSX, through a period of over two years.

As can be seen, the trend is a decrease in neutral temperature from an initial destressed value of 112°F down to 94°F. The influence of tie renewal and surfacing is clearly evident. Similar measurements on curved tracks show that the influence of lining and curve shift can also be of the order of 20°F-30°F. One of the major problems in controlling neutral temperature variation is the unavailability of a technique or device to non-destructively and accurately measure the longitudinal force in the rail. A technique currently under evaluation at TSC is schematically shown in Figure 7.

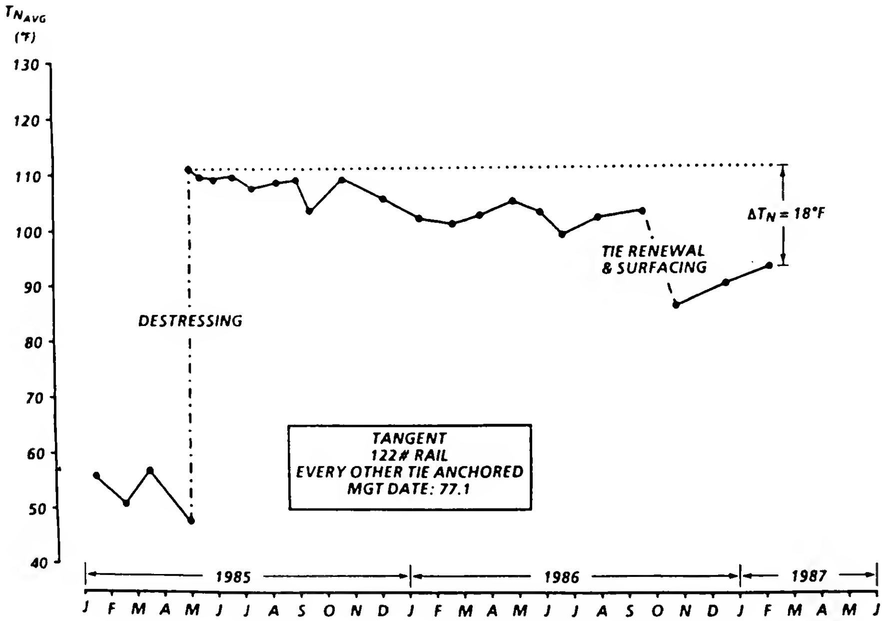


FIGURE 6. CSX RAIL NEUTRAL TEMPERATURE VARIATION TESTS

APPROXIMATE % RESISTANCE CONTRIBUTION

TIE ENDS (SHOULDER)	TIE SIDES (CRIBS)	TIE BOTTOM
20%	45%	35%

NOTE IMPORTANCE OF 20% SHOULDER CONTRIBUTION UNDER DYNAMIC CONDITIONS

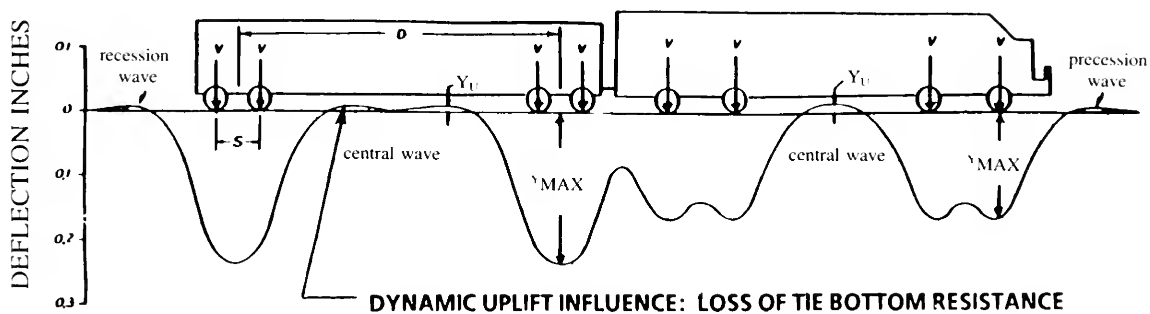


FIGURE 5. TRACK RESISTANCE DISTRIBUTION AND IMPLICATION OF DYNAMIC UPLIFT

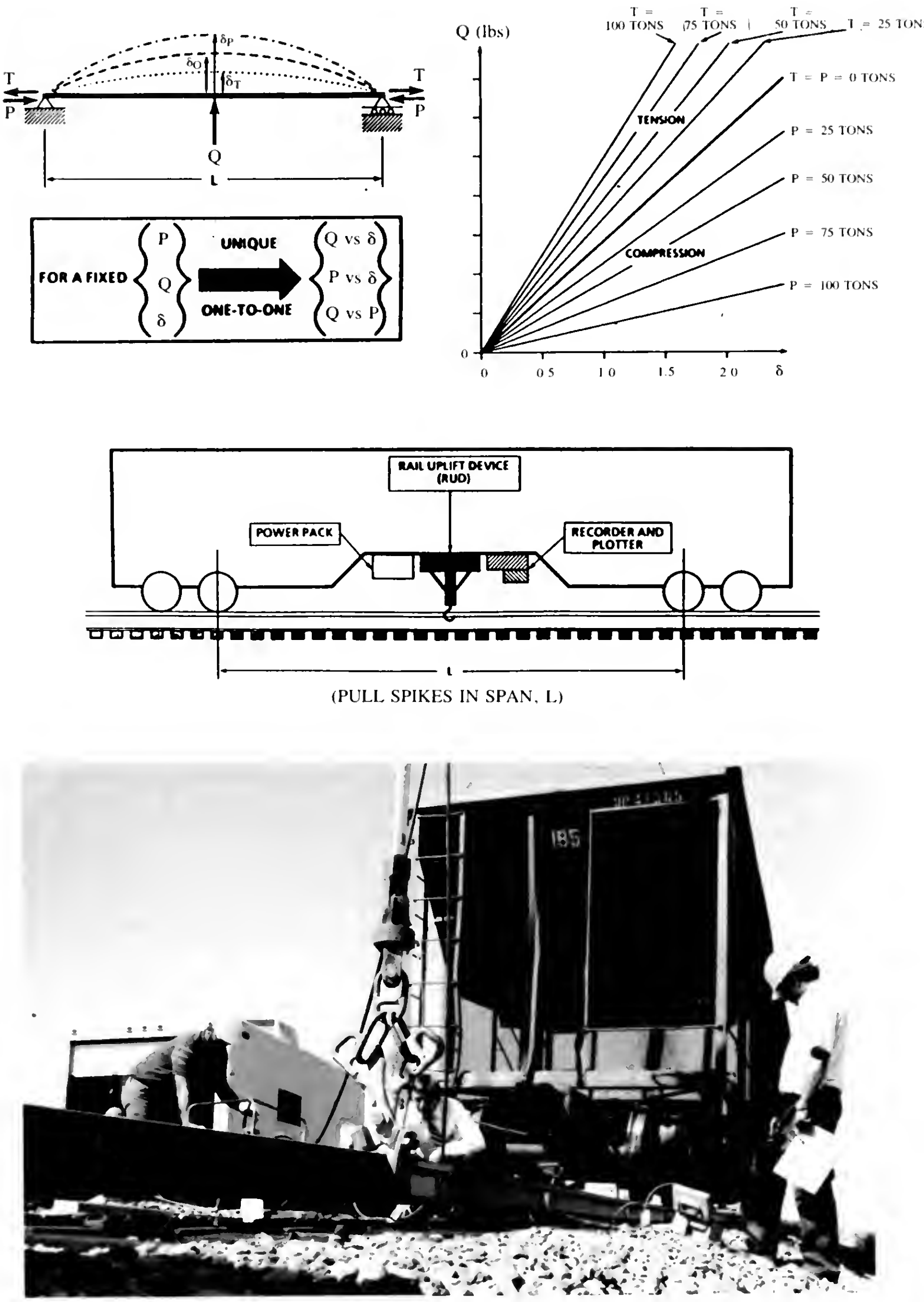


FIGURE 7. RAIL LONGITUDINAL FORCE MEASUREMENT CONCEPT BASED ON RAIL BENDING RESPONSE

This new approach is based on the fact that if the rail can be held at two points at some distance apart, and a concentrated load applied at the center of this portion, the structure behaves like a beam column and its deflection is influenced measurably by the longitudinal load in the rail. Clearly, the compressive longitudinal load will increase its deflection, whereas the tensile load will reduce it. Besides the longitudinal force, the deflection is dependent on the rail size, applied load Q, beam column length L and the nature of end constraints. It is possible to design a rig such that for all locations and measurements, the end conditions are sufficiently repeatable. Preliminary test results on this concept show good enough sensitivity and repeatability to warrant continued research.

6.0 SUMMARY OF TRACK BUCKLING PREVENTIVE MEASURES

The following is a summary of various considerations for buckling prevention compiled as a result of several TSC track buckling workshops over the past four years:

o ENSURE AND MAINTAIN GOOD TRACK RESISTANCE

Track resistance is one of the key parameters governing track stability, therefore it is most important to maintain full ballast section (i.e., full cribs and adequate shoulder). Avoid "working" ballast in hot weather, and require adequate consolidation after surfacing for resistance recovery, meanwhile implementing proper slow order procedures.

o ENSURE HIGH AND STABLE RAIL NEUTRAL TEMPERATURE

Neutral temperature variation has also been identified as a key cause of buckled track. Therefore it is important to install CWR properly, and readjust if rail is laid during the winter. Sufficient and effective anchoring is also imperative in preventing rail running hence limiting neutral temperature change. Care must be excercised in lining in and out of curves. When replacing broken rail, a sufficiently long destressing zone should be provided to keep neutral temperature uniform.

o CONTROL LINE DEFECTS

Alignment errors also influence CWR tracks' buckling potential. Therefore, it is important to hold alignment (both vertical and lateral) to close tolerances, especially during high temperature conditions. Additionally, consideration should be given to preventing and/or monitoring curve "breathing" (pull-in) during the winter time.

o EXCERCISE "GOOD PRACTICE" INSPECTION AND RECORD KEEPING PROCEDURES

More frequent inspection for line defects, "snakiness", rail running, ties moving, and weak ballast section can be important in identifying potentially buckling prone locations. Keep good records (setup data base) of pull-aparts, broken rails, destressing temperatures, and disturbed track; catalogue and analyze buckling incidents.

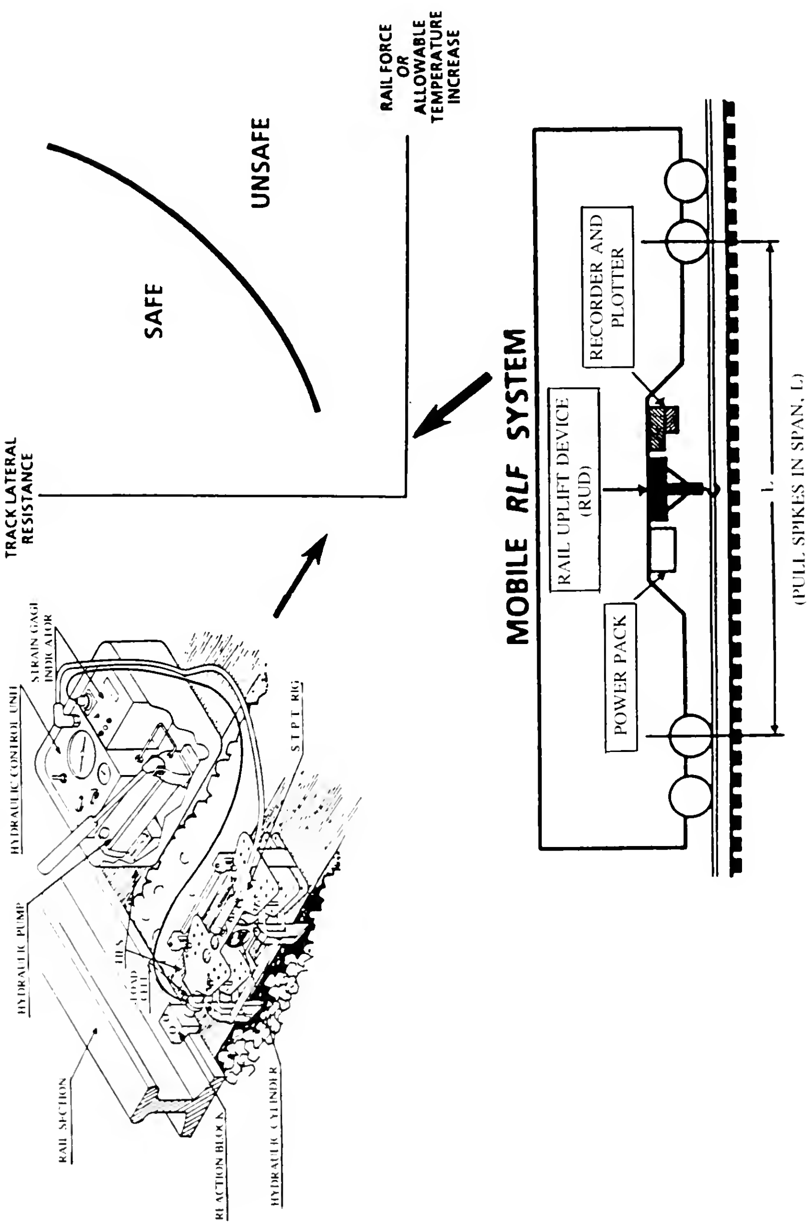


FIGURE 8. SAFETY LIMIT CONCEPT FOR BUCKLING PREVENTION

7. CONCLUSIONS

Current TSC/FRA research is well underway in developing the technical information for improving the buckling safety of CWR tracks. This includes the development and validation of dynamic buckling analyses, ballast resistivity characterization and development of measurement techniques (STPT device), neutral temperature variation behavior assessments, and developing concepts and techniques for rail longitudinal force measurement. It is hoped that in the near future, safety limits and guidelines for buckling prevention can be developed as schematically shown in Figure 8.

As Figure 8 indicates, for a specified curvature and line defect, safety limits are expressed in terms of track resistance required for specific rail force or allowable temperature increase value. The track lateral resistance could be measured via single tie push tests (STPTs) and the rail force (or neutral temperature) via a mobile rail force measurement system based on the previously discussed rail bending concept.

PRESENTATION ON HEAVY AXLE LOADS

By: L. T. Cerny*

I'm happy to say that this may be the last time that I give a talk regarding axle loads. This isn't because I dislike the subject but because of reasons I'll now explain.

When I took my present position in 1979, one of the most fundamental issues facing the railway engineering profession was the question of heavier axle loads. In 1980, under the leadership of then President Mike Rougas, the A.R.E.A. began looking into this question. This involved a trip over the Waynesburg Southern Railroad, which at that time originated the Pittsburgh and Lake Erie and Conrail move of 315,000 lb. cars to the Detroit-Edison generating plant at Monroe, Michigan.

This verified that it was technologically feasible to operate these cars and gave some information on possible rail life and other information that could be useful in making decisions regarding heavy axle loads.

Up until the present, information on heavy axle load questions has been a matter of gathering up bits and pieces of information from many sources. These talks I have given over the years on this subject have tried to organize this information from actual operations, railroad decisions regarding heavy axle load cars, research studies and various other sources, including the incorporation of foreign experience which was in most cases not directly applicable. This gathering of information in bits and pieces was the best that could be done under the circumstances.

However, as you heard in Dr. Reinschmidt's talk earlier in this conference, we are standing at the threshold of getting the best information we have ever had on the question of going to heavier axle loads. The heavy axle load tests that will be run at the Pueblo Test Center should provide good information on which to base heavy axle load decisions. Past information indicated a wide variety of answers to the question of how detrimental heavier axle loads would be to rail life. Based on this past information my view was that the rail life measured in MGT under 315,000 lb. cars would only be about half of that under 263,000 lb. cars, all other conditions being equal. The most recent information has indicated that at least in some cases this life measured in MGT maybe on the order of 2/3 rather than one 1/2.

If the results of the Pueblo tests show that going to a heavier axle load will bring considerable savings to the railroad industry, we will then have another tool with which to become more competitive. At a talk before this group in 1980, I said the following: "Ever since railroading began over 150 years ago, the trend has been towards larger and heavier equipment. If we are now to say that the 263,000 lb. car is as heavy as equipment should get on four axles, we are advocating a fundamental change in this direction. As the technology of other modes improves, such a change in philosophy could mean that railroading would not remain competitive."

If the tests at Pueblo show that the heavy axle load is beneficial from an overall railraod standpoint, what would be some of the advantages? One of those most immediate would be to more fully allow the potential of double stacks to be reached. My discussion here will deal with containers in the 40 ft. range, and not the short 20-footers which have such a potential for overload problems. If we have a double stack container train using the same 33 ton axle load as a 100 ton coal or grain car, we can achieve a payload-to-gross-weight ration of 64.9%. The restraint here is that both containers, which are designed to international standards, cannot be loaded to their 67,200 lb. maximum gross weight. My understanding is that this constraints about 30% of the commodities shipped. Double stack trains using 120 ton trucks with 39 1/2 ton axle loads would allow the containers to be loaded to an average of 92% of weight capacity, giving a 68.2% payload-to-gross weight ratio. Thus the use of 120 ton trucks versus the 100 ton truck on double stack container trains would improve the pay-load-to-gross-weight ratio by 5.1%. As I will mention later, this special situation is caused by having to accommodate containers of a specific international design and does not apply to bulk commodity unit trains, where going to a heavier axle load does *not* improve the payload-to-gross-weight ratio.

Allowing heavier axle loads would also have a benefit in the use of the single axle roadrailer type vehicle. The roadrailer is a highway trailer which also has rail capabilities. It, like the double stack, has

* Executive Director, AREA and Engineering Division, Association of American Railroads

one railway axle per trailer or container. The trailer and load are limited by highway load limits to about 64,700 lb. to allow for a 15,300 lb. tractor and a maximum total weight of 80,000 lb. 64,700 lb. on one axle is below the 65,750 lb. axle load of the 263,000 lb. car, but because of the need to tuck the rail wheels under the trailer when traveling on the highway, the wheel diameter is only 33 inches instead of the 36 inches that is normally used on 263,000 lb. equipment. Thus rail contact stresses are 7.4% over that of 263,000 lb. cars on 36 in. wheels. On a regular highway trailer the load can be 53,400 lb. and still be within the 80,000 lb. maximum federally allowable weight because it doesn't need the approximately 6500 lb. extra weight of the equipment necessary to make it capable of running on rails.

If we take the view that the trailer is going to be loaded the same whether it has rail capabilities or not, we would have a total weight of 71,300 lb. on one axle with 33 in. wheels which creates contact stresses 5.6% over that of a 315,000 lb. car with 38 in. wheels. I should mention, of course, that in both the case of the double stack and roadrailer many loads tend to cube out before they weight out, that is they take up the full volume of the container before reaching maximum allowable weight. Thus the maximum axle loads I mentioned would probably only occur on a small percentage of the axles, in contrast to a unit train where the maximum axle load is present on nearly all the axles.

Looking at unit trains of bulk commodities, it is important that we remember that for a given type of car technology there is no payload-to-gross-weight advantage in going to heavy axle load cars. A 315,000 car, carries the same weight percentage of commodity as a 263,000 wen both cars are of equal technology. Obviously if the 315,000 lb. car is built with aluminum instead of steel when compared to a 263,000 lb. car built only of steel, then the 315,000 lb. car will show a higher payload to gross weight ratio, but there is no reason that the 263,000 car could not be designed with aluminum also. Detailed studies of this matter have shown the payload-to-gross-weight ratio does not improve with heavier axle loads. The 315,000 lb. gross weight car, the "so-called 125 ton car", can only haul 20% more payload than the 263,000 lb. car when both use the same materials and design procedures. The locomotives will have to pull just as much weight of cars to haul a given amount of payload whether these cars are of 263,000 or 315,000 lb. design. Because of these facts it is more proper to call the 315,000 lb. car a 120 ton car, to be consistent with calling a 263,000 lb. car a "100 ton" car.

We can look at some of the experience with 315,000 lb. axle loads to date in various decisions made by various railroads. On Conrail the use of the 315,000 lb. cars on the Detroit-Edison unit train has been reduced and new cars being purchased are of the 263,000 lb. design. The Black Mesa and Lake Powell chose 315,000 lb. cars, but these were later light loaded to approximately 263,000 lb. The Union Pacific and Chicago and Northwestern have removed provisions for 315,000 lb. traffic from the Railway Lines Clearances publication so that such loads now have to handled on an individual case by case basis. The Union Pacific has also made the decision to use double axle roadrailers in a model called the Mark 5, thus reducing axle load to far below that experienced with 100 ton cars.

On the other hand the Norfolk Southern Railway, based on decisions made on the former Southern Railway, has had a policy of allowing 286,000 lb. cars on many of its coal trains, this being a 9% increase in axle loads, and believes that this policy has been advantageous to the railroad. The Burlington Northern, Union Pacific, and Chicago and Northwestern recently decided to operate some of the 120 ton truck double stacks and the Burlington Northern is, on an experimental basis increasing the load on some of its bulk commodity cars to 283,000 lb., this being a 5% increase in load.

It is important to look back on how far we have come since 263,000 lb. cars were introduced in the middle 60's. Most of our lines have been vastly improved with deeper ballast sections. Welded rail has replaced jointed on most of our main lines, and there is a considerable body of opinion that had we not gone to welded rail the track structure would not have been able economically to take the 100 ton 263,000 lb. gross weight cars. Back in 1980 there were some dire predictions about how rail life would be affected by the 100 ton cars. At that time a rail life of over 1 billion gross tons had been achieved on welded rail under 220,000 lb. maximum weight cars and predictions as low as 400 mgt for 263,000 lb. cars had been made. But the reality is that significant amounts of rail are now over 1 billion gross tons

with predominantly 263,000 lb. car traffic. The combination of better roadbed, welded rail, better rail metallurgy, and modern grinding policies has put us in nearly the rail life situation that we had before with 220,000 lb. cars. Because of their original design for heavy steam locomotives, bridges have not been a severe problem with the 263,000 lb. cars and the concentration of effort in regard to these cars has been to improve the track structure. It may be that the most fundamental problem with 315,000 lb. cars would be a redirection of emphasis towards railway bridges as the 315,000 lb. cars have an accelerated effect on reducing bridge fatigue life.

In summary, the heavy axle load project at FAST should give a definitive answer and plenty of information for making engineering decisions on heavier axle loads and it will no longer be useful for me to be making talks about increased axle loads by gathering up bits and pieces of information. The sophistication of railway engineering has come a long way. In the middle 1960's 263,000 lb. cars were thrust upon us without adequate study. Compare this to the present climate where research dollars are being wisely spent to decide the issue of 315,000 lb. cars before large investments are made. Thank you for your attention.

PUBLISHED AS INFORMATION BY COMMITTEES

COMMITTEE 16 — ECONOMICS OF PLANT, EQUIPMENT AND OPERATIONS

Chairman: C. Bach

Report of Subcommittee 6

Subcommittee Chairman: J. W. Rettie

APPLICATIONS OF ROBOTICS IN THE RAILWAY INDUSTRY

By: Carl D. Martland*

This report was prepared by Carl D. Martland* in cooperation with AREA Committee 16 as part of the Core Research of the Association of American Railroad's Affiliated Rail Program at MIT.

Abstract:

Robotics have only a limited role in improving railroad productivity. The most likely applications are in the shops for such activities as welding, cleaning, painting and materials handling. A survey of 13 railroads shows that they are generally satisfied with the 20 robots that they have installed in their shops. The economic benefits, however, are small compared to the total costs of operating a shop.

Introduction

Robotics offer the promise of improving the quality and the productivity of many manufacturing and maintenance activities. However, robotics applications have been concentrated in industries other than transportation, such as electronics and automobile assembly. As a result, most railroads have had too little experience with robotics to judge their true worth and their most appropriate role.

AREA Committee 16 therefore undertook various investigations regarding the potential applications of robotics within the rail industry. The Committee visited robotics laboratories at MIT and Carnegie Mellon Universities in order to see at first hand some of the technological advances being made in this field. During these visits, the Committee had an opportunity to listen to robotics experts describe the promise and the pitfalls of this technology. The Committee also inspected the use of robotics and other advanced automation techniques at Norfolk Southern's welding plant in Atlanta and General Electric's locomotive assembly plant in Erie, Pennsylvania. In addition, the Committee assisted researchers at the AAR's Affiliated Rail Research Program at MIT as they investigated the potential uses of robotics in locomotive rebuilding at Conrail's Juniata Shop.[1] Finally, the Committee conducted two surveys, in 1984 and again in 1987, concerning the applications of robotics within the rail industry. This paper presents the results of these surveys along with some general conclusions based upon all of the Committee's investigations.

* Principal Research Associate, Massachusetts Institute of Technology

Implications of the Juniata Study

The Juniata Study included an overview of the uses of robotics in other industries. The study found that robots are most commonly used in such activities as materials handling, welding, painting, and cleaning. Companies install such robots in order to reduce costs or provide a consistently higher quality than achievable in manual operations. Companies may also install robots to replace operators engaged in dull, dirty, or dangerous jobs.

The study addressed robotics applications, which were clearly distinguished from other kinds of automation. According to the Robot Institute of America, a robot is:

> "a programmable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks."

A robot is therefore quite different from machinery that is designed to perform a specific set of tasks. It is important to decide when it is appropriate to use specialized machinery and when it is better to use robotics. In particular, it is necessary to compare robotics to the existing automated machines that have been developed for use in rail shops and maintenance of way.

There is general agreement that shops are the most likely places to find railroad applications. Maintenance of way, which clearly has benefited greatly from automation, is less suited to robotics because of two factors. First, the work is done outside, which requires strong, durable machinery, while most robots are designed to work indoors. Second, maintenance of way has developed into a highly specialized set of activities that use highly specialized equipment. Shop activities, on the other hand, are performed indoors and include such things as welding, grinding, cleaning, painting, and materials handling, all of which are typical robotics applications.

Nevertheless, there are some major questions concerning the applicability of robots in railroad shops. For one thing, the components of freight cars and locomotives tend to be much larger and heavier than the materials typically handled in manufacturing operations. Second, maintenance is inherently a dirtier, less standard kind of operation than manufacturing. In addition, the workload tends to be low in volume and highly variable. Finally, railroads have already installed a great many automated machines that provide productivity and quality equivalent to or even superior to what could be done with robotics.

To address these questions, the AAR sponsored a detailed study of the potential applications of robotics in a particular shop. The study was carried out in close cooperation with Conrail and Committee 16 as part of the AAR's Affiliated Rail Research Program at MIT. The study focussed on the Juniata Backshop in Altoona, Pennsylvania. This was a well-designed, highly automated shop that had been completely renovated in 1981.

The MIT/Conrail study team systematically examined the possibilities for robotics at Juniata. Following several tours through the plant and discussions with robotics vendors, Conrail worked with a vendor to prepare a proposal to install a robot within an existing blast booth for cleaning traction motor armatures. Although the vendors were not particularly impressed with any other possibilities, the study team elected to investigate a total of 26 potential applications. A quick investigation of workloads and technical requirements indicated that only 7 of these were promising applications, i.e. straightforward applications where the manual labor was high or the environment was bad. These 7 plus 7 questionable applications were then examined in detail. Of these, only 6 had a payback of less than 5 years and only 2 had a positive net present value assuming an after-tax discount rate of 6%. A sensitivity analysis identified labor savings (the product of the workload and the labor saved per unit) as the most critical factor. However, even with a 50% increase in labor savings, only 6 of the other applications had a positive net present value. Furthermore, even if all of these applications were installed, the annual savings at Juniata would be under $0.4 million, which is well under 5% of the annual operating budget of the shop. The study also considered the possibility of creating general purpose work stations for welding, cleaning, painting and machining. Three such workstations were found to be attractive, but the annual benefits were still under $250,000 annually. Furthermore, these consolidated work stations would have to be installed as part of a general renovation of the shop, since material flows would be changed significantly.

In short, the study concluded that there was not yet a great need or a great opportunity for robotics in a modern railroad backshop. On the other hand, a railroad that is consolidating or modernizing shops should consider the use of robotics, especially in consolidated work stations for welding, cleaning, and painting. The main problems in justifying robotics were also found to be economic rather than technical.

Surveys of the Rail Industry

Two surveys of the railroads represented on Committee 16 indicated modest experience but substantial interest in robotics. Thirteen railroads responded to either the 1984 or 1987 surveys. Of these, seven had installed a total of twenty robots and developed plans to install two more (Exhibit 1). A number of other potential applications were identified by respondents (Exhibit 2). In many cases, railroads had formulated a study group to evaluate uses of robotics (Exhibit 3).

EXHIBIT 1

ROBOTICS APPLICATIONS REPORTED BY 7 RAILROADS

RAILROAD		APPLICATIONS	DATE INSTALLED	JUSTIFICATION
C	1.	Loading roller bearings onto bearing press (Volkswagenwerks GP132)	1985	Reduced manpower; hazardous operation
E	1.	Materials handling (to load a CNC machine) (Unimate Serial 400 5-B)	1979	Reduced manpower and improved quality
	2.	Welding (ASEA IRB-6)	1983	Improved quality and productivity
	3.	Painting the interior and exterior of cylindrical hopper cars	1985	Reduced manpower; hazardous environment
G	1.	Vision guided welding of wear plates onto truck side frames (Automatix)	1984	N.A.
	2.	Tamping and anchor positioning using an electromagnetic probe (Modified Canron Mark II)	1984	Reduced manpower and improved quality
	3.	Anchor adjuster*	1987*	N.A.
	4.	Tie plate distributor*	1987*	N.A.
H	1.	Welding freight car sub-assemblies (Unimation Apprentice)	1981	Reduced manpower
	2.	Welding locomotive gear cases (Advanced Robotics Cyro-750)	1983	Improved quality by manufacturing previously purchased product
	3.	Materials handling using photo cells and limit switches in material through a 250-ton press and a 150-ton punch) (Cincinnati Milacron Ht3)	1981	Reduced manpower
	4.	Welding various locomotive and freight car components (Comet Welding RT280)	1984	Reduced manpower
	5.	Welding traction motor assemblies (Comet Welding RT280)	1984	Replaced existing machine
I	1.	Welding, using a wiretouch sensor (Hitachi PW-10-11)	1984	Reduced manpower and improved quality
J	1&2	Manipulating locomotive governor and fuel injector parts within a washing cell (2 robots)	1975, 1982	Reduced waste and manpower; better quality; hazardous operation
	3.	Moving diesel pistons between a conveyor and 6 chemical tanks, where they are processed (Manufactured in house)	1975	Reduced waste and manpower; better quality; hazardous operation

EXHIBIT 1 (continued)

	4.	Inspecting and measuring traction motor cases (Brown & Sharpe 3000 Series Validator Horizontal CMS)	1986	Reduced manpower
L	1.	Moving wheels between 2 conveyors and boring mill (Farrel Corp. OEM)	1979	Reduced manpower; hazardous operation
	2.	Moving axles between in-bound rack, axle lathe, storage rack, magnaflux rack, and scrap car (Acco Babcock 8100000 Twin Hoist Tractor)	1987	Reduced manpower; better quality; eliminate forklift
	3.	Loading and unloading trays for 2 CNC car bottom furnaces and quench tank elevator (Modern Industrial Heating Model 11850587 Gantry)	1987	Reduced manpower; better quality; hazardous operation

*Installation planned for late 1987; details not available.

EXHIBIT 2

POTENTIAL APPLICATIONS BEING CONSIDERED BY RAILROADS

OPERATIONS

- PULL PINS AT HUMP
- AUTOMATIC LOADING, UNLOADING, AND STORAGE OF CONTAINERS AND TRAILERS

MAINTENANCE

- AIR BLASTING OF TRACTION MOTORS
- AUTOMATED POWER ASSEMBLY RECLAMATION LINE
- RENEWAL FOR RESIN BRAKE LININGS (ESPECIALLY MAKING HOLES FOR RIVETS)
- RENEWAL OF CORRODED OUTER SURFACES OF ROLLING STOCK
- LOCOMOTIVE PAINTING
- LOCOMOTIVE BACK SHOP APPLICATIONS
- FREIGHT CAR PAINTING AND REBUILDING

EXHIBIT 2 (continued)

CONSTRUCTION

- AUTOMATIC ASSEMBLY OF TRACK PANELS
- FORGING GUARD IRONS
- INSTALLING HOPPER DOORS AND DOOR BEAMS
- INSTALLING COUPLERS
- ASSEMBLING TRUCKS

ENGINEERING

- HANDLING TRACK JEWELRY
- PRODUCTION TAMPING

EXHIBIT 3

ROBOTIC STUDY GROUPS

RAILROAD	PERSONNEL	DEPARTMENT
C	2 (PT) (1984)	Mechanical (1) and R&D (1), reporting to Mechanical Department in 1984.
	1 (PT) (1987)	Mechanical department only in 1987.
E	4 (PT) (1984)	Equipment Department planning
F	2 (PT) (1984)	Manufacturing Engineering (part of group that develops capital projects)
H	2(FT) (1984)	Mechanical (2, and Industrial Engineering (1), reporting to Director of IE-Mechanical and to Director of OR and Planning
I	15 (PT) (1984)	Department of Rolling Stock and Maintenance
G	2 (PT) (1987)	Maintenance of Way & Structures
L	1 (PT) (1987)	Mechanical Department

NOTE:

FT = FULL TIME
PT = PART TIME

None of the North American Railroads, however, had examined robotics as carefully as the Japanese National Railway (JNR).[2] An intensive JNR study was headed by Professor Iguchi of Tokyo University and involved two JNR engineers on a full time basis plus thirty JNR and university people on a part time basis. Initially intended as a 3-year study, it was terminated in 1984 after two years because few immediate applications were discovered. JNR's conclusions are summarized in Exhibit 4. In addition, in the area of equipment construction, Japan does not use robots as widely as in the automobile or home appliance industries because of the low volume of production. It is also interesting that JNR engineers joined Kawasaki heavy industries (a rolling stock manufacturer with close ties to Unimate, a U.S. robotics firm) and successfully developed robotics applications, but not for the railway division.

EXHIBIT 4

CONCLUSIONS OF THE JNR STUDY OF ROBOTICS

1. ROBOTIZATION OF MAINTENANCE OPERATIONS IS PERHAPS 10 YEARS IN THE FUTURE WHEN MORE STANDARDIZATION OCCURS AND EXCESS EMPLOYEES ARE REDUCED THROUGH ATTRITION.
2. PRESENT ROBOTS CANNOT ACCOMMODATE THE CURRENTLY HIGHLY VARIABLE MAINTENANCE CIRCUMSTANCES, CANNOT BE JUSTIFIED ECONOMICALLY, AND CANNOT HANDLE HEAVY PARTS.
3. ROBOT COST, FLEXIBILITY AND EASE OF USE MUST BE IMPROVED FOR RAILWAY MAINTENANCE.
4. SINCE PRODUCTION LEVELS IN THE CAR MANUFACTURING SECTOR ARE CURRENTLY VERY LOW, ROBOT DEVELOPERS ARE PURSUING OTHER APPLICATIONS.
5. NEW VEHICLE DESIGNS SHOULD EMPHASIZE STANDARDIZATION COMPATIBLE WITH ROBOTIC MAINTENANCE; JNR SHOULD ADOPT A STRATEGY FOR DESIGNS AND ROBOT DEVELOPMENT TO COME TOGETHER IN 10 YEARS.
6. AT PRESENT, THERE ARE NO SOPHISTICATED ROBOTS IN JNR, BUT MANY AUTOMATIC SEQUENCE MACHINES ARE IN USE.
7. THE PRINCIPAL ROBOT APPLICATION THAT WAS DISCOVERED AND RECOMMENDED BY THE STUDY TEAM WAS THE CLEANING OF TRACTION MOTORS.


Translating
technology
into solutions
Amtrak

The remaining exhibits provide some technical details on the North American applications. For each application, the exhibits give technical specifications, operating conditions, financial return, and qualitative assessments.

Overall, the railroads were very satisfied with nearly all of the applications. The only exception was E-3, where it was necessary to dismount the robot from its wall-mounted frame in order to do any maintenance. Furthermore, the robot did not quite reach all interior points and it could not be used for exteriors. Nevertheless, this robot is still being used to paint 95% of the interior of cylindrical hopper cars. In two other cases, the robots are no longer used because their shop was closed as part of a consolidation program.

The following conclusions can be drawn from the results of the surveys:

1. As of mid-1987, few robots were in use or about to be installed in the rail industry, either in North America or in Japan.
2. The most common applications were:
   a. Welding, with robots made by 6 manufacturers in use on 4 railroads
   b. Materials handling, with robots made by 6 manufacturers in use on 5 railroads.
3. Applications and studies both emphasized the use of robots in maintenance, rebuilding, and construction of equipment.
4. Railroads were, in almost all cases, satisfied with their robots' performance. The greatest problems related to maintenance (high downtime or a lack of trained personnel for repairs) or to the complexity of programming the robots. Maintenance was a special concern because all of the robots were serviced in house either from the start or, in some cases, after a 1-year warranty period.
5. Robots were generally installed to reduce manpower or to improve quality, although in one case the robot replaced an existing machine and in another the robot allowed a railroad to manufacture rather than purchase a particular product.
6. All of the US applications cited an ROI of at least 13% or a payback period of less then five years.
7. Most of the recent applications were integrated with other automatic equipment.
8. In general, railroads are slowly adopting robotics, almost entirely in conjunction with on-going efforts to automate maintenance activities.

Exhibit 5

Details Concerning Materials Handling Applications

	C-1	E-1	H-3	J-1,2
1. Technical Specifications				
a. Degrees of freedom:	6	6	6	5
b. Positioning Accuracy (+/-inches)	03	.08	.050	1/16
c. Repeatability (+/-inches):	.03	.08	.050	N.A.
d. Reliability (% uptime):	90%	85%	93%	99%
e. Mean Time Between Failures:	600 hours	40 hours	45 days	N.A.
f. Payload Capacity:	132 lb.s	350 lbs.	250 lbs.	500 lbs.
g. Type of Controls:	Point-to-Point Servo	Point-to-Point Servo	Point-to-Point Servo	Non-Servo
h. Programming:	Leadthrough	CRT	Walkthrough, Teach Pendant	CRT
i. Power Systems Used to Control Robots (electric or pneumatic):	E,P	E	E	E,P
j. Sensory Devices:	-	-	Photo Cells & Limit Switches	Limit Switches
2. Hours/Day in Operation	24 hours	16 hours	8 hours	8 hours
3. Expected ROI and/or Payback Period	18 months	46%	27%, 3.4 years	30%
4. Advantages/Disadvantages	- Some downtime is to be expected - No vacations, sick days, accidents, or raises	- Material needs to be close tolerance - Lack of trained repairman	- High load capacity - Good maintenance - Programming simplicity - Good software	

Exhibit 6

Details Concerning Materials Handling Applications

	J-3	L-1	L-2	L-3
1. Technical Specifications				
a. Degrees of freedom:	4	2	1 direction, single speed	2 directions, single speed
b. Positioning Accuracy (+/-inches):	1/8	1	1.5.	.09
c. Repeatability (+/-inches):	N.A.	1	1/8	.09
d. Reliability (% uptime):	99%	99%	N.A.	N.A.
e. Mean Time Between Failures:	N.A.	N.A.	N.A.	N.A.
f. Payload Capacity:	250 lbs.	1000 lbs.	1300 lbs.	25,000
g. Type of Controls:	Non-Servo	Non Servo	Non-Servo	Continuous Path Servo
h. Programming:	CRT	CRT	Manual, CRT	Manual, CRT
i. Power Systems Used to Control Robots (electric, hydraulic or pneumatic):	E,P	E,H	E	E,H
j. Sensory Devices:	Limit switch	Photo eye tolerate wheel plus pressure switches to locate down position	No	Encoder (rotary rack & pinion)
2. Hours/Day in Operation	8 hours	16 hours	16 hours	16 hours
3. Expected ROI and/or Payback Period	30%	N.A.	14%	15%
4. Advantages/Disadvantages		- No downtime except for preventive maintenance	N.A.	N.A.

Exhibit 7

Details Concerning Welding Applications

	E-2	H-1	H-2	H-4
1. Technical Specifications				
a. Degrees of freedom:	5	5	5	5 axles on 2 axis positioning table
b. Positioning Accuracy (+/-inches):	+.002"	.06	.008	.004
c. Repeatability (+/-inches):	+.002"	.06	.008	.004
d. Reliability (% uptime):	95%	85%	95%	UNK
e. Mean Time Between Failures:	40 hours	45 days	UNK	UNK
f. Payload Capacity:	6 kgm.	N.A	50 lbs.	25 lbs.
g. Type of Controls:	Closed Loop	Continuous Path	Continuous Path	Continuous Path
h. Programming:	DC Servo	Servo	W or CRT	Walkthrough, Teach Pendant
i. Power Systems Used to Control Robots (electric or pneumatic):	E	E	E	E
j. Sensory Devices:				
2. Hours/Day in Operation	8 hours	8	2 shifts, 8 hours each	16 hours
3. Expected ROI and/or Payback Period	82%	3 years	29%, 4.4 years	35%, 3.3 years
4. Advantages/Disadvantages	- Material has to be of close tolerance - Lack of trained repairman	- High downtime - Poorly designed wrist assembly - Teaching is simple - Low cost - Can't store multiple routines	- Very reliable & precise - Complicated to program - Complicated diagnostics	UNK

Exhibit 8

Details Concerning Welding (H-5, I1) and Other Applications (G-2, J-4)

	H-5	I-1	G-2	J-4
1. Technical Specifications				
a. Degrees of freedom:	5 axles on 2 axis positioning table	5	N.A.	5
b. Positioning Accuracy (+/-inches):	.002	.078	.02	.001
c. Repeatability (+/-inches):	.004	.078	N.A.	N.A.
d. Reliability (% uptime):	UNK	UNK	95%	90%
e. Mean Time Between Failures:	UNK	UNK	N.A.	N.A.
f. Payload Capacity:	25 lbs.	2 kgm.	N.A.	None (just a probe system)
g. Type of Controls:	Continuous Path Servo	Point-to-Point or Continuous Path Servo	Non-Servo	Continuous Path
h. Programming:	Walkthrough, Teach Pendant	Walkthrough	CRT	Leadthrough, CRT
i. Power Systems Used to Control Robots (electric, hydraulic or pneumatic):	E	E	E,H,P	E
j. Sensory Devices:		Wiretouch Sensor	Electromagnetic	Probe
2. Hours/Day in Operation	16 hours	8 hours	10 hours	8 hours
3. Expected ROI and/or Payback Period	25%, 4.5 years	5+ years	N.A.	Justified by total remanufacturing system for traction motors
4. Advantages/Disadvantages	UNK	- Reduced cost Lack of trained repairman	- Roadbed inconsistencies occasionally confuse the sensor - Hard to find components that withstand environment (especially vibration)	- Reduced manpower

The Potential for Robotics in the Rail Industry

Taken together, the Juniata study, the surveys, and the Committee's discussions point to a common conclusion. There is indeed a role for robotics in the rail industry, but it is not a major role. There are only limited opportunities for applying robotics in railroad shops, and that is the area where robotics are most suitable for use. Unlike manufacturing facilities, railroad shops have relatively low volumes of very large parts that in many cases can already be processed through a variety of special-purpose machines. Until inexpensive, mobile, multi-purpose robots become readily available, it will be difficult for railroads to consolidate enough work to keep robots busy. More fundamentally, robotics are most likely to affect maintenance, which is not the main product offered by railroads. Unless there is a direct and substantial effect on the cost of rail operations or the quality of rail service, robotics or any other technology will have a minor impact on overall railroad performance.

Perhaps the greatest opportunities for robotics will arise when a railroad is consolidating or modernizing its shops. At such a time, it should be possible to use off-the-shelf technology to create a robotic welding, cleaning, machining, or painting center. It may also make sense to use robots to move material to and from automated machines or testing stations. In most cases it will not make sense to try to develop a highly specialized robot, simply because the development costs are likely to exceed $1 million and offset potential benefits. Also, it is necessary to remember that other kinds of automation may be as good or better than robotics, especially if maintenance is thereby simplified.

Robotics technology is of course developing rapidly. In the visits to the university labs, Committee 16 was able to see examples of what may lie ahead. Research is being devoted to many topics, including sensory perception, highly accurate positioning, and controllability. Vision and other sensory capabilities are very important because of the possibility of automating inspection activities. Robotic capabilities are also being integrated into larger machines that could more easily deal with massive railroad components. Intermodal terminal operations could conceivably be vastly improved by such technology. Hence, the rail industry should continue to stay abreast of technological developments that may open up many new applications in the future.

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1 Carl D. Martland, "Analysis of the Potential Impacts of Automation and Robotics on Locomotive Rebuilding," IEEE Transactions on Engineering Management, May 1987, pp. 92-100.

2 JNR, "Report on Study of Automation of Rolling Stock Inspection and Repair Service," JNR Technical Topic M-0121, March 1984, Japan Railway Engineering Association.

COMMITTEE 22 — ECONOMICS OF RAILWAY CONSTRUCTION AND MAINTENANCE

Chairman: W. C. Thompson

Report of Subcommittee 4

Subcommitte Chairman: J. M. Johnson

Economics of Ballast Cleaning

Ballast cleaning has recently become a more common method of track structure or ballast maintenance. Generally, ballast cleaning means the use of large ballast undercutter-cleaners (BUC). These machines remove the entire ballast section from the track and process the ballast through a series of vibrating screens. The cleaned ballast is returned to the track and the waste is discarded. The use of the machines is a result of improvements in technology, recognition of importance of drainage, and a need to improve rail, tie and surfacing cycles.

This sub-committee circulated a questionnaire to members of Committee 22 and to the Chief of Engineers of some other railroads. Eleven responses were received, representing most of the large railroads in the United States and Canada and a good cross-section of the smaller ones. The survey indicates that ballast cleaner costs are generally better than those of undertrack plows. This may be in some degrees an indicator of improvements in the railroad engineer's ability to accurately track the costs associated with ballast cleaning. Although not clearly indicated, the use of ballast cleaners also implies an overall improvement in track conditions, since it is common practice to use undercutters on "good tie track" as opposed to rehabilitation work.

This report covers the factors involved in the decision to use a ballast cleaner, some of the benefits of ballast cleaning, some costs of ballast cleaning and presents a hypothetical economic case for a ballast cleaning project. The questionnaire results are the primary source for this information. Some other research was also done and included in the report.

Factors Involved in the Ballast Cleaning Decision:

It must be recognized that the decision to use an undercutter-cleaner is a complex and expensive proposition. The cost of leasing or owning such a machine can run into several thousands of dollars per day. Therefore, careful analysis and consideration must be given to the program size and cost and to the resources available for such a program. Several large railroads have determined it is more economical to own rather than to lease the equipment. This is largely a result of the size of the program the railroad has annually. A second primary consideration is the condition and type of ballast that is being considered for cleaning or renewal. If the ballast in the track is of poor quality or is extremely fouled, it is not worthwhile to clean it. Assuming the ballast is worth reclaiming, subgrade conditions occasionally prevent the use of ballast cleaners by maintaining a high moisture content in the ballast section. It should be noted, however, that ballast cleaners often present an opportunity to improve subgrade conditions by introducing a geotextile or sand filter between subgrade and the ballast section. Also, some railroads feel that an undercutter is an economical method even when 100% of the ballast is wasted.

Ballast transportation costs are a critical issue of ballast cleaning. For many years railroad engineers refused to recognize the cost associated with transporting the ballast from the pit to the site where it is used. The recent changes in railroad accounting methods and overall cost pressures have caused more consideration of this factor. Because ballast cleaners reduce the amount of ballast required (as opposed to plowing or sledding), there is a considerable savings in transportation and other overhead costs, especially when a reasonable amount of the ballast is reclaimed.

As mentioned earlier, most railroads require a good tie condition before an undercutter cleaner is used. There are varying methods, ranging from tie renewal immediately in front of the undercutter to renewal in the prior year. Others opt for spot tie renewal immediately ahead of the undercutter. In any case, poor tie condition will have a very detrimental effect on undercutter production. This is because

the ties are suspended from the rail in the undercutting process and because the track is ordinarily dumped full of ballast behind the undercutter for the surfacing raise.

Within a given track segment, track profile and adjacent structure limitations must also be considered. Ballast cleaners allow the track profile to remain essentially the same since the ballast beneath the tie is cleaned as opposed to replacement. If there are problems with overhead clearances, embankment width, station platforms, etc., undercutter cleaners have a definite advantage. However, with the presence of any structure or limitation preventing the undercutter from moving forward normally, expensive delays can occur. These include road crossings, turnouts, bridges, platforms, etc. Each one of these restrictions must be considered separately to determine whether it is possible to cut through them or if it is necessary to go around them. One must also consider the need to renew or clean the ballast through these structures as well with some other method if necessary. These problems, and available track time will determine the rate at which the undercutter can progress and will consequently affect the overall cost substantially.

Benefits of Ballast Cleaning:

The railroad industry has been slow to recognize the economic or life cycle value of various projects or programs, especially in terms of ballast and subgrade. It is clear that ballast cleaners represent an economic, effective way to increase the ballast life cycle and consequently increase the life cycle of ties and rail as well. Ballast cleaners have some economic benefits that are not frequently considered. Undercutter start-ups are generally easier than plows and sleds, and smaller gangs are required. Raises for road crossings are minimized, and it is possible to cut through some turnouts. Ballast transportation savings were previously mentioned. A long-term undercutting program would also reduce the requirements for capital investment in ballast pits, ballast cars and the associated physical plant. This consequently reduces the number of people required to operate the pits, transport the ballast and distribute the ballast. This is in addition to any net savings from ballast cleaning as opposed to undertrack plow operations, which one Chief Engineer placed at approximately $13,000 per mile. Finally, as previously mentioned, undercutter cleaners provide a good method for installation of geosynthetics or even sand filters to improve subgrade conditions and extend ballast and surfacing cycles. On the negative side, the cost of the machine, high maintenance and consequent delays must also be considered.

Cost of Ballast Cleaning

The typical ballast cleaner cost and some basic assumptions are used to produce the attached example. (Table 1.) Basic labor rates, equipment costs and production rates are assumed as indicated. The engineer can vary these factors to accommodate his particular situation. The case study (Table 2) examines the proposed hypothetical forty mile undercutter segment where tie renewals are accomplished by gangs working immediately ahead of the undercutter and track time is available for a full seven hour productive window.

The question of whether to lease or own such a large piece of equipment is dependent primarily on the goals of the railway company involved and the size of the annual undercutting program. Our survey indicates that those railroads with programs in excess of 100 to 150 miles of undercutting (6-8 months working time) usually consider purchase. As mentioned earlier, there are significant cost savings associated with larger, consistent undercutting programs in terms of reduced ballast production, trnasportation, and distribution costs over the long term period.

Table 1.

This comparison indicates the influence ballast recovery and ballast transportation have on total cost per mile. Those factors which are common are not included and these costs are in addition to tie renewal.

Gang Type	Tie & Undercut	Cost ($)	Plow	Cost ($)
Daily Costs				
Lease w/Operator		4500		1200
Support Gang Consist				
Foreman	1		1	
Operator	2		0	
Laborer	4		6	
Total	7		7	
Support Gang Cost				
Men @ $150 each		1050		1050
Equipment		100		0
Supplies, Truck		250		250
Work Train		0		1200
Total Daily Costs		5900		3700
Average Ft/Day	4200		5200	
'Daily' Costs/Mile		7417		3757
Total Ballast Volume				
Cubic Yards/Mile	3381		3381	
Ballast Recovery (%)	50.0%		0.0%	
Ballast Cost				
Delivered/Cu Yd	15.00		15.00	
Ballast Cost/Mile		25358		50715
Total Cost Per Mile		32775		54472

Table 2.

Case Study—Hypothetical Track Segment—Undercutter and Plow Comparison

Track Segment Length	40 Miles
Total Turnout Count	20
Average Turnout Length	200
Total Road Crossing	25
Bridges to Skip	4
Average Bridge Length	100

This study attempts to illustrate some of the factors involved in ballast renewal work. The engineer must consider each segment and its costs carefully to determine the actual costs involved.

Gang Type	BUC	BUC	BUC	BUC	Plow
Production—Ft/Hr	1050	1050	1050	1050	1200
Productive Hrs/Day	4	4	4	4	5
Delay (Hrs)/Skip	0.8	0.8	0.8	0.8	1.0
Delay to U/C Turnout	1.0	1.0	1.0	1.0	N/A
Cu Yds Ballast/Mile (8 in. clean ballast)	3381	3381	3381	3381	3381
Ballast Recovery Rate	70.0%	50.0%	30.0%	0.0%	0.0%
Ballast/CY Delivered—$	15.00	15.00	15.00	15.00	15.00
Small Undercutter/Ft—$	10.00	10.00	10.00	10.00	10.00
Additional Runoff @Skip	100	100	100	100	200
Crossing Approaches—$	0	0	0	0	200
Daily Cost for Gang—$	5900	5900	5900	5900	3700
Total Feet to Work	211200	211200	211200	211200	211200
Less Skips					
Bridges	800	800	800	800	1200
Turnouts	6000	6000	6000	6000	8000
Net Footage	204400	204400	204400	204400	202000
Total Ballast Required	40572	67620	94668	135240	135240
Total Ballast Cost—$	608580	1014300	1420020	2028600	2028600
Hours Required	195	195	195	195	168
Plus Bridge Delay	3	3	3	3	4
Plus Turnout Delay	20	20	20	20	0
Total Hours Required	218	218	218	218	172
Total Days Required	54	54	54	54	38
Total Gang Cost—$	321353	321353	321353	321353	141696
Small Undercutter Cost—$ (Skip Footage Less Total Bridge Length @ $10/Ft)	64000	64000	64000	64000	88000
Road Crossing Approach Additional Asphalt—$	0	0	0	0	5000
Comparative Cost—$	993933	1399653	1805373	2413953	2263296
Comparative Cost/Mile—$	24848	34991	45134	60349	56582

Conclusion

As the railroad industry has shifted more toward the maintenance of fewer, higher capacity lines, the use of ballast cleaners has become more attractive. This is due in part to technological improvements in ballast cleaners which allow much higher production than in the past. Better over-all tie conditions and the use of higher quality ballast have also encouraged their use. Changes in railroad accounting have also made it desirable to more carefully examine all the costs associated with track maintenance projects. This has led to examination of the savings associated with ballast reclamation and to some efforts to determine a life cycle or present value of the ballast reclamation work.

These undercutters are large, expensive machines as indicated in this study. The factors involved in their use must be carefully examined and evaluated. Further effort should also be directed toward attempting to more accurately quantify the service life of this and other maintenance work. For instance, this should consider not only the cost of the work and its future savings, but also consideration of the cost of maintaining the status quo. This would include reduced life cycles, increased slow orders, and additional spot maintenance expenses.

COMMITTEE 24—ENGINEERING EDUCATION

Chairman: C. E. Ekberg, Jr.

Report of Subcommittee No. 1—Recruiting

Subcommittee Chairman: J. W. Orrison

A survey of MW&S Chief Engineers concerning college graduates hired in 1986 has been completed. Replies were received from 18 of the 20 railroads of which information was requested. Forty-four graduates were employed during 1986, compared to 50 during 1985.

Table 1 summarizes the type of degree and major courses of study for 44 newly employed graduates. Table 2 shows a summary of schools represented by the graduates employed.

Seven of 18 responding railroads employed at least one graduate in 1986. Twenty-two graduates were employed by one railroad, 11 graduates by a second and less than 5 graduates each by the other hiring roads. The average number employed by hiring railroads was six.

One of the graduates hired was previously a co-op student and three had prior experience. Most railroads hiring graduates paid identical salaries to students with prior experience, as compared to students with no experience. Employment of electrical engineering graduates increased from one in 1985 to 12 in 1986, while hiring of civil engineers dropped from 45 in 1985 to 23 in 1986.

The average monthly salary of the 44 graduates employed is provided in Table 3. Salaries reported by U.S. Railroads included a high of $2,450 per month and a low of $2,041 per month. Of the railroads hiring graduates, one paid all graduates the same salary regardless of experience.

Co-op student programs were provided by three railroads with the companies sponsoring 37 students in 1986. The sponsoring railroads paid salaries ranging from $1,158 per month (new co-op students) to $1,800 per month (for two quarters of experience). Table 4 lists schools of railway-sponsored co-op students. All railroads sponsoring more than one co-op student selected from two or more universities.

Table 1.

Degrees and Major Courses of Study of College Graduates Employed by Railroads

Degree	Number of Graduates				1986 Distribution	
	1983	1984	1985	1986	US	CA
B.S.	30	84	45	43	40	3
M.S.	1	5	4	0	—	—
B.A.	—	1	1	1	1	—
Total	31	90	50	44	41	3

Major Course of Study

	Number of Graduates				1986 Distribution	
	1983	1984	1985	1986	US	CA
Civil Eng.	22	57	45	23	22	1
Electrical Eng.	3	15	1	12	10	2
Business	—	4	1	1	1	—
Eng. Tech.	1	3	1	3	3	—
Construction Eng.	2	3	1	1	1	—
Transportation	—	1	1	1	1	—
Other	3	7	—	3	3	—
Total	31	90	50	44	41	3

Table 2.

Schools of College Graduates Employed by Railroads During 1986

Penn State	4
Georgia Tech	3
Michigan State	3
Temple	3
University of Illinois	2
University of Missouri Rolla	2
Rochester Inst. Tech.	2

All schools listed below were represented by one graduate hired in 1986.

Bluefield State
Bucknell
University of Cincinnati
Clemson
Cleveland State
University of Kentucky
Lafayette College
Lehigh
McGill University
University Manitoba
Michigan Tech. University
N.J. Inst. Tech.
Old Dominion
University Pittsburgh
Purdue University
Roanoke
Rensselaer Polytechnical
Rutger College
Southern Illinois University
Southern University
Syracuse University
University Texas
University of Toronto
Villanova
Western Michigan

Table 3.

Average Monthly Salaries

Categories	America—US $		Canada—CA $	
	1985	**1986**	**1985**	**1986**
Overall Average	2161	2223	2214	2447
Masters	2700	—	2174	—
Bachelor	2122	2223	2223	2447
w/Prior Experience	2135	2297	2316	2196
w/Co-op Experience	2126	2175	—	—
w/No Experience	2061	2220	2083	2573
Civil Engineering	2104	2137	2278	3153
Electrical Engineering	—	2380	—	2094

Table 4.

Schools of Co-op Students Sponsored by Railroads During 1986

School	Number of Co-ops
University of Waterloo	9
Georgia Tech	5
University of British Columbia	3
University of Tennessee	3
Alberta	2
University of Missouri-Rolla	2
North Dakota State	2
U.T.-Chattanooga	2
Alabama	1
College de l'Abitibi-Temiscamingue	1
Illinois Inst. of Technology	1
Iowa	1
University of Nebraska-Lincoln	1
St. Lawrence College	1
Sherbrook	1
Southern Tech	1
Western University	1

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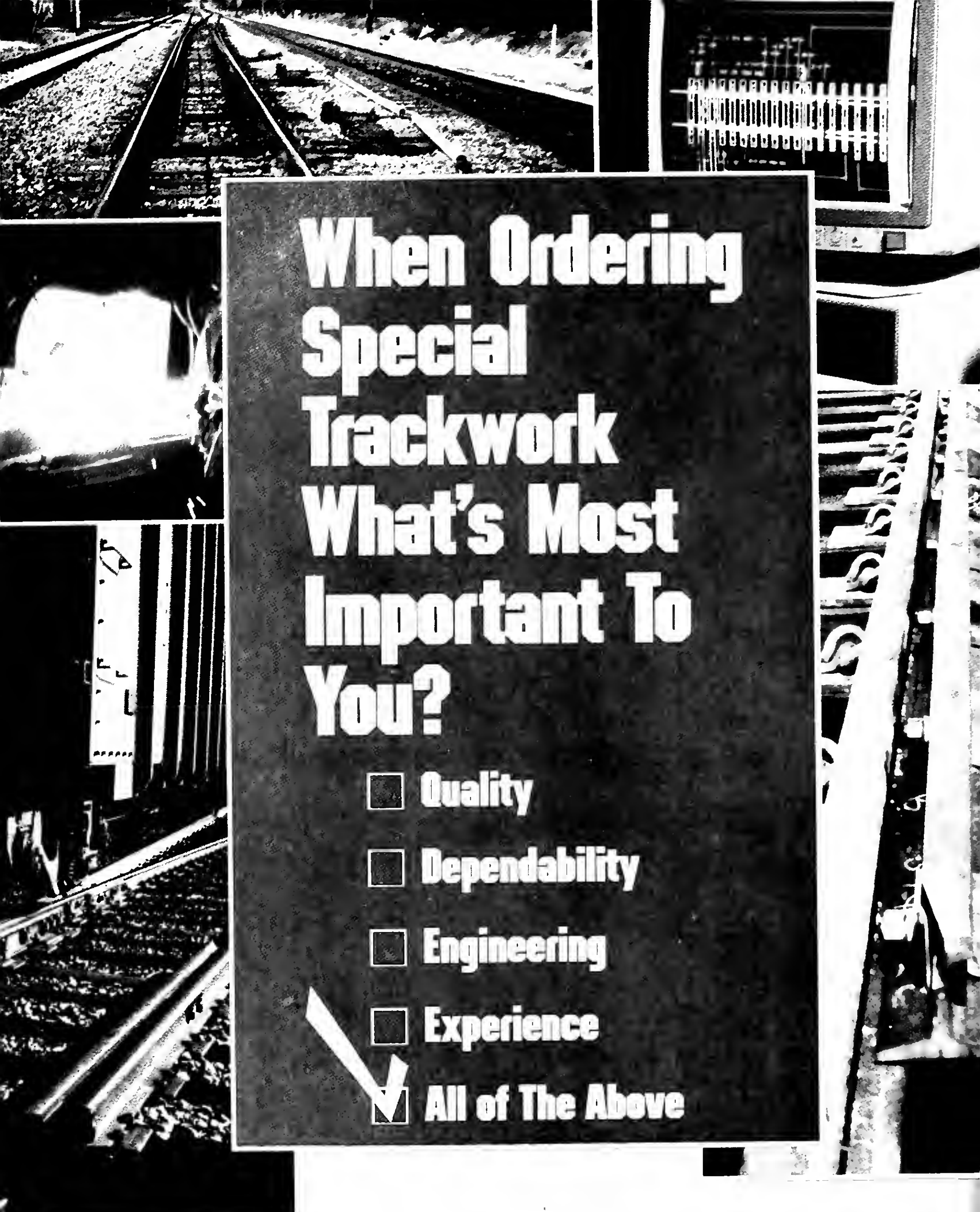
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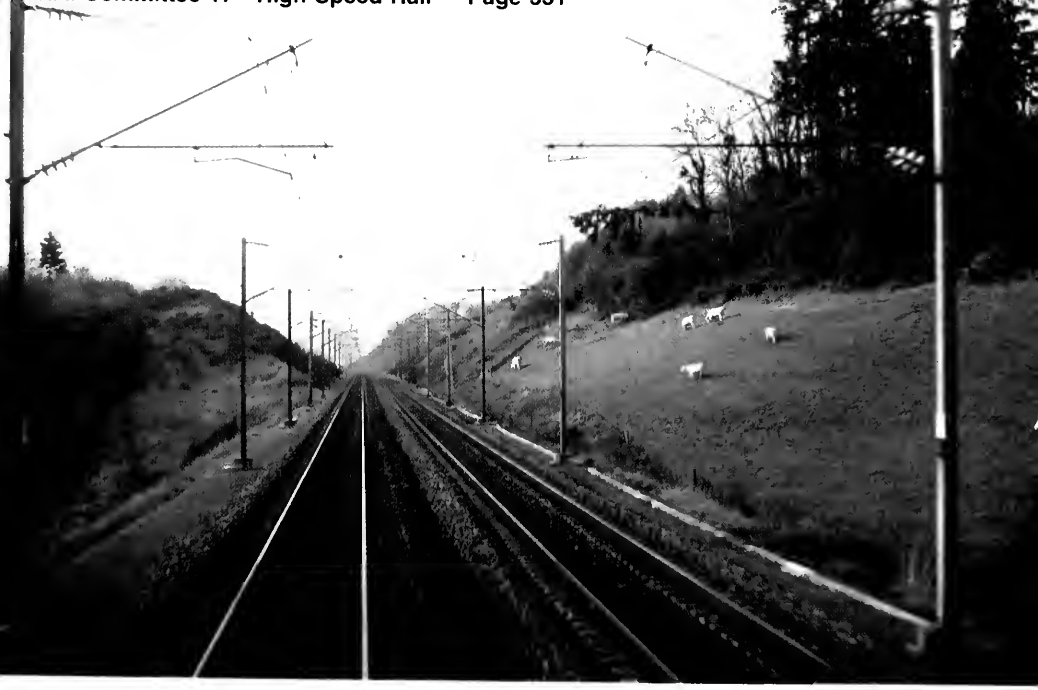
.R.E.A. Committee 17—High Speed Rail — Page 331



CONTENTS (Details Inside)

OCTOBER 1988

Thoughts at 160 mph

Sitting in the cab of a locomotive going over 160 mph on the line between Paris and Lyon in France, a dominating thought is the lack of any perception that the track or the rolling stock is near its limits. Note-taking is easy and the writing is as legible as if it were written at an office desk. Only the sight of the catenary supports speeding by gives away our high velocity. Cattle less than 100 feet from the train appear oblivious to our passing. Here it is a common everyday occurrence—nothing extraordinary.

From the locomotive, one sees a quite conventional railway structure of ballast, ties, and rail. The only basic difference from typical North American track is the bi-block concrete ties with elastic fastenings.

The ride is not thrilling, for thrilling implies an element of danger and there is no perception of that. There is, however, an intense emotion—a deep feeling of professional satisfaction of knowing how much speed potential there is in the rail mode. That this perception is correct is shown by test runs of the TGV equipment used on this line up to 236 mph. Testing over 200 mph is carried out while regular operations proceed on the other track of this double track line. In Germany, tests of their ICE train reached speeds of 252 mph earlier this year.

In terms of normal operating speeds the French TGV is now running at 168 mph and the new TGV Atlantic line is scheduled to run at 186 mph (300 kph). In a letter to the AREA from TGV Vice President Nicholas Brand, a definite yes was given to the question of whether the TGV is ready for projects where specifications are for normal running speeds above 200 mph.

While the U.S. still holds the world steel-wheel steel-rail record of 255.7 mph, set at the Pueblo Test Center August 14, 1974, this was with a single-unit experimental vehicle which was not suitable for passenger-carrying operations. Also, both the French and the German trains that set the records delivered power through the wheel to the rail in a conventional fashion whereas the U.S. vehicle was powered by a linear induction motor assisted by a jet engine. Thus this U.S. record is not comparable to the French and German records set by passenger-carrying trains of multiple cars.

The question of high speed trains then is not one of wondering whether the technology is ready. The technology exists, and has been proven in operation for some time and is subject to even further

The sentence below was written in the cab of a TGV locomotive going 160 m.p.h.

This was written at 160 m.p.h.

improvement and higher speeds yet. Alternate advanced modes such as mag-lev remained to be proved in service and present an array of environmental problems and safety considerations if they are to be anywhere near as safe as train travel, and because they are incompatible with conventional rail, they would need new rights-of-way into city centers if they are to be competitive with the convenience of rail or auto transport.

Whether we have truly high speed railways (over 150 mph) in the United States is a matter of economics and governmental decisions regarding new expenditures in airports and highways versus expenditures for railways. It is thus very appropriate that an AREA committee on high speed rail be formed in order to prepare for the high speed railway development which could be the main transportation thrust of the 21st century.

Formation of AREA Committee 17—High Speed Rail

At its meeting June 9th in Chicago, the Board of Direction of the AREA voted to form a new Technical Committee to deal with High Speed Rail matters. This committee has been given the number 17.

This committee will be responsible for the development and publication of information and recommended practices regarding wheel-rail systems capable of operating in the 150-250 mph speed range, and also reporting on developments which would permit operation of such systems above 250 mph.

R. D. Johnson, Assistant Chief Engineer of Amtrak, was named Chairman of the new Committee. He indicates that the committee may also wish to consider questions involved with the transition between the present Federal Railroad Administration maximum of 110 mph and speeds above 150 mph.

The first meeting of the new committee will take place in Washington, D.C. November 3, 1988. Participation of all interested parties is encouraged. For details call or write to AREA Headquarters, Room 7702, 50 "F" St., N.W., Washington, D.C. 20001, (202) 639-2190.

R. D. Johnson
Assistant Chief Engineer—Amtrak
Chairman of A.R.E.A. Committee 17

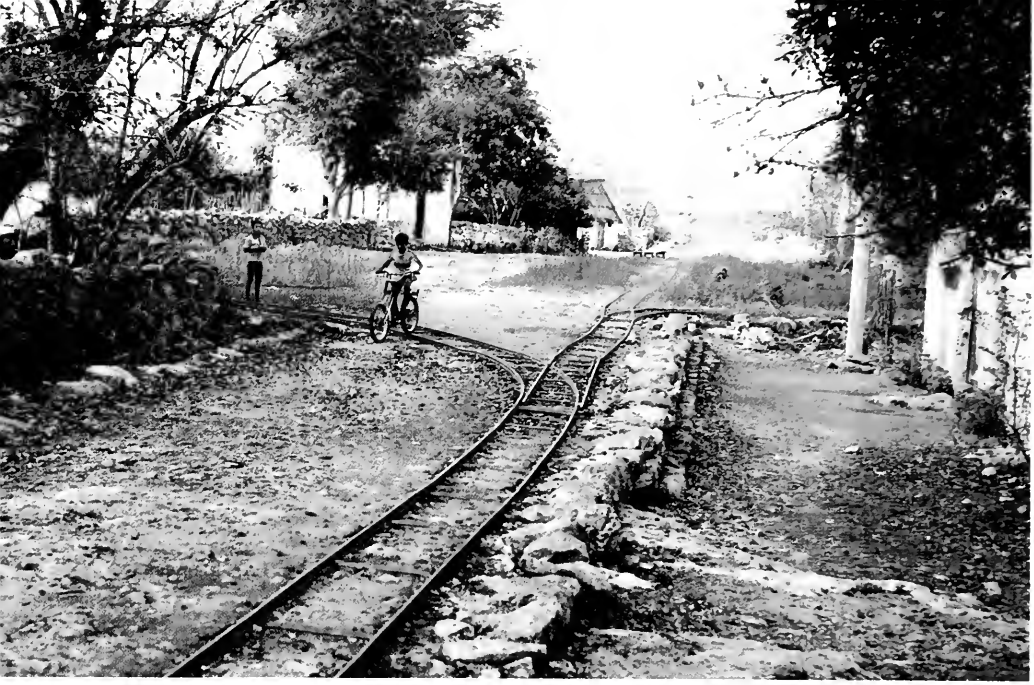


Photo 1—1 ft. 8 in. gauge tracks substitute for streets in village south of Cuzama, Yucatan, January 1988 (note stub switch).

Local Public-Use 1 ft. 8 in. (50 cm) Gauge Railways in the Yucatan Peninsula

While we as professional railway engineers devote our skills and talents to the challenges and conditions of today, along with planning for the next several years, it is still interesting to note a potential possibility which could be viable should a widely different set of circumstances ever exist than at the present. In such a speculative category is the concept of railways as a total means of land transportation including providing the most local of services, akin to those now provided by local delivery trucks and automobiles.

While such very local railways are not a meaningful alternative in today's conditions (which include easy access to petroleum and material for pneumatic tires), it is potentially useful to remember that such possibilities do exist. Such concepts were promoted by Heywood and later Howey in England and by Sandley in the United States using steam-powered 1′3″ gauge railways. Such railways, first developed in 1875, still exist in England in lines up to 14 miles long, and can carry over 200 passengers at 20 mph with a two-person crew, but their continued existence depends on their status as a tourist or hobbyist attraction.

However, actual examples of fundamentally local rail usage do exist in the world today, without any trace of tourist or hobbyist support, in isolated pockets in the Yucatan Peninsula of Mexico. These 50 centimeter (1 ft. 8 in.) gauge lines have their origins in a formerly extremely dense network that comprised a 2,500 mile group of lines that served the Sisal Plantations in an area generally east of Merida, Yucatan. (It should be made clear that these lines are in no way associated with the National Railways of Mexico.) These animal-powered lines went right into the fields for harvesting and go down the streets of towns as substitutes for pavement and carts (photo 1). Between towns the lines are quite substantially constructed with rock cuts through the many small rocky ridges that go across many areas of the Yucatan (photo 2). The fill areas are traversed by fills constrained by well-constructed rock retaining walls (photo 2A). These retaining walls minimized the amount of fill material needed, which was mostly taken from the steeply-sided rock cuts, which appear to be stable at almost vertical angles.

Photo 2—Family on horse car heads through rock cut between Homun and Cuzama, Yucatan—photo at right below shows fill between rock retaining walls at Tixkokob, Yucatan.

The track on these lines is very light, with rail of about 20 lb. per yard and on steel ties which form panels. Many of these lines are now used as a road and street network by the local population. The general method of operation of these now-public railways is that a family with a home along the track (which takes the place of the street) would own one or more small two-axle flat cars. Instead of there being turnouts, the cars are simply derailed at the house and stored in the front yard or at the front gate (photo 3). This is also the usual mechanism for making meets on the single track lines, although there were some turnouts at junctions.

Here is railroading in a concept more than 200 years old, where wheels and rails are used to improve the amount that an animal (or other form of power) can move in addition to improving the smoothness and reliability of the operations. These fundamentals of course are still applicable in railroading today.

Photo 2A

While it is certainly amazing in 1988 to see such small gauge railways being used in a day-in day-out basis, there is a certain feeling of kinship, however remote, with these people that use this means of transportation which is our professional livelihood. But this is accompanied by a special anguish in viewing these operations, since the people using them are mostly poor and appear to have very little power in terms of forming a constituency to maintain these lines.

It appeared that, in most cases, whenever there was a street improvement project in town, the tracks were simply removed, forcing the users of these tracks coming in from small villages away from the larger town to walk in from the town's edge to the market and the town center. Along one line, between the towns of Ancaneh and Canicap, a highway project had crossed one of these small railways at an elevation one or two feet above the railway line. The tracks were cruelly removed and no provision

Photo 3—Rail carts parked in front of homes on street in Tekanto, Yucatan.

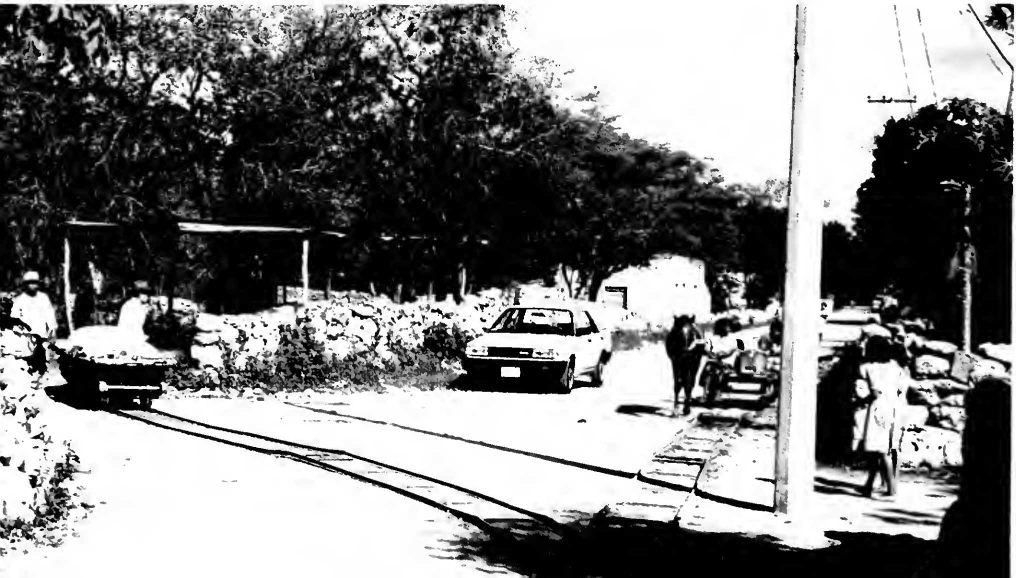
made for the crossing, forcing the owners of these small flat cars, which were their only means of transportation, to struggle to pull the cars onto the highway embankment after reaching the removed section of track and then lower them down the other side of the highway embankment to re-rail them on track on the other side of the highway.

These tiny, ill-maintained railways fit hauntingly into this area of the Yucatan, which has a long sequence of ruins from Mayan cities to Spanish colonial structures to the Sisal industry of the 19th and early 20th centuries—a land still seemingly in the grasp of many earlier departed eras.

In many cases, finding the destinations of these lines defied exploration. Starting at a point near the edge of the larger town of Tekanto, a line headed to the northwest, crossing a main highway (in this case with a crossing provided) then paralleling a dirt road. The line was cautiously followed by automobile along the dirt road as a single horse-drawn flat car with two riders clipped smartly along at perhaps 12 or 15 mph. At a point the road and the railway diverged, and the horse-drawn car and its passengers headed across a field until it disappeared into the far distance towards wherever its destination was, probably some village without other forms of transportation. The feeling was of watching them depart not to another place, but to another time in the past. *(Continued on page 339)*

Photo 4—Spur to horse car repair facility at Cuzama, Yucatan. Switch points are moved separately by foot. (below)

Photo 5 (facing page)—Horse cars on inter-village line between Homun and Cuzama, Yucatan.



At another larger town, Cuzama, a 50 cm gauge line headed out of town to the east through the countryside to a town called Homun where the track ended on the western edge of town. Here the little two axle cars were used despite the paralleling of a paved highway the entire distance between the two towns. At Cuzama, the line from Homun did go to nearly the center of the city and make a quick turn down a local street. About a block down this local street, there was a turnout leading to a crude shelter where two men were repairing the little cars (see photo 4).

The track headed south from the center of Cuzama, for a long distance functioning as a city street, with the two axle cars parked in the yards or by the gates of the houses on each side of the street. Then it went out of town for a few miles to another town to the south which was reachable by road. At this point there was a nearly deserted Sisal processing facility, which was served by the 50 cm gauge rail system, and the tracks also turned down some side streets (see photo 1), eventually emerging from the town in two directions, apparently heading for other villages which were not reachable by road.

A feature of nearly all the 50 cm gauge lines is the very dilapidated condition of the tracks. It is not uncommon to have no joint bars between the rails and the railends mismatching vertically by 1 in. or so. Though it was hard to believe that the lines were still in operation, families came along in their two axle flat cars and proceeded over such track with no hesitation.

The combination of such deteriorated track being operated without apparent maintenance by these poor families left a disturbing aura. But still, these *are* railroads, not kept for any tourist or hobby purpose, and they obviously are important to the people that use them. The lesson here is that under a set of circumstances widely different than that of the present, railways can be a viable mode of transportation for even the most local of transportation purposes.

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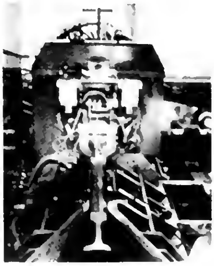

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PRESENTATIONS TO THE
A.R.E.A. TECHNICAL CONFERENCE
CHICAGO, ILLINOIS
MARCH 14, 15 and 16, 1988

410 Foot High Double Track Bridge on New Line Across Metlac Canyon

By: Ing. Alfonso Hernańdez Lozano*

Background

The rail line linking Mexico City with the port of Veracruz is called the Mexican Railway. It is one of the most important corridors in the Mexican Rail network as it connects the capital of our country which is the largest city in Mexico and one of the largest in the world from the standpoint of population, with the port of Veracruz, one of the most important ones in Mexico both for imports and exports.

Construction of the Mexico City-Veracruz line began on the 31st of August 1857 and was inaugurated on January 1st, 1873. As originally built it served 30 stations and had 15 tunnels, 10 viaducts, 55 steel bridges, 93 wooden bridges and 358 culverts.

Objectives

The original route of the Mexican Railway provided an adequate service to the country for about 100 years. With the passage of time and the development of traffic, the physical characteristics of the line became increasingly inadequate. As a result the Ministry of Communications and Transport decided to carry out the modernization of its most critical sections. The 76 kilometers between Los Reyes and Ciudad Mendoza had maximum curvature of 17°40′ and a ruling grade of 4.6%. The new line between the two points has 9°00′ maximum curvature and 2.5% maximum grade. (The figures given in this paper relating to curvature have been converted to the English system.)

Another critical section of the line that had to be re-located was the stretch between Sumidero and Fortin, both in the state of Veracruz. The distance between the two points is 4 kilometers as the bird flies. Between these two points there is a formidable natural obstacle, the Metlac Canyon which obliged the original line to descend along the left slope of the ravine, cross the river at the bottom of the ravine in a sharp curve and then ascend along the right slope with a 4.4% maximum grade. Maximum curvature was 10° and total length 7 kilometers.

Train operating costs were very high due to the high ratio of tractive effort per trailing ton, as well as for the long traveling time due to low speed. This resulted in a very low line capacity.

In order to solve the just mentioned conditions it was decided to relocate the line between Sumidero and Fortin. This made it necessary to build a new bridge across the Metlac canyon.

The Project

The geometric characteristics of the new line between Sumidero and Fortin had to be in accordance with the specifications set for the entire route of the Mexican Railway: 2.5% maximum grade and 9° maximum curvature.

Three different routes were considered. (Photo 1) All three required bridging the Metlac Canyon. The first route crossed the canyon at a point close to the existing bridge. The structure necessary to cross the river was short. Nevertheless, this route had to be discarded because it required the construction of several kilometers of new track resulting in high operating costs.

The second route connected Sumidero and Fortin in a straight line, but due to the short distance between the two points, the resulting grade was heavier than 2.5% initially set as a maximum. Furthermore, the line would cross the Metlac Canyon at a place requiring a bridge more than 700 meters long.

The forementioned circumstances led to rejecting this alternative. The third alternate route which was finally chosen as the most advantageous is slightly longer than the one just described, but it satisfies the project specifications of 2.5% grade 9° maximum curvature. Besides, the structure required to bridge the canyon, was only 400 meters long approximately. It parallels the highway bridge.

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*Advisor to Director General, Ferrocarriles Nacionales de Mexico

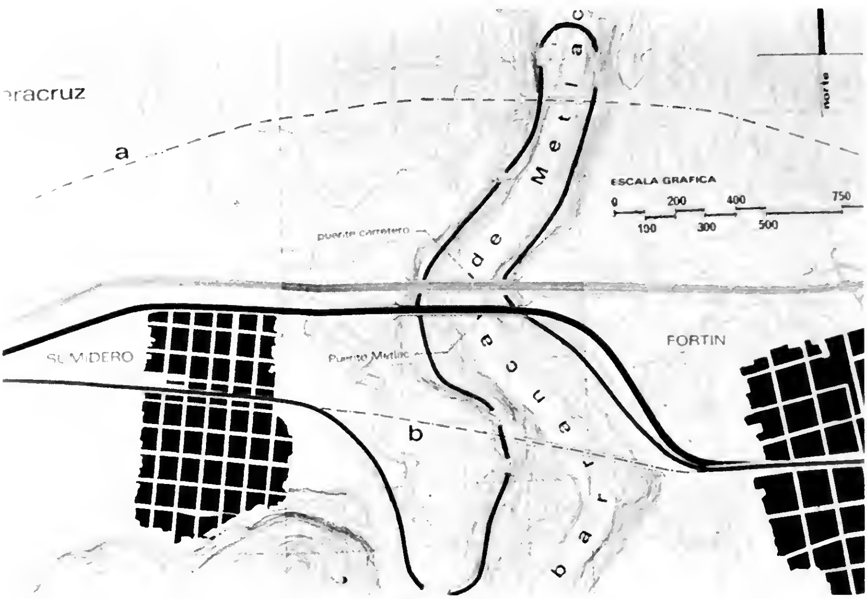


Photo 1

Selection of Type of Bridge

Once the layout had been established, studies were undertaken to select the most adequate type of bridge, taking into account the cost and time of construction, safety during construction and the necessity of allowing train traffic to continue uninterruptedly on the old line during construction of the new bridge, which had to cross twice above the existing line.

A detail survey of the area provided the profile of the natural terrain over which the bridge would have to be built. With this profile as a basis several structural solutions were studied. Two preliminary projects with steel structures were made and three with concrete structures.

The first option was steel girders on concrete piers with five spans. The central span would be 117 meters long, two lateral spans 96 meters long and two 88 meters long.

The second option consisted of steel trusses on concrete piers. The central span would be 194 meters long and two lateral spans 145.5 meters long.

The steel alternatives, taking into account the cost of material, the cost of construction and the maintenance cost, turned out to be more expensive than the concrete alternatives. The cost of maintenance was an important factor because in the Metlac Canyon there is a considerable degree of humidity that might cause corrosion to steel. The possibility of utilizing corrosion resistent steel like CORTEN was considered, but as this type of steel is not produced in Mexico, it would have to be imported resulting in higher cost. Therefore, the possibility of utilizing this type of steel was rejected.

Three concrete alternatives were studied. The first was an arch structure that did not require intermediate support. The second was a cable stayed concrete structure made up of three spans: the central span 300 meters long and two lateral spans 108 meters long each, supported on two concrete piers.

The concrete arch alternative was rejected because it required a greater volume of concrete and steel. Besides, it required a continuous constructive process beginning at both ends of the arch that would have to be supported by steel cables anchored to the ground during construction until the arch was closed. Another very important factor considered for the decision was the fact that the area where the bridge had to be built is highly seismic and the slopes of the canyon being of a different geologic formation. During earthquakes each slope would vibrate differently, developing forces that would endanger the structure.

The cable stayed concrete alternative had the advantage of needing only two piers, but required a greater amount of concrete and steel. Therefore, it was rejected.

Finally a third concrete structure alternative was studied. In this case there would be five hollow piers. The superstructure would be made up of box elements.

This third alternative turned out to be the most economical both in materials and construction costs. Besides, its structural behavior was the adequate for the type of terrain and for the load-carrying capacity required.

Structural Project

Once the decision about the type of structure to be built was taken, a detailed topographic survey was made, as well as geological studies, both of the region and of the bridge site and soil and rock mechanics studies. Thirty meter deep soundings were made at the places where the piers would stand. The unaltered samples of materials were analyzed and tested in laboratory and the necessary calculations were made to determine the loading capacity of the rock. The subsidence of the material under load was determined to be very small.

Geological studies revealed a failure at the bottom of the canyon, which, combined with the fact that the slopes are of different geological formation, in case of an earthquake would cause them to vibrate differently, thereby producing great forces which might jeopardize the structure.

The above described condition made it necessary to design a discontinuous superstructure obtained through a double hinge at the middle of the bridge, allowing an independent behavior of the two halves of the structure.

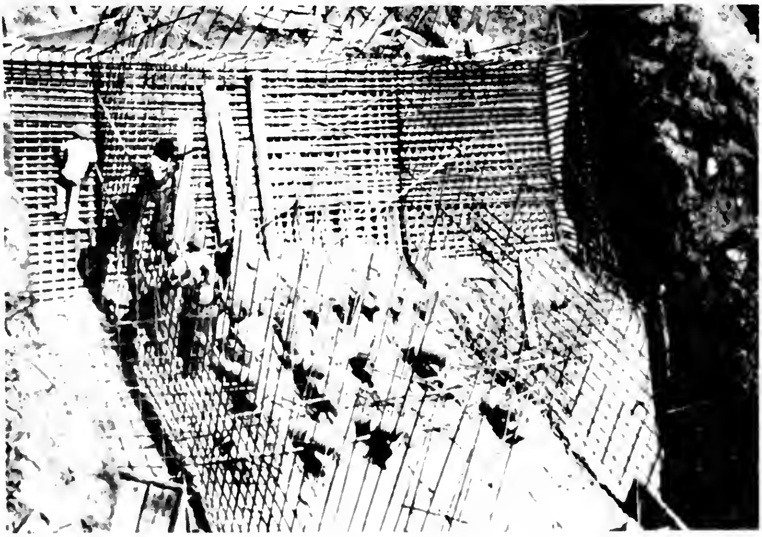


Photo 2.

The longitudinal forces derived from train braking and acceleration and from earthquakes were to be absorbed by the abutments which were fastened to the terrain by means of prestressed cables anchored to the rock. (Photo 2)

The computer calculation of the bridge structure took into account the following:

Dead Load
Live Load
Dynamic Impact
Seismic Effects
Train Acceleration and Braking
Wind Effect

The results of the calculation were the following:

The foundation was resolved through individual solid concrete footings of $F'_C = 220\ kg/cm^2$ with reinforcing rods and prestressed steel cables.

Piers were designed of hollow, rectangular section whose cross dimensions vary with height, built of 250 kg/cm^2 reinforced concrete.

Abutments were designed of solid reinforced concrete of 250 kg/cm^2, fastened to the rock as was said before, by means of 135 prestressed cables.

The superstructure was designed of reinforced, post-tensioned concrete of $F'_C = 400\ kg/cm^2$, Box-type sections, 6.5 meters high and 10 meters wide. (Photo 3) For post-tensioning, nineteen 1/2″ diameter strand cables were used, with an initial tension of 250 metric tons. The construction procedure was that of double cantilever.

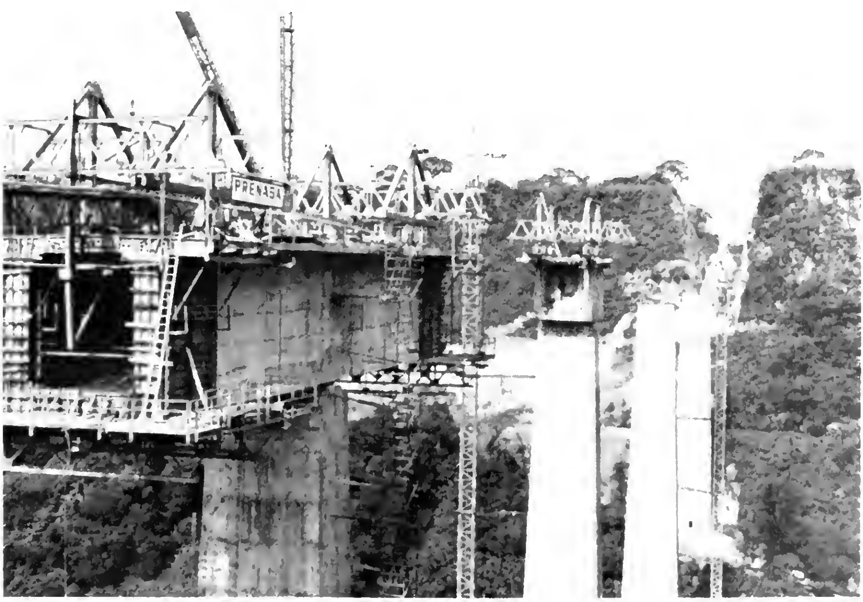


Photo 3.

The main data pertaining to the Metlac Bridge are the following:

Length between abutments	400 m
Maximum height	130 m
Number of spans	6
Length of main span	90 m
Capacity: double track	Cooper E-72
Ballasted deck	
Longitudinal grade	2.5%

Construction

Excavations were made to build the footing foundation for the piers. For the one for pier number 2, which was the largest, 30 000 m^3 had to be excavated. For this footing, 57 tons of reinforcing steel, 15 tons of prestressed steel and 1900 m^3 of concrete were used.

Once the foundation was ready, construction of piers began using a sliding form of a very ingenious design that rised by itself as the construction advanced. The sides of the form were being adjusted to reduce the cross section of the pier progressively with the height of the pier. Once the pier was completed, the form was lowered to the ground by its own mechanism.

Construction of the superstructure began with the fabrication of the so called pier voussoir which was a longitudinal section, 10 meters long. This voussoir was fastened to the pier by means of vertical prestressed cables. The pier voussoir was made using a form which was capable of sliding along the pier by its own mechanism. When the construction of the voussoir was finished, the form was lowered to the ground.

Photo 4.

In order to continue the construction of the remainder of the superstructure, two pouring devices were used which were tied to the pier voussoir and allowed pouring one five-meter voussoir on each side of the pier. These voussoirs were built two at a time in order to maintain balance. (Photo 4)

Once the concrete reached the projected resistance (F'_c = 400 kg/cm^2) these voussoirs were fastened to the pier voussoir by means of prestressed cables.

The pouring devices slid out from the pier but always remained supported by the previous voussoir. In this manner another cycle of construction of two balanced voussoirs could begin.

The same type of work was simultaneously done on the neighboring piers so that the cantilevers of the superstructure advanced toward each other and met at the center of the span. To connect the two cantilevers, the so called closing voussoir was fabricated and put in place. In this manner a span was complete.

The double hinging at the middle of the bridge was obtained by means of a voussoir of special shape supported in the central cantilevers of the superstructure by means of two brackets and reinforced neoprene. The voussoir for the joint was made utilizing the same pouring devices used for the rest of the superstructure.

Much care was taken to control the deflection which appears in the cantilever during the construction of the voussoirs. This deflection was previously calculated through a computer program and during the process of construction a camber was given so that the closing voussoir could be put in place without problem.

When the construction of the superstructure was finished the cables that fastened the pier voussoirs were relieved of tension, the provisional supports were removed and the permanent supports put in place.

Photo 5.

Complementary work consisted in putting in place the prefabricated concrete sidewalks and installing the metallic railing on both sides of the bridge.

Finally the track was laid and ballasted. Modern equipment was used for leveling and lining the track, to assure the best results.

The outstanding characteristic of this bridge is its 130 meters height which makes it one of the highest structures of its type in the world and of which the Mexican engineers participating in the project are proud. (Photo 5) This bridge is a very significant part of the modernization of the Mexican Railway one of the most important rail lines in Mexico.

PANEL ON LAYING AND MAINTENANCE POLICIES ON CONTINUOUS WELDED RAIL

UNION PACIFIC RAILROAD LAYING AND MAINTENANCE POLICIES FOR CWR

By: J. M. Sundberg*

As you can observe, Union Pacific's eastern border runs from Brownsville, Texas on the south to Chicago, Illinois on the north. We run as far west and north as Eastport, Canada and Seattle, Washington. We span the mountains and deserts of Wyoming, Utah, Nevada, and California to the Pacific Ocean at Oakland and Los Angeles.

We start our CWR rail laying process with a Job Briefing which is basically a four step procedure:

Step 1—Plan the briefing:
1. From a Safety Standpoint
2. Reviewing procedures, tools, equipment and assigned manpower.

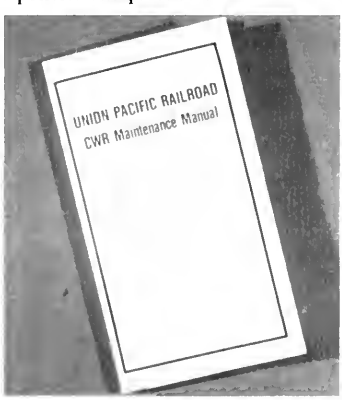
Step 2—Explain to all individuals concerned:
1. Who, What, When, Where and How. Review and make definite assignment. Make sure to obtain necessary tools, equipment or method necessary.

Step 3—Brief for special conditions:
1. Weather, Emergencies, Double Track versus Single Track, Etc.

Step 4—Follow up to ensure the work is being performed properly and safely.

Because of the geography, we commence our CWR rail laying process by laying to a prescribed controlled temperature. We accomplish this by heating the rail before anchoring using an on-track propane heater car or, if necessary, cooling the rail by a hi-rail refrigerated water truck. Where heaters are not available, we utilize rail stretchers and temperature tables to achieve the desired laying temperature.

As you can see by the table, our minimum laying temperatures range from 90°F to 115°F depending on geographical location. Our rail laying temperatures are monitored by a Heat Control Engineer on each steel gang and must not exceed the recommended temperature outlined on this chart by more than 20°F. We then anchor the rail to the prescribed temperature using rail anchors. Our Standard Anchor pattern on our mainline 133 lb. rail section is to box anchor every other tie and solid anchor every tie 195′ each way from rail joints, insulated joints or switches. We have learned, however, the rail neutral temperature shifts downward over time for a variety of reasons. It is because of this downward shift that we developed our maintenance policies and practices.

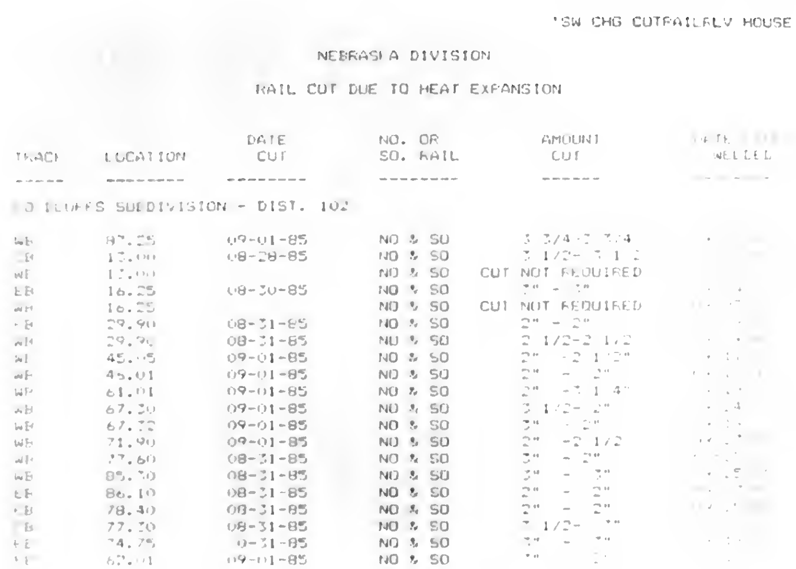


Union Pacific CWR Maintenance Manual

*Maintenance Engineer—Track, Union Pacific Railroad

We start both our laying and maintenance programs with an annual training program for our field maintenance-of-way forces. This includes our system steel, surfacing, sledding, undercutting, and tie gangs as well as our track, signal, B & B, engineering, and maintenance forces. These sessions are held on an annual basis the first quarter of the year, but no later than April 30th. Our maintenance managers are taught by the Maintenance Engineers and they in turn conduct the training sessions with their respective foremen, welders, track inspectors, etc. The Program Engineers conduct the sessions for our system, track, bridge, signal, and construction gangs. These sessions usually are one-half day in duration. In these sessions we view our training video—"Rails that Grow", which you viewed earlier. We explain and review in detail the concepts of this video. We review our Chief Engineer's Instructions on Track Buckling, Track Inspections, and Speed Restrictions account of track work. We explain the proper use of a rail thermometer for obtaining ambient and rail temperatures. We cover our standard ballast section pointing out the requirement of a 12″ shoulder and full crib with 3:1 ballast side slopes. Discussed are the effects of train traffic on newly worked track and a review of the number of days required to regain 50 percent and 95 percent compaction on the disturbed ballast section. This year we intend on using a ballast stabilizer behind some of our system tie and surfacing gangs to stabilize the ballast after disturbance and reduce the time slow orders are required. Also, we go over our maintenance of way rules pertaining to the laying and maintenance of CWR and also our welding and grinding rules, placing particular emphasis on field welding procedures.

This slide shows a summary of our minimum slow order requirements and we review them thoroughly. We mandate our field forces to place slow orders when disturbing the track in line with these requirements. We stress the importance of not adding rail during cold weather months when performing tasks such as laying curves, changing out detector car rail defects, repairing pull-aparts, bolt hole breaks or installing replacement rail or insulated joint plugs. We also realize that in certain circumstances it is necessary to add rail; therefore, we insist on a written record being kept by the local supervisor listing the specific location to allow for monitoring during warmer months and making adjustments such as cutting rail. We encourage and teach every field manager how to set up a computer record of rail cuts and excessive or tight rail locations, additions or subtractions in lengths, similar to those indicated on the slide. (Photo 2) Please note on the extreme right hand a column for follow up



'SW CHG CUTRAILRLV HOUSE'

NEBRASI A DIVISION

RAIL CUT DUE TO HEAT EXPANSION

TRACK	LOCATION	DATE CUT	NO. OR SO. RAIL	AMOUNT CUT	DATE WELDED
[illegible] BLUFFS SUBDIVISION - DIST. 102					
WB	87.25	09-01-85	NO & SO	3 3/4-3 3/4	[illegible]
EB	13.00	08-28-85	NO & SO	3 1/2- 3 1 2	[illegible]
WB	13.00		NO & SO	CUT NOT REQUIRED	
EB	16.25	08-30-85	NO & SO	3" - 3"	[illegible]
WB	16.25		NO & SO	CUT NOT REQUIRED	[illegible]
EB	29.90	08-31-85	NO & SO	2" - 2"	[illegible]
WB	29.90	08-31-85	NO & SO	2 1/2-2 1/2	[illegible]
WB	45.05	09-01-85	NO & SO	2" -2 1/2"	[illegible]
WB	45.01	09-01-85	NO & SO	2" - 2"	[illegible]
WB	61.01	09-01-85	NO & SO	2" -3 1 4"	[illegible]
WB	67.30	09-01-85	NO & SO	3 1/2- 2"	[illegible]
WB	67.32	09-01-85	NO & SO	3" - 2"	[illegible]
WB	71.90	09-01-85	NO & SO	2" -2 1/2	[illegible]
WB	77.60	08-31-85	NO & SO	3" - 2"	[illegible]
WB	85.30	08-31-85	NO & SO	3" - 3"	[illegible]
EB	86.10	08-31-85	NO & SO	2" - 2"	[illegible]
EB	78.40	08-31-85	NO & SO	2" - 2"	[illegible]
EB	77.30	08-31-85	NO & SO	3 1/2- 3"	[illegible]
EB	74.75	[illegible]-31-85	NO & SO	3" - 3"	[illegible]
EB	62.01	09-01-85	NO & SO	[illegible]	[illegible]

Photo 2.

field welding to control pull-aparts during colder weather months. We also suggest that whenever field forces find it necessary to add rail, they mark on the side of the rail the date and amount of additional rail using paint stick. This can later be noted by the welders and the excess rail removed at the time of welding.

Union Pacific institutes a heat order restricting the speed of trains averaging 90 tons per car or greater when ambient temperatures reach or exceeds the temperatures shown. In addition, in the spring or early summer when ambient temperatures first reach a daily peak temperature 5° below the temperature shown, the heat order restrictions also apply. These orders are placed by our field managers of track maintenance. Every foreman, manager, maintainer and welder is issued this pocket sized booklet to be used as a ready reference guide when performing their daily activities on CWR territories. ALL of our system gang supervisors and foremen are likewise issued one. Our supervisors are taught and encouraged to plot all rail cuts, excess rail locations and past sunkink locations on a condensed profile segment of their territory. This establishes a history of potential trouble spots and suspected tight rail locations so that they may be monitored during warm weather months.

We alter our track inspection hours during hot weather periods to allow for critical inspections during the extreme high temperatures of the day, i.e. mid to late afternoons. We also inspect these areas seven days per week. We use a follow up tool entitled One/One Audit Program to monitor our compliance with our Standards, Policies and Rules. We, as officers and managers, make a comprehensive field audit with the appropriate field supervisors in which safety, quality, standards and rule compliance are evaluated. The employee being audited is given a copy of the audit. Our field forces are required to report service failed rail, pull-aparts and track buckles or "sunkinks" (as they are referred to by us gandies) to afford additional knowledge of this phenomenon and so that preventative steps may be introduced. It is because of our experience and knowledge of the past that we have initiated these programs.

Our internal records on derailment incidents reflect the steps we have initiated are positive and our track caused derailments are declining at the same time our in-track miles of CWR has increased.

It is our belief that when discussing the subject of CWR, the following basic rules apply to prevent track buckling:

1. Temperature control rail when laying.
2. Follow prescribed standards both in laying and maintaining.
3. Do not add rail unless absolutely as a last resort.
4. Keep a record if additional rail is added to allow for its removal at a later date.
5. When in doubt, cut rail out then follow up to field weld the track cut.
6. Place appropriate Slow Orders during track disturbance in hot weather.
7. A Standard Ballast section and rail anchor pattern must be maintained.
8. Curves must not be lined in, that is shortened, without cutting rail.
9. Frequent inspections must be made during hot weather.
10. Speed Restrictions placed account of track work must extend beyond the limits of the work to insure trains have reached the desired speed before reaching the work limits of the unstable track.
11. History will and often does repeat itself at locations of excess or running rail.

We can further improve our performance by additional research, proper reporting and then sharing our knowledge with others. It is our job as leaders to ensure we have a thorough understanding of CWR installation and maintenance and better understand this track buckling phenomenon. Our maintenance and rail laying procedures are a process that is continually changing as our knowledge and experience with CWR expands. We currently have stretches of CWR that have carried in excess of one (1) billion gross tons of traffic, and we expect to improve on that record as we expand our rail grinding programs.

In conclusion, it is our job to properly train and equip our employees to ensure the continued safe operation of the railroad and to develop our future leaders.

ILLINOIS CENTRAL RAILROAD
LAYING AND MAINTENANCE PROCEDURES FOR CWR

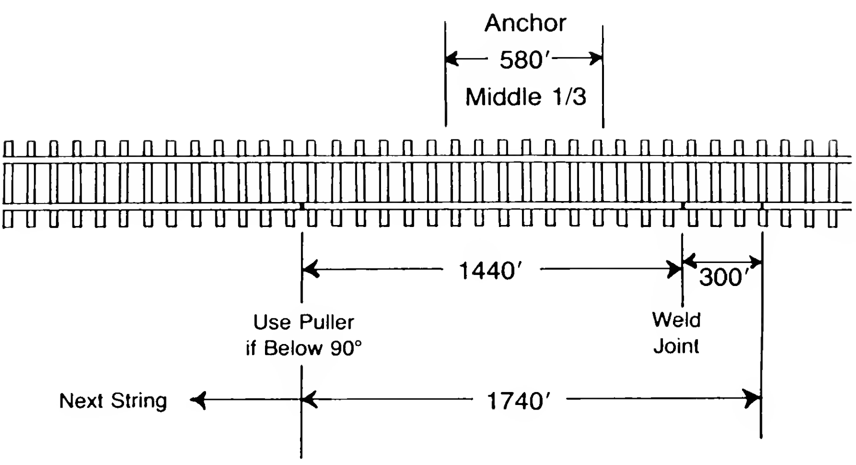
By: D. A. Lowe*

Installing Welded Rail

On the Illinois Central Railroad it has been determined that installing continuous welded rail at 90 degrees or higher produces the most desirable conditions to prevent problems on our railroad. As it is impractical to lay all our rail at a temperature of 90 degrees or above, we can produce the same condition by stretching the rail with a hydraulic rail puller when it is laid at a lower temperature.

The temperature of the rail is measured at the time the new rail strings are jointed and this joint is laid with no gap in it. The measured temperature is painted on the web of the rail in 3 inch letters 6 feet from the end of the string with only one temperature painted at each joint. If this temperature is above 90 degrees, the rail strings are anchored per ICRR standards. The welder will then cut the required gap and make the field weld. When the rail temperature is below 90 degrees at the time the joint is made the welders in the rail gang will adjust the rail using a hydraulic rail puller using the following procedure.

When the length of either string is less than 400 feet, one end of the rail string must be welded to the adjoining rail string and the total combined rail string is then to be treated as one rail for all stretching procedures. (see Example 1) When the length of each rail string is more than 400 feet, the center 1/3 of the length of each rail string must be anchored according to our standards and the rail is then stretched.



Example 1

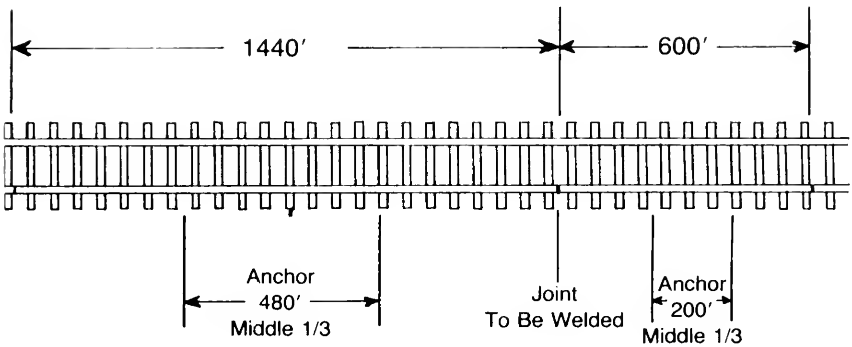
Where continuous welded rail abuts jointed rail, turnouts, track crossing, expansion joints, and other such track appliances, the existing track or track appliance must be fully anchored before any stretching is done. The stretching must not be performed nearer than 400 feet to the existing track or track appliance and the welded string between the existing track or track appliance must be anchored per ICRR standards.

Where the track appliances are not at least 800 feet apart, stretching procedures must not be used to adjust rail strings and field welds must be made at rail temperatures of 90 degrees or higher.

*Engineer of Track, Illinois Central Railroad

To calculate the amount to stretch each joint determine the approximate length of each rail string and sum the lengths and divide by two to calculate the length to be stretched. Remember you are effectively stretching one half of each string. (see Example 2)

$$1440 + 600 = \frac{2040'}{2} = 1020'$$



Example 2

Using the rail temperature and the average length, select the amount of stretch that is required from the graph in Example 3. This amount does not include the gap required for the field weld. This graph was made using the coefficient of expansion of rail steel for various lengths of rail.

After the rail gang has followed the anchoring procedure for 1/3 of the rail string and the welder has calculated the amount of rail to be stretched, the welder will cut the required rail gap. The rail jack must be applied and the rail pulled to the proper position for welding. Following the welding procedure, the jack must not be released until the weld has cooled to 700 degrees or 30 minutes after the weld is poured. Following stretching and welding, the balance of all remaining welded rail will be anchored per our standards.

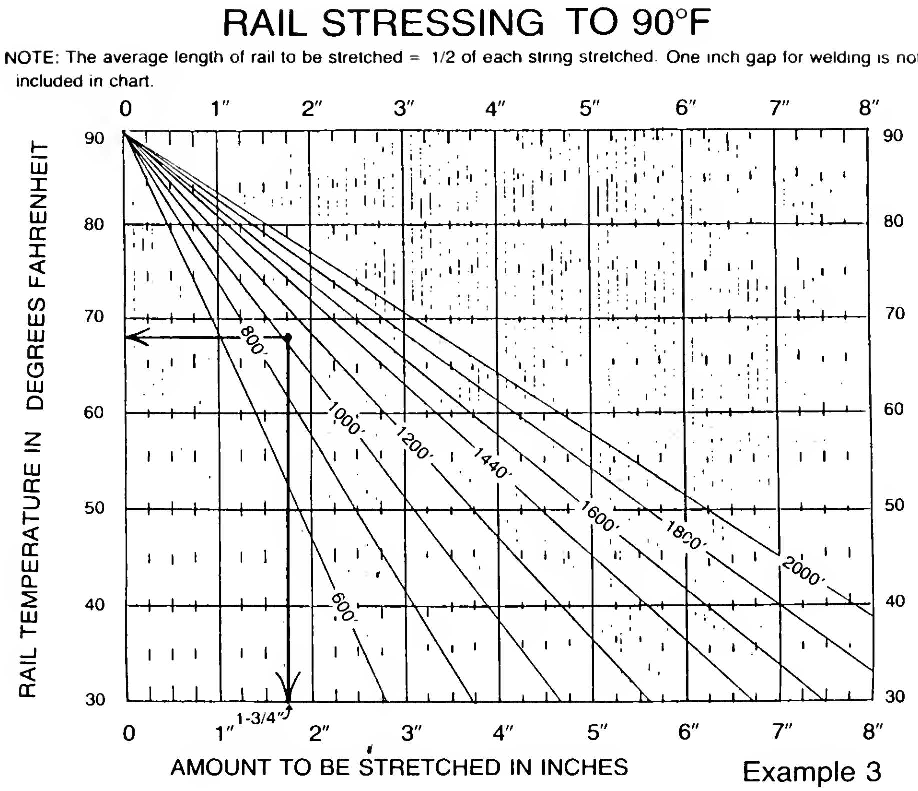
Glued insulated joints are treated as continuous welded rail for stretching and anchoring procedures.

Maintenance of Welded Rail

The safe operation of trains is of first consideration and special care must be taken under the following conditions,

1. When there is a rapid rise in temperature,
2. When performing track or bridge work, or
3. Extreme high temperatures.

The first time in the year that the air temperature exceeds 82 degrees F, track supervisors and track inspectors must patrol main tracks on their territory observing carefully for any signs of excessive compressive forces which may lead to buckling track. This inspection must include observations of anchor patterns, longitudinal rail movement, rail kinked in plates, churning ties, disturbed ballast,



alignment deviations and any other physical changes which may be caused by compressive forces in rails. Special attention must be given at locations where train actions may cause longitudinal track forces and at bottom of grades, sags, open deck bridges, turnouts, road crossings, track crossings and other fixed points.

During these inspections, or at any time in the hot weather season when it is observed that "tight" track exists, the rails must be cut, adjusted and maintained using the following procedure:

1. Rail is cut with a propane cutting torch (using method for cutting rail in compression) until compression is relieved.
2. Cut the required gap and make weld.
3. If line kinks are visible on either side of location where weld is to be made:
   a. Put rail puller on.
   b. Cut two-inch (2″) gap between rail ends.
   c. Pull rails together. Repeat this procedure until rail is straight or 60 tons is indicated on puller gage. Then cut required gap and make weld.

If immediate corrective action cannot be taken, proper slow orders must be placed being sure to extend such orders sufficient distances to insure that train actions do not add compressive forces to the track structure.

The safe course must be taken in performing track and bridge work and special care must be taken to prevent buckling track, using extraordinary care in welded rail territory. Before any work is started where the track will be disturbed, a careful examination must be made of all conditions to determine if the work can be done without causing buckling track. Consideration must be taken of the effects of such work not only while in progress, but the effects thereafter. If there appears to be a danger of buckling track, such work will be done only upon authorization of the Supervisor of Track. Who will correct by:

1. Cutting out excessive rail and adjusting according to the above procedure,
2. Setting all rail anchors against ties and install additional anchors where necessary, and
3. Adding additional ballast if necessary.

In extreme hot weather, when the air temperature exceeds 95 degrees F, a slow order must be placed by the track supervisor or designated person to limit track speeds to a maximum speed of 60 mph passenger and 35 mph freight, between 10:30 a.m. and sunset, when the sun is shining on the rail. Local conditions must be constantly monitored for changes that might warrant removal of the slow order.

Slow orders may be applied at lower temperatures and/or lower speeds may be specified if, in the judgment of supervisors or designated persons, conditions warrant.

NORFOLK SOUTHERN
LAYING AND MAINTENANCE POLICIES FOR CWR

By: P. R. Ogden*

Just as the other panel members have outlined the procedures in place on their respective railroads for working with CW rail, I will do so from NS's perspective. I suppose another title for this discussion could have been prevention of buckle track.

I think we all equally understand the reasons why track will buckle, whether or not we know all the reasons is open for discussion. I agree we have learned a lot about thermal stresses and other factors related to buckle track over the last two decades. Still today all of the findings from research are not in total agreement.

The use of CW rail is a very big part of our maintenance program on NS, and has been for a number of years. We laid our first welded rail in 1958. Today we have 14,204 miles in track, 12,521 miles of main line, and 1,683 miles in yards and sidings. 70% of our road mileage is CW rail.

As the mileage of CW rail in track began to accelerate in the late 60's and early 70's, we began to have some problems with sun kinks, buckle track and unfortunately, several derailments caused by buckle track.

One of the derailments was at a location where crossties had just been installed on a curve with CW rail. It was a hot spring day shortly after noon. Existing instructions for using slow orders had not been followed. As we know now it was a classic case with all the factors that can cause a track to buckle. All of these problems made it clear to us that a set of standards and procedures for laying and maintenance of CW rail was needed.

The instructions had to be clear, concise, and written in a way that everyone down to the track foreman could understand. It was decided to collect all the various instructions pertaining to CW rail and consolidate them into one procedure. This procedure would then establish a uniform system for working with CW rail. After an evaluation of existing and needed instructions, Standard Procedure 390, Maintaining Track Stability, for the prevention of buckle track was written.

For the next few minutes I will briefly review with you parts of this procedure as it best describes NS's policies with respect to today's discussion.

The subjects covered in this procedure are as listed below:

- Track stability factors
- Track conditions
- Track inspection
- Crosstie or switch tie replacement
- Surfacing track
- Combined timbering and surfacing
- Measurement of track behind surfacing work
- Rail laying by system gangs
- Smoothing
- Cribbing track and spot undercutting
- Undercutting track out of face
- Bridge work
- Laying or transposing welded rail by LM
- Adjusting welded rail

Again, time does not permit each item to be covered in detail so I will just review some of the more important subjects. Some of these procedures are the same as already discussed by other panel members and some are unique to NS.

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*Chief Engineer Production, Norfolk Southern

Track Stability Factors:

In the beginning, we make several statements concerning lateral stability as follows:

1. Track with CW rail must not be disturbed without using the proper slow order.
2. Track disturbed by new ties, surfacing or smoothing can lose up to 80% of it's original resistance to lateral forces.
3. Once disturbed, track stability can only be restored by tonnage or the use of a ballast compactor at a reduced train speed.

There are many component parts which make up a track structure and each of these parts must be sound for a safe and stable track. For this discussion, I will mention just two of those components, ballast and anchors.

BALLAST

We are very meticulous to insure that all ballast sections are maintained at least to the following minimum sections for CW rail.

Welded Rail
Tangent Track—6″ shoulders
Curve Track— 6″ shoulders—low side
12″ shoulders—high side

During program work, where the track has been disturbed, there are several reminders throughout this procedure that slow orders will not be removed until a standard ballast section has been restored.

RAIL ANCHORS

For controlling thermal and compressive forces in the track there is no track component part more important than rail anchors.

The point emphasized in Procedure 390 is that all anchors must be applied as required. All missing or defective anchors are replaced in each timbering cycle and all anchors are squeezed tight against the crossties. The anchors serve no purpose unless tight against the ties.

Track Inspection:

Track inspection is our first line of defense for detecting any flaws in the track. During sudden changes in rail temperature and extremely high temperature, CW rail requires inspections almost on a daily basis. We do not add any jobs for the additional inspections, but we do change the time inspections will start and also schedule weekends on and off for supervisors so that the track will always be protected.

Some rules and guidelines for track inspections are:

- All scheduled track inspections must be maintained.
- Additional inspections will be made during sudden changes in temperatures in locations where CW rail or recently disturbed track will be subject to getting out of line.
- During periods of excessive temperature changes, weekend inspections will be made. When a slow order is being used for tight track, it will be necessary to make weekend inspections.
- Special attention must be given to track on curves, in dips, at the ends of bridges, heavy grades, recently disturbed track or track worked during the past winter.

Disturbed Track:

I have mentioned our concern with CW rail when there is a sudden change in rail temperature. Another factor which must be given equal attention is disturbed track. Tie renewal, surfacing and

smoothing track all create a temporary unstable track condition. Therefore, we have some special guidelines for each in the track stability procedure. Each one is covered separately, but the instructions are similar and for the purpose of this meeting. I will treat them all as one.

When crossties, or switch ties are replaced or surfacing work is perform a slow order must be used as follows:

a. A 10-mph slow order must be used in welded and joint rail territory when the rail temperature is 110°F or above.
b. A slow order of 25 mph maximum may be used when the rail temperature is less than 110°F.
c. When in doubt as to temperature, follow the instructions for 110° or above rail temperature.
d. When a slow order of less than 25 mph is used, the passage of two tonnage trains is required before slow order is raised.
e. When the 110°F rail temp instructions are used, slow order must remain in effect for at least two days of traffic.

Rail temperatures are critical and is the catalyst which flags or activates other guidelines. For this reason, all production gangs are required to take rail temperatures a minimum of three times daily (start of work, middle of day and end of work). These temperatures are reported with the production reports to the Atlanta office.

After several cases of buckle track in the early 70's on curve locations that had been worked the previous winter, we began to suspect the track had possibly moved in account it had been worked at a temperature below the rail laying temperature. After checking some locations we found that indeed our suspicions were correct and this section was written into the procedure.

Measurement of Track Conditions Behind Surfacing Work:

a. Where track will be surfaced at a rail temperature of 50°F or below reference stakes will be set ahead of the work.

b. One week behind the surfacing gang measurement will be taken to record any movement of the curve. This information will be furnished to the chief engineer's office where a report is prepared listing all locations which moved 1" or more. The division engineer is responsible for adjusting the rail at these locations.

Rail Laying:

The foundation for CW rail begins with the laying process. There are a number of components which must come together for a good rail laying job such as line, gage, application of all fasteners, plates, spikes and others, but for the discussion today, I will talk about temperatures only.

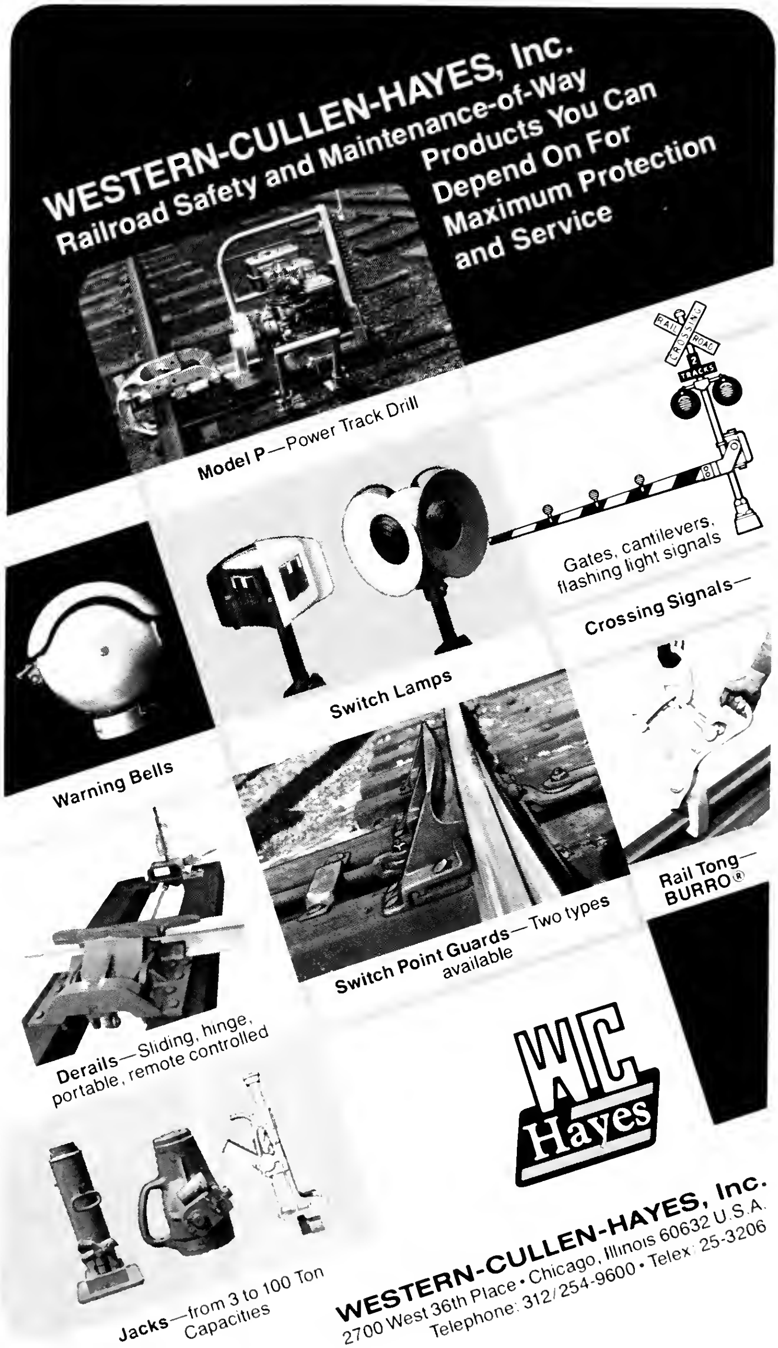
1. If rail temperatures are below 80°F, a rail heater must be used. Rail must be heated so that the temperature at the time of spiking and anchoring will be 85°F-100°F, ideally 95°.
2. Temperature charts are furnished the division engineers for all rail laid on his territory. He then must make adjustments if required.

Other Work:

There are other subjects such as cribbing, undercutting, bridge work, rail transposing and adjustment of rail, covered in procedure 390 which I will not review today due to the time restraint.

Training:

We feel procedures and standards are an absolute necessity for a safe uniform system of laying and maintaining CW rail. The standards though are effective only if they are properly communicated to and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understood by all field personnel that actually perform the work. We go through several steps to get this message down to our field people:

1. First, in the spring of each year, staff meetings are scheduled at several central points over the System. These meetings are conducted by the Assistant VP of MofW and Chief Engineers. The theme of the meetings is prevention of buckle track. The discussions are directed to the first level of supervisors, the field people. The program will explain why sun kinks and buckle track occurs and then Standard Procedure 390 is reviewed section by section for prevention. These meetings are mandatory for all MofW officers and have been part of our program since 1974.
2. The second step is for the division engineers to take the message back to the field and review the instructions with the foreman.

We go through this procedure annually. Some may ask is it all really necessary. I can only reply that we feel that the subject matter of working with CW rail must be given top priority for safety of operations and this is one method of driving the point home to the people actually involved in the field work. Also, after the inception of this type program in 1974 the number of buckle track incidents dropped dramatically.

We are also constantly reviewing these instructions and evaluating their effectiveness. After a recent review, the following training programs for our field people were added.

— All scheduled employees promoted to field track or bridge supervisory positions will get five weeks of classroom training.

— All officers and some scheduled track employees will take a written exam on FRA Safety Track Standards. This will be part of the annual spring meetings.

— A formal training school, consisting of two weeks of classroom instructions for foremen and assistant foremen.

These programs cover all phases of track maintenance, including working with CW rail, and should improve the effectiveness of our maintenance procedures.

To conclude my part of the program, I will quickly summarize the policies in effect on the NS for working with CW rail by stating that we feel we have a very good program based on sound engineering decisions for the conditions that we encounter. To make this program effective, employee training is provided annually at the field level. We are committed to safety of operations and are convinced we can work safely with welded rail under any circumstances if we just follow the procedures we have in place.

We have a statement that we pass out at the annual spring meetings which pretty much sums up our philosophy.

Disturbed track in hot weather plus failure to follow instructions equal buckled track.

EMERGENCY RESPONSE TO TUNNEL FIRE AT SPROUL, W.V. ON CSX

By: T. P. Schmidt* and J. P. Epting**

At approximately 1:30 P.M. Thursday, November 5, 1987, a tunnel fire was reported by a train crew at Sproul Tunnel in Sproul, West Virginia. This timber lined tunnel is located about 15 miles south of Charleston, W.V. on a main coal feeder line between Danville and St. Albans, W.V., which serves 17 coal mines, and carries thirty-four (34) million gross tons of coal a year. All of this coal, affecting over 3000 miners, was on the wrong side of the tunnel. The carloadings from these mines represent ten (10) percent of all CSX Transportation coal business. Considering that CSX is made up of the C & O, B & O, L & N and Clinchfield, all of which were major coal roads in their own right, this is a staggering number and we clearly had a disaster in the making.

Tunnel fire reported at Sproul

*Chief Engineer—Maintenance of Way, CSX Transportation

**Assistant Chief Engineer, CSX Transportation

The tunnel is 954 feet long and was constructed in 1906. It was of natural rock until rebuilt with timber in 1942, a practice common on the former C & O.

1. Sproul Tunnel was completely lined with creosote material with the exception of 110 feet at the time of fire. This liner consisted of 12 x 12 posts, 12 x 12 ring segments, 4″ post planks and packing consisting of 4″ diameter round timber. The timber liner was constructed to protect passing trains from falling rock and boulders.

2. Clearances: Top of rail vertical has a minimum of 18′-2 5/8″ to the timber liner and had a horizontal clearance of 8 feet from centerline of track.

3. Sproul Tunnel has one curve located on the east end and is surrounded by two rivers: Big Coal River on the west and Little Coal River on the east end to the left of track, both of which run adjacent to the mainline. There is a 219 foot steel bridge located on the west end of the tunnel spanning Big Coal River. The original bridge was built in 1906 and rebuilt in 1986 and is approximately 100 feet from the west portal of the tunnel. The mountain range in this area through which the tunnel is located is approximately 800-1000 feet high. There is no other entrance or exit to Danville except through Sproul Tunnel. Construction to open cut this mountain would be costly, with 59 days or more to perform the work. The track structure through Sproul Tunnel is 132# CWR, full ballast section.

Track inspectors were through this area the morning of November 5th, and observed nothing. However, during this period forest fires had been detected in the vicinity and were extinguished. You may recall these fires in West Virginia were a major problem and were featured on the national news. Precautions were taken at the west portal during inspection, and it was thoroughly protected before continuing. The conductor on a westbound train at 12:50 P.M. reported a small brush fire in the area, but not in the tunnel. However, a westbound train passing through the tunnel at approximately 1:15 P.M., only 20 minutes later, reported fire on the east end, just inside of the tunnel area. We believe that the passage of these two trains created a draft which sucked burning, blowing leaves into the tunnel, igniting it. Fire fighters were dispatched and arrived on the scene within 40 minutes. Five (5) local volunteer fire companies responded in addition to CSX personnel, but by this time the fire was rolling from both portals 75-100 feet with large amounts of smoke and could not be controlled by conventional means. This was the scene which greeted Jerry Epting upon his arrival later than afternoon.

The normal procedure in a tunnel fire on our property has been to let it burn itself out. In this case however, we were reluctant to do that because of the volume of wood lining and packing known to be inside the tunnel, and the concern that prolonged high heat would damage the sandstone rock causing a major cave in. Furthermore, we suspected there may be seams of coal inside which, if ignited, could burn indefinitely. Consequently, the decision was made the afternoon of November 5th, the 1st day, to try to extinguish the fire by smothering if possible. In attempting this we requested and received the advice of Peabody Coal Company, which not only had experience in mine fires, but also owned most of the coal east of the tunnel.

Once this course of action was determined, we immediately began to close up each end of the tunnel with dirt and provide a seal to cut off oxygen flow and allow pumping of various chemicals through the 954 foot shaft of roaring flames. Dozers and large backhoes were ordered to provide necessary equipment to accomplish this task. Dirt material from the immediate area was quickly determined to be of use and was pushed into place to form temporary seals on both east and west sides. During the process of erecting seals, 48″ pipe, 40 feet in length was installed on the west side approximately 16 feet from ground level to provide entrance into the tunnel, both for use of chemicals and personnel. A 4′ x 8′ box was built around the 48″ pipe to provide a means to allow the flow of chemical and oxygen through a damper process into the tunnel area. It also would serve as access for Peabody Mining rescue team to enter the tunnel for inspection when the need presented itself.

Water and chemicals being pumped into Sproul Tunnel.

A second pipe 24″ and 40 feet in length was installed approximately 16-18 feet from ground level on the east side of the tunnel in the east seal to provide for installation of a 32″ cone shaped fan inside the 24″ pipe for exhaust and checking of:

1. Temperature inside tunnel
2. Air flow inside tunnel
3. Oxygen content inside tunnel
4. Chemical content inside tunnel when pumping from the west side.

A generator was secured to provide power to operate and drive the fan on the east side. A local chemical company was ordered to be in place immediately. During late afternoon and early morning November 6th and 7th, the 2nd and 3rd days, the tunnel was completely sealed at both ends and CO_2 (carbon dioxide) was inserted into the tunnel through the west end to extinguish the fire. Example of readings taken from the east portal fan at 1:30 P.M., November 8th, the 4th day.

Temperature inside tunnel:	192.9 degrees F
Carbon monoxide;	9.75%
CO_2:	Off instrument scale
Oxygen content:	5.50%
Exhaust on east side has some smoke detected	

One tank car containing CO_2 (carbon dioxide) was moved into place and pumped chemicals into the tunnel. Approximately 72,000 gallons were used (320 tons).

On November 8th at 6:21 P.M. having little success with CO_2, the decision was made to also pump nitrogen in order to eliminate hot spots in the roof lining and try to continue to cool down the tunnel area. During late evening a Peabody Mine emergency crew attempted to enter the tunnel with special equipment through the west portal 48″ pipe and box without success. Temperature at this entrance was

200 degrees plus. Specialists in this field were contacted from different parts of the area to assist in evaluating and recommending methods of extinguishing the fire. Chemicals, both CO_2 and nitrogen continued to be pumped into the tunnel and readings were taken on each portal every 30 minutes through November 10th, the 6th day, when upon careful observation of temperature readings which had begun to drop, the decision was made to open part of the tunnel seal on the west end. This was accomplished, however, upon inspection and verification by the chemical readings, the tunnel began to ignite resulting in the seals being rebuilt.

Having elected to extinguish the fire, our strategy had been to control the oxygen intake, which we had successfully done and to control the temperature to prevent reignition and control heat damage to the rock, which at this point we had not successfully accomplished. In fact, we had inadvertently created a kind of Dutch oven which was trapping the heat. The tunnel was still at about 180 degrees whereas we now believed 100 degrees was required before reopening. We needed a medium to provide cooling, and quenching if possible, without injecting oxygen. We made the bold decision to flood the tunnel. This required not only pumping 1.6 million gallons of water into the tunnel, but also strengthening the seals at each end to retain that amount of water.

Beginning on the morning of November 11th, the 7th day, water was pumped into the tunnel through the use of large mobile pumps with the capability of placing 5700+ gallons of water per minute. In order to strengthen the seal to prevent catastrophic failure, polyurethane was pumped through ground probes into tunnel seals on both ends to further seal and stabilize the fill. Our objective at this time was to completely fill 954 foot of tunnel with water. As the pumping operation continued through November 11, 12 and 13, temperature readings became favorable inside of the tunnel (160 degrees), and the decision was made to further speed up the cooling process by injecting nitrogen foam to the ceiling area. Normally foam would be air based, containing oxygen, so we chose to use nitrogen as a base.

Incidentally, during the pumping procedures, water samples were taken both at Big Coal and Little Coal River and booms were installed with settlement ponds in both areas to assist in catching any chemicals which might be released from the tunnel. Tests continued on the east side for temperature drop. By dawn Sunday, November 15—the 11th day—it became obvious that our strategy was going to succeed. The temperature in the tunnel had dropped to about 115 degrees, and the atmospheric readings inside the tunnel were completely devoid of oxygen, carbon monoxide and CO_2 indicating no combustion whatsoever. We blew one last hour long blast of nitrogen through the tunnel, which lowered the temperature the last 15 degrees, and at 11:00 A.M., we cut a hole in the west portal, started the fan on the east portal, thus injecting oxygen into the tunnel again. At this point there was nothing to do but wait and take readings to see if the fire had restarted. And so we waited . . . by 3:00 P.M., however, with oxygen levels in the tunnel returning to normal and no chemical evidence of combustion, we gave the order to tear down the seals at both portals using dozers and large backhoes so we could drain the water and begin cleanup operations. The water, which was about 16 feet deep, was drained into adjacent settlement ponds and further into the Big and Little Coal Rivers. At 9:30 P.M., we entered the tunnel to inspect the damages and prepare the cleanup operations. Station points were marked and placed inside the tunnel at this time for identifying location and eliminating confusion on cleanup operations.

We found that the entire timber lining was destroyed or damaged beyond salvage by the fire. Walls and ceiling were in good condition but would have to be scaled before and during the cleanup operation. Basic rock formation is layered sandstone with variable seams of shale. Coal seams were noted throughout, but were small and had not burned. The shale seams occur primarily near the spring lines at subgrade. Track structure was destroyed throughout. Large amounts of timber, both lining and stuffing had not burned but were covered by large amounts of fallen material including an accumulation of rock over the years which had come loose. The entire length of the tunnel was covered with unburned materials to a depth of approximately 12-15 feet.

Opening tunnel after fire extinguished.

A cleanup operation was established at both portals, each using 2-955 front and rubber tire machines and 2 D-6 dozers. Debris was removed from the tunnel by late evening Tuesday, November 17th, the 13th day, with scaling operation being accomplished by use of a Cat 225 excavator. Completion of track removal and grade work inside the tunnel was completed early morning Wednesday. All track work, ballast unloading, surfacing and lining of track was accomplished by 6:30 A.M., November 19th, the 14th day, when, at reduced speeds and under the direction of flagman around the clock, trains again began to move through Sproul Tunnel bringing empty hoppers to the now suffering mine fields, and moving loaded hoppers to all points on CSX for distribution. The first 24 hours, 19 trains were operated.

Considering the magnitude of the fire, we were pleased that service could be restored in just under two weeks. As you can see from this slide controlling the fire and cooling in order to prevent greater damage to the rock in the tunnel paid off in the time saved in cleanup and repairs.

After service was restored, we began permanent cleanup operations which included loading out of about 275 gondola loads of material, most of it combustible which had not burned, and shipping it to various landfill sites, including one near the site. This was completed by mid-December. The cost of this was not cheap, with the cost of fire fighting chemicals amounting to $255,000, but viewed against the daily loss of revenue, and the potential repair cost to the tunnel, we believe this was a good investment.

Peabody Coal, which assisted us throughout, has told us that they have since used the nitrogen foam procedure pioneered at Sproul in controlling a mine fire they had in February.

We did our best to cooperate with the West Virginia Department of Natural Resources throughout this emergency, particularly in the stringing of booms on the rivers, construction of settlement ponds, and removal of debris. Subsequent to reopening, however, considerable criticism was leveled at CSX

Shoulder Ballast Cleaner

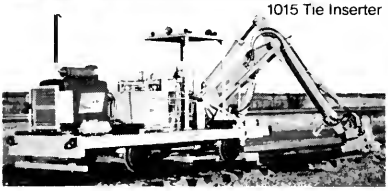
"Badger" Ditch Cleaning Machine

SX-16 Switch & Crossing Grinder

Loram's LRT Rail Grinder

SP-88 Rail Grinder

1015 Tie Inserter



First train operating through Sproul after 14 days of disaster.

by state officials, specifically as a result of problems experienced by downstream water districts. All of these issues were successfully resolved through negotiations, and we expect no further repercussions.

We are *not* going to reline Sproul Tunnel. Detailed inspection by our engineering people indicate that approximately 1800 rock bolts and selective shotcreting will be sufficient protection against further rock falls. We do, however, plan to construct new portals at each end due to the almost vertical rock over-burden.

Sproul Tunnel is now quiet. But its walls, roof and portals reflect the many scars of damage which resulted from the fire. This has not been the first, and perhaps won't be the last tunnel fire, but many valuable lessons have been learned from this experience, and to the many families effected from the loss of coal movement and "shutdown" of mines during the then approaching holiday seasons, this still remains as 14 days of "disaster."

Causes of Ballast Fouling in Track*

By: Ernest T. Selig[1], Bruce I. Collingwood[2], and Stephen W. Field[3]

Introduction

The AAR working group on ballast and subgrade maintenance has been investigating maintenance costs relating to ballast. The AAR study has concluded that the minimum average annual cost for ballast related maintenance is $5,400 per mile. This includes ballast purchase and transportation costs, as well as labor and equipment costs for one renewal with undercutting a d several intermediate surfacing cycles over the life of ballast. These costs are then converted to an equivalent annual cost per track mile. If 120,000 miles of mainline track were maintained this way by US railroads, the total average annual cost for ballast maintenance in the US would be approximately $650,000,000 -- a rather impressive sum of money. Even a 10% improvement through a better understanding of ballast behavior would save the railroads $65,000,000 per year, which is certainly worth considerable effort to achieve.

Because track surfacing and undercutting with associated ballast replacement are major cost items, the railroad industry should find substantial economic benefit from improved means of selecting the most cost effective ballast material and grading for a particular application. A major factor in this process is determining ballast life, that is the length of time until ballast becomes so fouled that it must be replaced.

This paper will describe recent research at the University of Massachusetts to develop a better understanding of the causes of ballast fouling in track. The objective is to help improve the ballast maintenance decision process.

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[1]Professor of Civil Engineering, University of Massachusetts, Amherst, MA
[2]Geotechnical Engineer, GEI Consultants, In., Winchester, MA
[3]Assistant Professor of Geology, Stockton State College, Pomona, NJ

*Basis of presentation by E. T. Selig and M. J. Klassen at 1988 March Technical Conference

This study was designed to extend the pioneering work by Klassen et al. (Ref. 1) for the Canadian Pacific Railroad. Their work has led to a new CP ballast specification.

Causes of Fouling

New ballast placed in track consists of clean, coarse, angular particles with a relatively narrow range of sizes. Over time ballast becomes fouled, that is the voids become filled with fine particles (fine sand and silt-clay sizes, termed fines) which impede drainage and degrade ballast performance. The worst condition is known as mud pumping when a slurry of fine particles and water squeezes out of the ballast surface.

A fundamental question is "how does ballast become fouled." A list of the potential sources of the fines is as follows:

1. Surface
   a) Dropped from trains
   b) Wind or water transported

2. Subgrade
   a) Pumping
   b) Seepage

3. Ballast breakdown
   a) Handling
   b) Tamping
   c) Traffic
   d) Environment (weathering)

All of these sources are known to be present, but their degree of importance varies appreciably with the specific combination of field conditions. Opinions of railroaders in Europe and North America as to the primary cause of fouling vary widely. There not only is no consensus, but there is practically no documentation to resolve any of the conflicting opinions.

UMass Study

Because an understanding of the causes of ballast fouling is essential to the development of improved maintenance practice, the AAR Working Group made the decision to have UMass collect field samples from a variety of track locations in North America (Fig. 1) and conduct laboratory analyses to determine the source of the fines. Sites were selected in consultation with

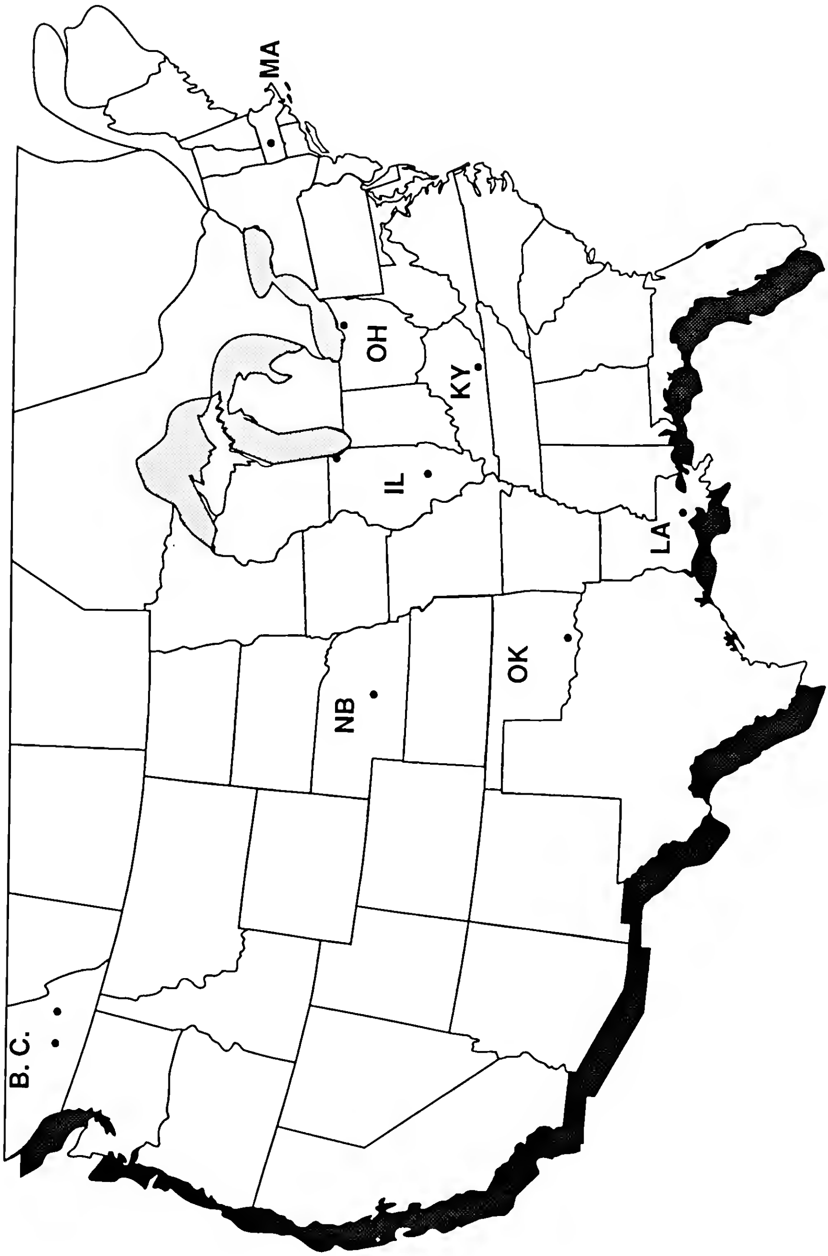

Fig. 1 Fouled Ballast Field Investigation Locations

railroad members of the working group. More details of this study can be found in Ref. 2.

At a designated site the first step in the process was to collect ballast samples from the crib and shoulder. Then the cribs and shoulder around one tie were carefully removed to the base of the tie, so than the tie could be pulled out without disturbing the remaining ballast. Ballast samples were then taken below the cribs and tie bearing area. Next a cross trench was dug under the track with a back hoe. The ballast, subballast and subgrade layers below the ties were then examined and sketched from the trench and representative samples taken of each material. Typical sample locations are shown in Fig. 2.

In the laboratory the samples were separated into coarse and fine components by hand and then sieved, inspected and photographed. Each size was examined under a microscope, with the aid of petrographic thin sections, to determine mineral composition.

Several examples will be given of specific site investigations. Then the results of the investigation will be summarized.

Kentucky Site

The Kentucky track site was in a cut with water in the drainage ditches standing at the level of the ballast. In some places mud was pumped to the ballast surface and slurry was splashed onto the rails. The ballast was completely fouled and saturated at the base of the ties. Fouling extended into the cribs and shoulders although the ballast surface in general appeared clean.

The cross trench showed (Fig. 3) a subgrade of good quality granular material down to rock at about 4 ft depth. There was no fine subgrade soil to account for the ballast fines.

In contrast in a nearby track area outside the cut the ballast at the base of the tie was only moist, and at the base of the crib was dry. Ballast breakage was present, but the ballast was only partly fouled, and no mud or slurry was present.

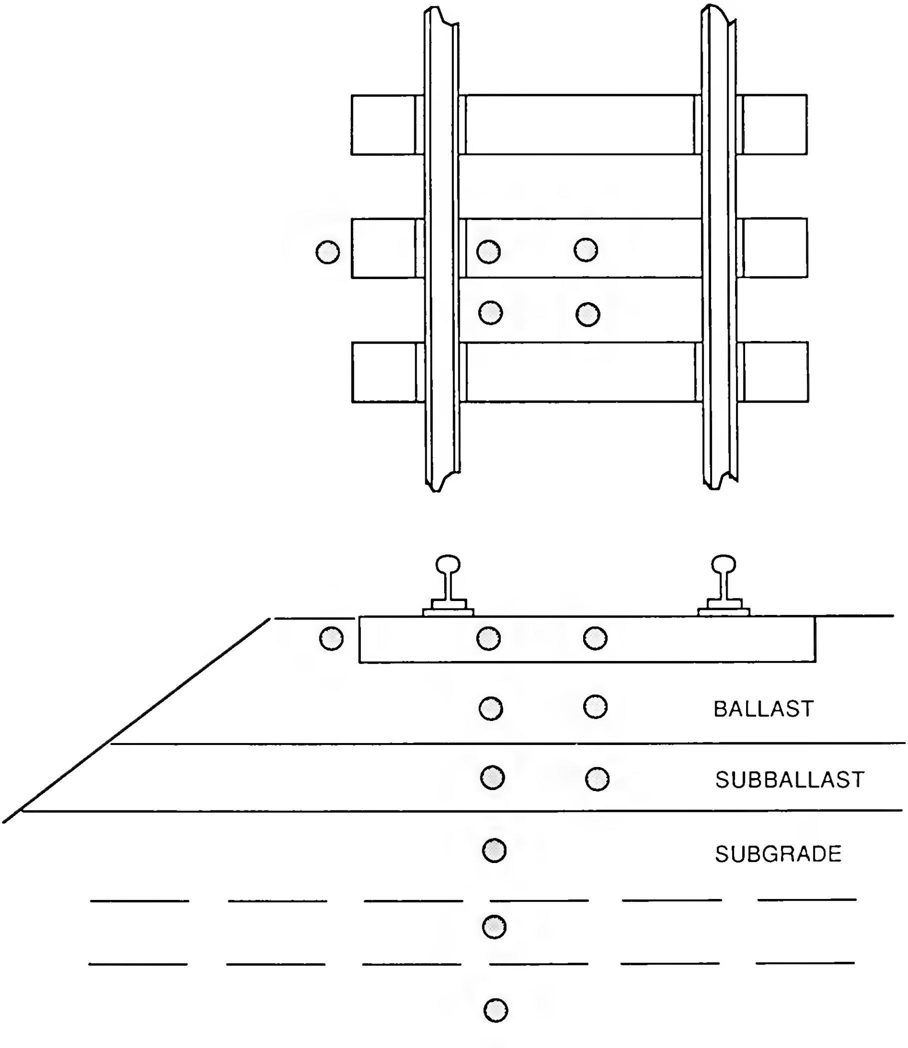

Fig. 2 Sample Locations

The track in this location carries about 25 million gross ton (MGT) of traffic per year. The ballast was replaced 2 years previous to the sampling and so became fouled in this short time period.

The laboratory examination of the fouled ballast in the cut showed that the composition was limestone with minor amounts of granites, gneisses and schists. The fines in all sizes appeared to be derived primarily from ballast breakdown, although some coal fragments and wood fibers were present. A likely cause of the extensive ballast mud is that the limestone contained pyrites which form sulfuric acid when kept in a wet state as in the cut. Limestones degrade rapidly to very fine particles in the presence of sulfuric acid. Mechanical breakage from train traffic will accelerate the process by exposing more ballast surface to this weathering action.

Louisiana Site

The Louisiana site was in a relatively flat terrain, but the subgrade was known to be weak, causing repeated occurrence of track roughness which required frequent surfacing. The site was reballasted 4 years prior to the visit and carries about 18 MGT traffic per year. Mud pumping to the surface was observed in many places and the ballast in general was highly fouled.

Inspection of the trench showed horizontal layers of ballast and granular subballast over a soft, lean clay subgrade (Fig. 4). There was no evidence of subgrade failure or subgrade intrusion into the subballast or ballast.

Laboratory analysis showed that the ballast consisted mainly of granite and syenite with feldspar being the dominant mineral. Particles of rock from mechanical breakage were observed in the sand sizes, but alteration of these particles to clay was clearly evident. Below the sand size the particles were mainly clay produced from weathering of the feldspar in the rock. Some quartz particles were also present as the non-weathered constituent. This weathering is probably accelerated by the warm, wet climate of Louisiana. Mechanical breakage from train loading is a factor as well because it greatly increases the particle surface area exposed to weathering.

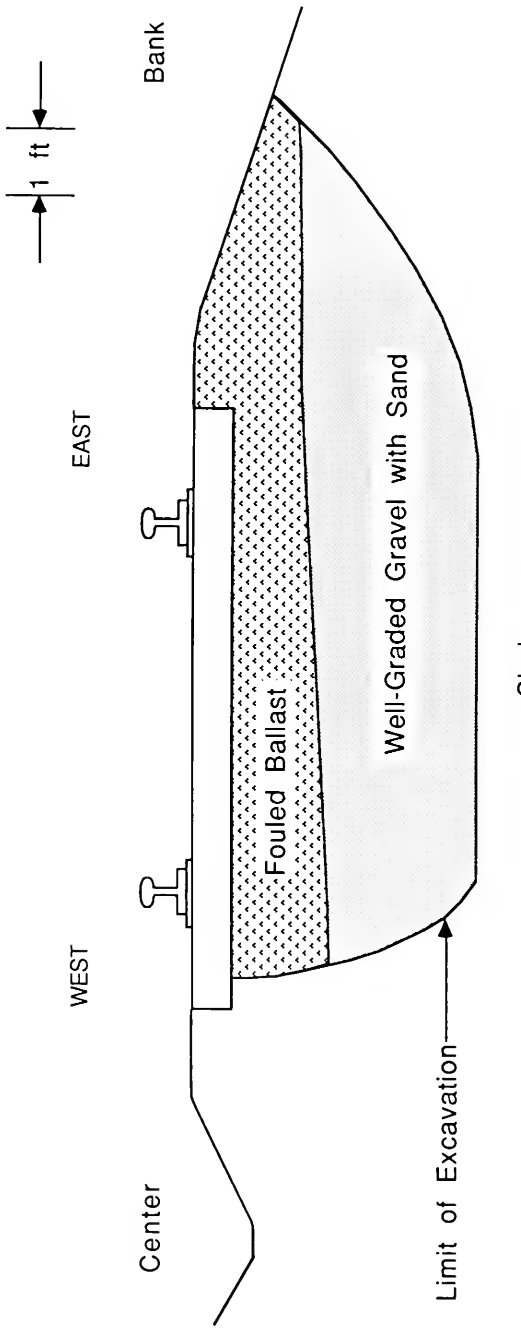

Fig. 3 Soil Profile at Kentucky Site

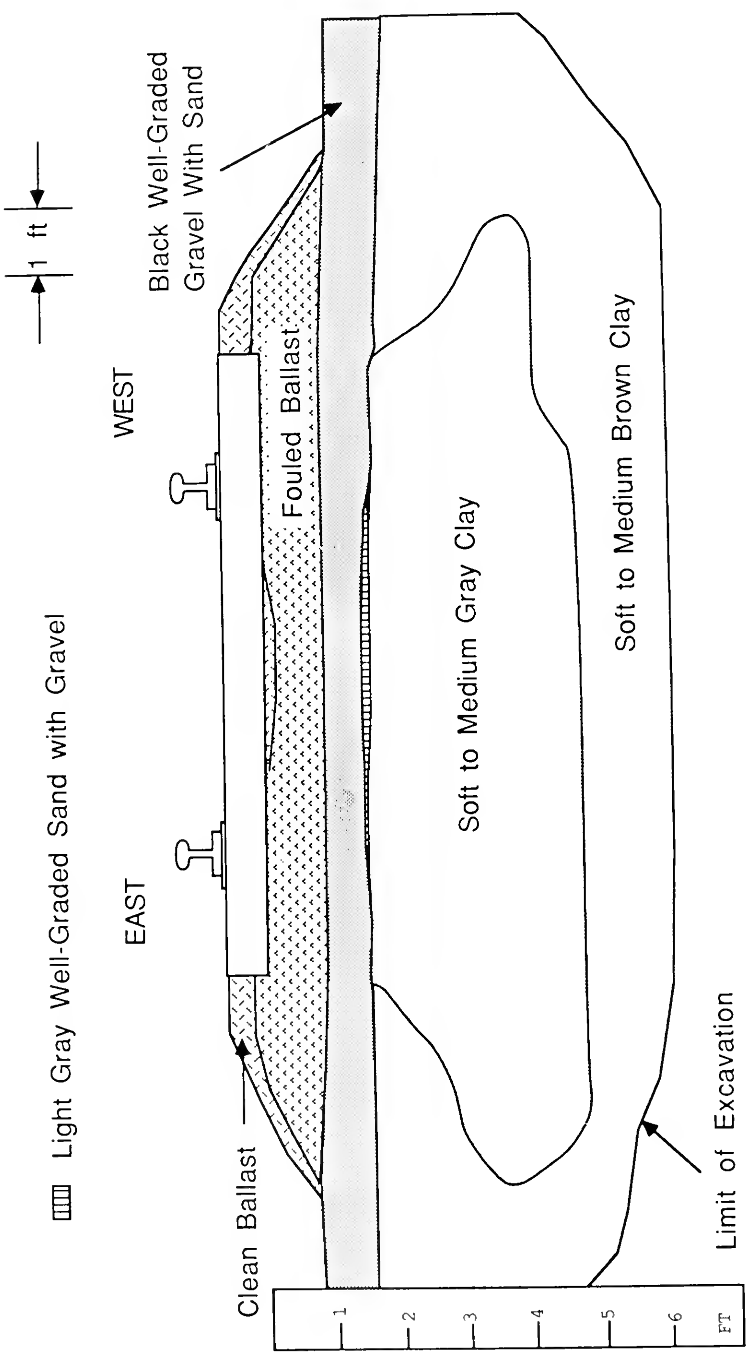

Fig. 4 Soil Profile at Louisiana Site

British Columbia Site

The British Columbia site was cut into a rock slope and so was well drained. The excavation was done by hand to subballast, so a trench was not available for subgrade inspection. However this track structure was built according to CP Rail specifications with 8 in. of ballast under the tie over 12 in. of gravelly sand subballast. This track was newly constructed 11 years prior to the visit and surfaced 4 years prior to the visit. The track carries 60 MGT traffic per year.

Except for the crib surface considerable ballast breakdown mainly into sand size particles was apparent, but the ballast was not fully fouled and still appeared capable of good drainage. The crib surface particles were probably placed in conjunction with the recent surfacing operation. No mud was present, and the total amount of clay was small.

Laboratory analysis showed that the most common rock type was basalt, but quartzite, marble and schist were also present. The coarse particles were dominantly volcanic breccia which means rock fragments of variety of origins (sedimentary, metamorphic, igneous rock) which have been welded into another rock mass. This explains why the ballast breaks readily into small particles. Clay aggregates were the main component of the fine sand size and the clay formed the majority of the material finer than sand. This clay was derived from the basalt. There was no indication of subgrade intrusion into the ballast at this site.

Massachusetts Site

The track at the Massachusetts site was on a high embankment which was well drained. The roadbed is estimated at 100 years old and cinders were apparently previously used as ballast. Perhaps 30 years ago traprock ballast was added and it has remained there without cleaning or replacement since that time. The track carried about 8 MGT traffic per year.

The cross trench (Fig. 5) showed clean ballast to 2 in. below the tie bottom. Under this was 18 in. of black, fully fouled ballast. A subballast

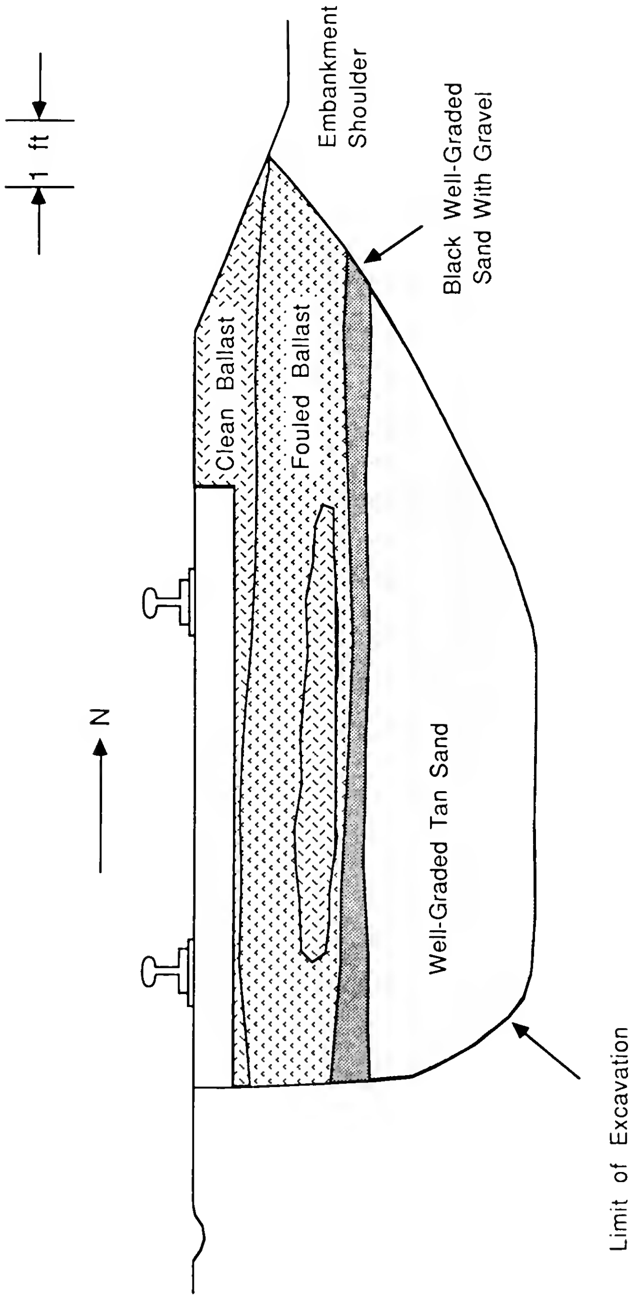

Fig. 5 Soil Profile at Massachusetts Site

layer of black gravelly sand separated the ballast from a tan sand subgrade containing cobbles and boulders. The ballast contained no mud and there was no evidence of subgrade intrusion into the ballast.

The laboratory investigation showed that the ballast composition was a coarse-grained basalt which is resistant to weathering and breakdown. Very little ballast breakdown was evident. The composition of almost all of the fine particles of sand size and smaller is a black carbonaceous material most likely derived from crushing of the cinders from the old track bed.

Conclusions from Site Investigations

Altogether about 20 sites were examined in the UMass study. The detailed laboratory work is still in progress on these sites. However the observations to date support the following conclusions:

1) Ballast breakdown was the primary cause of fouling.
2) In no case did the subgrade appear to be the source of ballast fouling.
3) In several cases the fouling was caused by surface infiltration of wind or water transported particles.

This leads to the conclusion that ballast has a finite life which is strongly influenced by traffic and environmental factors. Considering the enormous annual cost of ballast related maintenance, the potential economic benefit to the railroads of a better understanding of ballast fouling is great. Further ballast research should therefore be encouraged.

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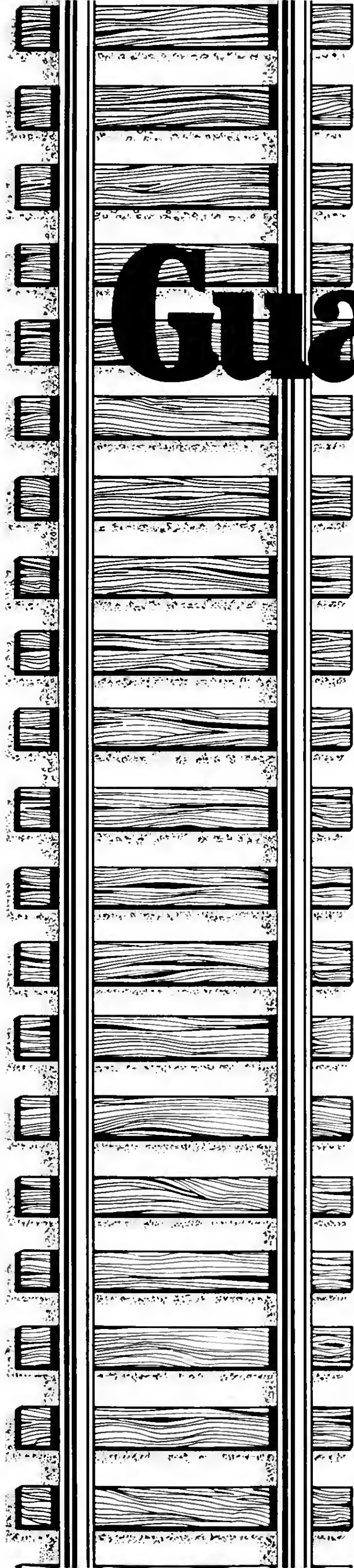


Acknowledgments

This research was sponsored by AAR under the general guidance of Dr. A. J. Reinschmidt. Planning and coordination of the field work was done in cooperation with the AAR working group on ballast and subgrade maintenance under the chairmanship of John D. Baker, Santa Fe Railroad. Steven Chrismer of AAR assisted with field trip arrangements and compiled the ballast cost information. Contact persons for the cooperating railroads whose sites were described in the paper were Richard L. Zimmerman, Norfolk and Southern; William C. Thompson, Union Pacific; Merle J. Klassen, Canadian Pacific; and Walter L. Heide, Conrail. Kok Wah Tung and Brian Byrne graduate students at UMass assisted with the testing. At the time of the study Bruce Collingwood was a graduate student in the Civil Engineering Department at UMass and Stephen Field was a graduate student in Geology Department at UMass.

THE LARAMIE TIE PLANT ENVIRONMENTAL CLEANUP

By: Robert C. Kuhn*

Greetings from the world of environmental engineering—that realm within which we speak openly about such forbidden subjects as "Contamination," "Cleanup Costs," "Superfund," "CERCLA," "RCRA" and the grandaddy of them all—"PRP" or Potentially Responsible Party. There is now a category called "RPRP" which means "Really Potentially Responsible Party"—that's a PRP with money.

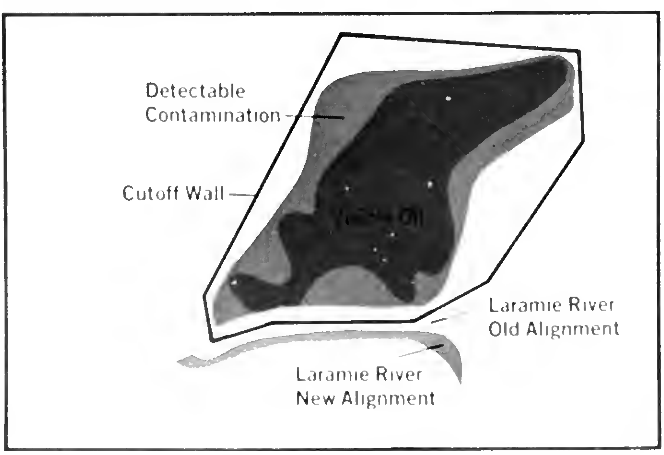
You know I don't believe I've ever known railroaders to gather to compare Superfund sites. In fact, being an environmental engineer on the railroad often has all the advantages of leprosy. We are engaged in an activity with little opportunity for cost avoidance and seemingly zero potential to contribute to the bottom line except in the negative. In our modern competitive atmosphere, our reputation as environmental engineers is often one of "The Big Spender."

The picture is not all bad, but it is very important to develop a perspective as to what present regulations call for. Our challenge is to develop ways of conducting our business which do not perpetuate a legacy of messes for future generations to deal with. It's a lot like the public debt! Until we stop overspending, we can't hope to reduce the debt. We are still polluting our properties more than is reasonable. Much of what we hear from state and federal environmental agencies touches on past (and present) sloppy waste disposal practices in our industry. I'm not here to preach about it, but you all know what I mean.

The defense mechanism is denial that the problem exists.

This was much the same with us at Union Pacific as we reviewed the results of preliminary soil borings at our Laramie site in 1981. At that time, we operated a tie treating plant at Laramie serving the eastern portion of our system. Over the next four years, through early 1985, we performed about three million dollars worth of tests and engineering studies to define a 140-acre plume of creosote and oil lying on a bedrock surface 12′ below the ground surface, migrating slowly westward toward the Laramie River.

Site Location



The 140-acre contaminated area ran right up to the edge of the Laramie River, which posed a threat of human exposure to the contamination.

*Director Environmental and Mechanical Design, Union Pacific Railroad

Today I want to summarize this investigation and to describe the site isolation system we have put in place to prevent migration while we determine the required cleanup plan and accomplish it.

The Laramie Tie Plant was built in 1886 about one-half mile east of the Laramie River along our main line track, south of the community of Laramie. The plant operated 97 years, treating an estimated 50 million ties. It served as a field experimental station for the U.S. Forest Products Laboratory of Madison, Wisconsin in the mid-1920's when preservatives and treatment methods were in their early development stages. Laramie was a major station on the Union Pacific, with a passenger depot, steam locomotive shop, a tie treating plant and an ice house operation during the early 1900's. We hit our peak employment in Laramie in 1946—employing 1,460 people. Today, we have less than 100 people in Laramie.

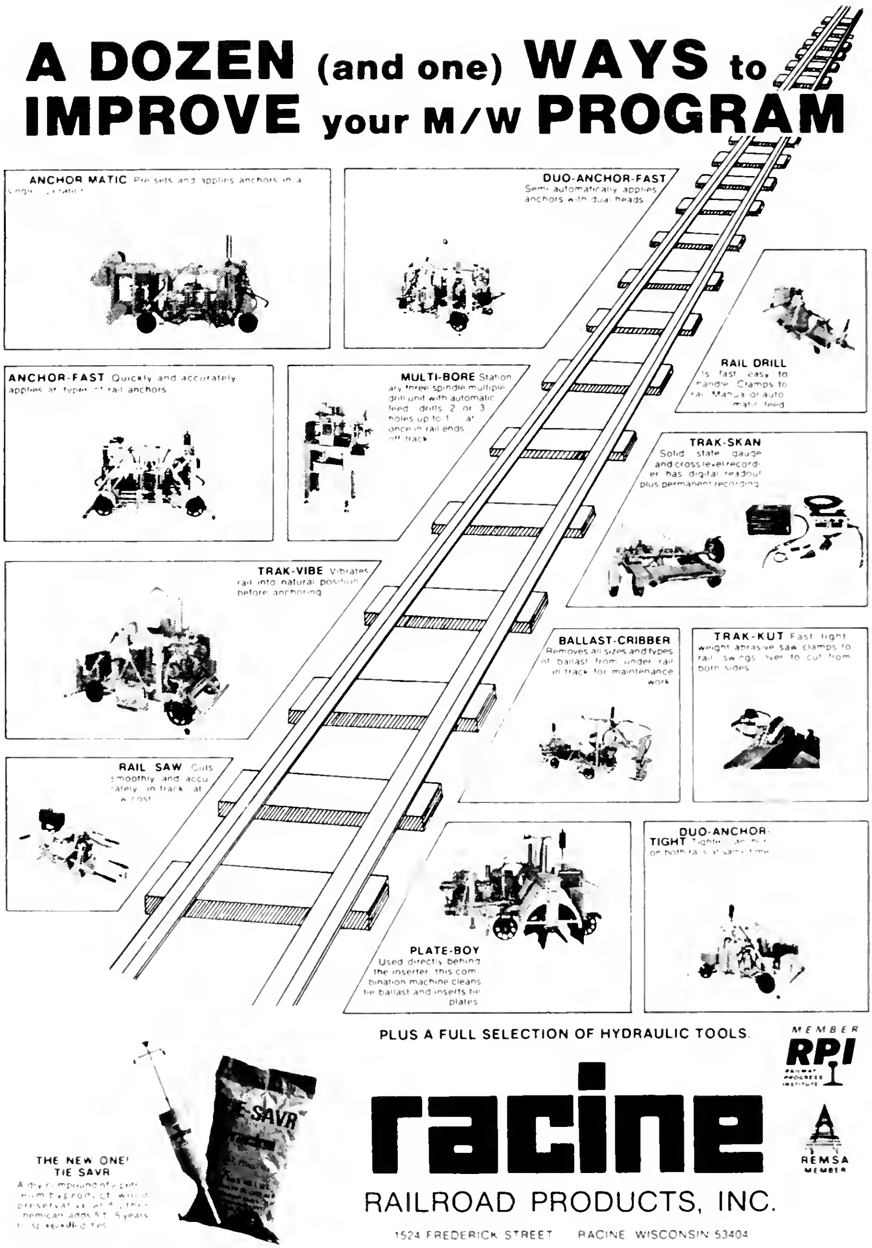
Between the tie plant and the river were ponds created by damming the river. These ponds were used to harvest ice in winter for summer cooling of perishable goods shipped by rail. These ice ponds ultimately served double duty as a collector for green hand-hewn ties floated down the river in the drives each spring. This practice continued through the early 1900's and became a connection between the river and the tie plant. In the 1940's the tie drives were discontinued, the dam removed and the ponds partially filled with dirt and shop wastes. The river channel was restored to its natural meander and ties were received by rail at the plant. There is evidence these ice ponds had become contaminated with creosote.

In early years at the plant, waste water was discharged onto the ground. The waste water and the products it carried either soaked into the ground or followed the pull of gravity to the river. Various oil separation attempts were made, but in the late 1950's a series of unlined ponds were installed to intercept the waste flow. These were not the ice ponds mentioned earlier, but small ponds for wastewater evaporation. By the mid-1970's the tie plant was a significant black spot on the ground colored by the residue of 85 years of timber preservatives ranging from the early zinc chloride treatment to the more recent creosote and oil mix and Penta.

In 1981 we hired a consultant to investigate the site. In October 1981, based on the preliminary tests, the State of Wyoming requested we clean up the site. After further soil and water testing and some anguished negotiations, the litigation was suspended by the State of Wyoming in favor of a four-phased approach to addressing the site. The pond facilities were already registered by the federal EPA as a RCRA facility, and during this period the site was added to the Superfund-NPL as a hazardous waste site. It became evident that we would have to satisfy the requirements of several agencies with our cleanup efforts. On March 21, 1983, Union Pacific announced the permanent closure of the plant.

The testing (Phase II-Remedial Investigation) continued through 1985. We borrowed shocker gear from fish and game. There were plenty of fish, plenty of volunteers and we found no site-related contaminants in the fish flesh. We collected thousands of soil and groundwater samples from about 300 test borings and monitoring wells. By early 1985, we had mapped out the contaminated area which amounted to about 140 acres.

During late 1984 and early 1985, the wastewater ponds' contents were removed and disposed off site and the plant facilities were demolished. It was a messy process to recover the creosote/oil mixture and ship it to another tie plant for reuse. We applied heat to allow solids to settle out and drive off some water. We recovered 700,000 gallons of creosote and oil. There were 300,000 gallons of water treated on site and discharged to the local sewer system. 15,000 cu. yds. of sludge solidified with kiln dust were shipped to hazardous waste disposal at USPCI at Grassy Mountain, Utah. During late 1984, we removed all the asbestos from the plant facilities. In early 1985 the plant was demolished. All work was done under health and safety precautions and equipment was decontaminated before leaving the site on a decon slab. The steel was all cut up and sent directly to a smelter to preclude reuse.



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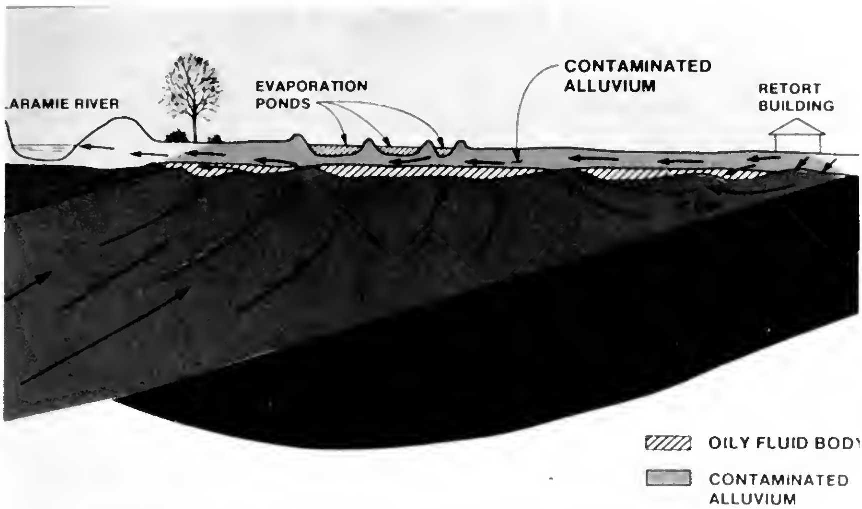

CONTAMINATION AT THE UPRR TIE PLANT

We should describe the stratigraphic picture of the site subsurface. There is an alluvial more or less sandy soil layer of about 10 to 15 feet of depth covering the site. This layer has been disturbed over long history by the Laramie River and in recent history by Union Pacific Railroad. The site has a gentle cross slope over its half-mile width dropping about 15 feet from east to west toward the river. There are three bedrock aquifers subcropping into the alluvium. They are the Morrison, the Sundance and the Chugwater. The dip is nominally 4° down to the west for all three structures. The Sundance bedrock aquifer is artesian within the site. In plan view, most of the site contacts the Sundance.

There is a lens of contamination down through part of the Morrison to the west and some in the shallow Sundance to the east. Fortunately there are no water wells in the vicinity affected. The EPA verified this in an independent study.

Because the waste had migrated to the river's edge and beyond in the river bed, we decided to move the river channel west about 150′ and construct a below-ground cutoff wall to contain migration of the contaminants. The river relocation took place in the Fall of 1985. The new channel was designed to match the length and flow characteristics of the old channel and it included fish habitat and replacement of riparian vegetation and wetlands. We had to coordinate with four state agencies, five federal agencies, three local government commissions and departments and three departments of our railroad to move this river. The construction only took about three months.

The site isolation system consists of a soil-bentonite slurry trench cutoff wall with a reverse gradient water management system. There is a water treatment plant consisting of a gravity separator followed by activated carbon filters. All excess water is treated and discharged to the river under a NPDES permit. In plan view, the slurry trench cutoff wall is a closed figure about 2 miles long. Its depth ranges from a shallow 15 feet along the east side to almost 80 feet at the northwest corner.

The reverse gradient is maintained by keeping the water table inside the wall one foot below the groundwater level outside the wall. This is accomplished by means of oversized perforated pipe drains at the required elevations.

Backhoe with 70 ft. boom for cut-off wall excavation.

Cutoff wall construction took place during 1986 and the wastewater plant was completed in the Spring of 1987. Excavation was mainly with a backhoe with a 70-ft. boom. The trench is kept full of water/bentonite slurry to support its walls. All excavation is by feel under the slurry. The backfill is mixed on the ground next to the trench using fine-grained soil, bentonite and water, in accordance with a predesigned recipe to achieve the required low permeability. It is then pushed into the trench displacing the slurry mix.

The excavation and backfilling operations proceed at a pace which keeps several hundred feet of trench open (filled with slurry but not backfilled) at a time. The deeper excavation in the harder Morrison rock along the west side was accomplished by predrilling 30" holes on six-foot centers and then removing the remaining material with a clam shell and chisel arrangement. The backhoe bucket was a large capacity with hardened steel teeth. In spite of this, teeth were constantly broken or bent and an extra bucket was required. The backhoe crawled on a timber platform. The clam bucket was a heavy steel item which was a formidable battering ram itself.

The bentonite was delivered in large bags each containing nearly a cubic yard of material. It was distributed by pulling a tab on the bag while it was suspended from a crane line. The bentonite for the backfill was spread on the ground for mixing with soil and water. A special mix of Portland cement was used for portions of the cutoff wall under the tracks. We crossed twice under our main line and under three yard tracks. The mix of concrete was tested during placement and the soil bentonite mixture was continuously sampled and tested.

Mixing backfill material on the ground.

The drain lines to maintain the reverse gradient and to feed the water treatment plant were installed as continuous pipe placement. The perforated plastic pipes were installed in a bed of pea gravel. Manholes were then added at appropriate locations.

We have considered a number of alternate remedial actions ranging from "Do Nothing" to "Full Excavation and Incineration." The costs ranged from $100 million to over $500 million. We are presently attempting to demonstrate that we can treat this soil in situ (in place) at a cost near the low end of this range. This would involve oil recovery and enhanced oil recovery, followed by an extended period of biological treatment to oxidize the remaining contaminants.

PUBLISHED AS INFORMATION BY COMMITTEES

COMMITTEE 4—RAIL

Chairman: A. W. Worth

Report of Subcommittee 3
Rail Statistics

Subcommittee Chairman: A. E. Shaw, Jr.

Consolidated Report of Rail Shipped to North American Railroads from North American and Non-North American Producing Mills in 1986 By Weight and Section

Weight	Section	N. American Tons Shipped	Non-N. American Tons Shipped	Total	% Total
140	AREA	2,246	0	2,246	0.30
136*	AREA	284,773	72,670	357,443	43.10
133	AREA	103,807	18,000	121,807	14.70
132	AREA	70,058	95,626	165,684	20.00
122	CB	4,068	0	4,068	0.50
119	AREA	11,399	2,531	13,930	1.70
115	AREA	106,416	44,582	150,998	18.20
100	AREA	3,237	0	3,237	0.40
100RA		9,007	0	9,007	1.10
OTHER		0	193	193	.02
	TOTAL	595,011	233,602	828,613	100.00

*Includes 136# rail which has modified head contour by some roads.

COMMITTEE 13—ENVIRONMENTAL ENGINEERING

Chairman: R. C. Brownlee

Report of Subcommittee 3

Subcommittee Chairman: R. G. Alderfer

Solid and Hazardous Waste Management— An Overview of Regulations

Foreword

The purpose of this document is to introduce the basic structure and content of regulations affecting the management of solid and hazardous waste to railroad personnel responsible for compliance. The legal foundation for these regulations is the Resource Conservation and Recovery Act (RCRA) of 1976 and the Hazardous and Solid Waste Amendments (HSWA) of 1984.

There are three goals established by RCRA and three distinct but related programs developed to achieve these goals. The RCRA goals are:

- To protect human health and the environment,
- To reduce waste and conserve energy and natural resources, and
- To reduce or eliminate the generation of hazardous waste as expeditiously as possible.

While these goals were established in pursuit of the public interest, all of them (especially the second and third) also have direct benefit to operating railroads. Waste reduction means reducing the regulatory burden and waste management costs.

The three interrelated programs to achieve RCRA goals are:

- The Solid Waste Program (RCRA Subtitle D),
- The Hazardous Waste Program (RCRA Subtitle C), and
- The Underground Storage Tank Program (RCRA Subtitle I).

It is important to note that Subtitle D encourages states to develop comprehensive plans for the management of solid waste, therefore each reader is encouraged to investigate in detail the status of these programs in states where his or her railroad operates. Many states are also active in hazardous waste management, therefore state programs related to hazardous waste must be investigated as well. It is important to note that the RCRA definition of solid waste includes non-hazardous wastes and wastes which are not solid (see 3.1, Definition of Solid Waste).

Whereas RCRA and HSWA describe the kind of program Congress sought to establish, it is the RCRA regulations which tell how the policy objectives of the Act are to be carried out. As regulations are being developed by the Environmental Protection Agency (EPA), they are published for review and comment in the Federal Register. Each year, RCRA regulations are compiled and published in the Code of Federal Regulations (CFR), specifically Volume 40, Chapter I, Subchapter I - Solid Waste, Parts 240 to 271. Hence, the shortened citation 40 CFR Part 240, etc. It is vitally important that persons with responsibility for compliance with these regulations monitor them regularly because of frequent and substantial changes.

One very significant provision of HSWA is that it directs EPA to develop regulations for small quantity generators. Prior to this directive, EPA regulated only those facilities generating more than 1,000 kilograms (2,200 pounds) of hazardous waste each month, although certain states regulated facilities generating smaller quantities. Under the new regulations, facilities generating between 100 kilograms and 1,000 kilograms are also regulated by EPA, although certain provisions are less stringent than for facilities which generate more than 1,000 kilograms per month. This means that certain railroad facilities which were previously unaffected by RCRA are now directly affected. Repair shops, paint facilities, car washing facilities, fueling facilities etc. which handle more than 100 kilograms per month of any hazardous waste (or roughly one-half of a 55 gallon drum) must comply with RCRA regulations. See Section 3.3 of this report for information pertaining to small quantity generators.

As a general guide to the lengthy and complex regulations promulgated under RCRA, it is helpful to answer the following questions.

1. Does the facility in question generate a RCRA solid waste? (See Subtitle D of RCRA - Managing Solid Waste)
2. If the facility in question does generate solid waste, is any of that waste hazardous? (See Subtitle C of RCRA - Managing Hazardous Waste. It is this subtitle which outlines the well known "cradle to grave" provision for the management of hazardous wastes.)
3. Does the facility in question use underground tanks for the storage of petroleum products and hazardous substances? (See Subtitle I of RCRA - Underground Storage Tanks)

3.1 A DEFINITION OF SOLID WASTE

Under RCRA, the term "solid waste" is very broad. It not only includes non-hazardous solid wastes, but it also includes hazardous solid wastes and wastes which are not solid. More specifically, RCRA defines solid waste as garbage (milk cartons, coffee grounds), refuse (metal scrap, wallboard, empty containers), sludge from a waste treatment plant, sludge from a water supply treatment plant, scrubber sludges from an air pollution control facility, discarded materials including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations and from community activities.

It is important to note that the definition of solid waste excludes:

- Domestic sewage (untreated sanitary wastes that pass through a sewer system);
- Industrial wastewater discharges regulated under the Clean Water Act;

- Irrigation return flows;
- Nuclear materials, or by-products, as defined by the Atomic Energy Act of 1954; and
- Mining materials that are not removed from the ground during the extraction process.

The primary goals of the Solid Waste Management Program (Subtitle D, Sections 4001 to 4010 of the act) are to:

- Encourage environmentally sound solid waste management practices,
- Maximize the re-use of recoverable resources, and
- Foster resource conservation.

The two main components of the Solid Waste Management Program are:

1. Regulations applicable to the development and implementation of state plans, and
2. Criteria used as a minimum technical standard for solid waste disposal facilities and to identify open dumps.

These criteria are used as a set of minimum technical standards with which all solid waste disposal facilities must comply. The criteria cover eight areas: floodplains, endangered species, surface water, ground water, waste application limits for land used in the production of food chain crops, disease transmission, air, and safety. Specific requirements are set by the regulations under each of these areas. It is important to note that the criteria apply to all facilities, regardless of whether or not the state in which they are located has an approved management plan. Furthermore, states have the option of developing criteria more stringent than the federal ones.

In addition to serving as minimum technical standards, the criteria are used to identify open dumps. An open dump is defined as a disposal facility which does not comply with one or more of the Subtitle D criteria. Using the criteria, each state must evaluate solid waste disposal within its border to determine which, if any, are open dumps and therefore need to be closed or upgraded.

As a result of HSWA, Subtitle D criteria will be revised. HSWA requires that EPA prepare a report determining whether or not the criteria are adequate to protect human health and the environment from ground water contamination and whether or not additional authorities may be needed to enforce them. Furthermore, the criteria must be revised to cover facilities that receive hazardous household waste or hazardous waste from small quantity generators. Revisions will require ground water monitoring as necessary to detect contamination, establish criteria for the acceptability of new facility locations, and provide for corrective action as required. A permit program will be required for facilities which receive hazardous waste from small quantity generators.

3.2 HAZARDOUS WASTE DISPOSAL

Subtitle C of the Resource Conservation and Recovery Act establishes a program to manage hazardous wastes from "cradle to grave". The objective of the program is to assure that hazardous waste is handled in a manner that protects human health and the environment. RCRA authorizes EPA to regulate hazardous wastes with the following goals:

1. Identification of hazardous waste;
2. Establishing standards for hazardous waste generators and transporters;
3. Setting performance, design, and operation requirements for treatment, storage, and disposal (T/S/D)facilities;
4. Developing a system for issuing permits for hazardous waste facilities;
5. Setting guidelines to allow states to handle their own hazardous waste management programs; and
6. Establishing procedures for modification of hazardous waste activities.

In managing projects involving hazardous wastes, it is mandatory that current federal and state regulations be reviewed thoroughly to determine those which are applicable. Federal regulations pertaining to hazardous waste management are found in 40 CFR Parts 260 to 267.

3.2.1 IDENTIFICATION AND LISTING OF HAZARDOUS WASTE

A solid waste is hazardous if it meets any one of the following four conditions.

1. Exhibits, on analysis, any one of the characteristics of a hazardous waste as defined in 40 CFR Part 261.21 to 261.24 (Subpart C);
2. It has been named as a hazardous waste and listed in 40 CFR Part 261, Subpart D or state equivalent;
3. It is a mixture containing a listed hazardous waste and a non-hazardous solid waste (unless the mixture is specifically excluded or no longer exhibits any of the characteristics of hazardous waste); and
4. It is not excluded from regulation as a hazardous waste.

Furthermore, the by-products of the treatment of any hazardous waste are also considered hazardous unless specifically excluded. The four characteristics of hazardous waste defined by EPA are: ignitability, corrosivity, reactivity, and EP toxicity. Responsibility for determining whether or not a particular solid waste is hazardous falls on each generator. A generator who has listed waste which he considers not to be hazardous may petition the EPA to have that waste "delisted" and excluded from regulation under Subtitle C of RCRA. The petitioner must prove to EPA that the waste is not hazardous because of facility-specific variations in raw materials, processes, or other factors.

3.2.2 EPA REGULATIONS APPLICABLE TO HAZARDOUS WASTE GENERATORS

RCRA regulations (40 CFR Part 262) require the following of hazardous waste generators:

1. EPA notification/identification. Each generator must notify EPA of hazardous waste being generated and obtain a unique identification number. Without this number the generator is prevented from treating, storing, disposing of, transporting, or offering for transportation any hazardous waste.

2. Pre-transport regulations. EPA adopted Department of Transportation (DOT) regulations for hazardous waste transportation, and these regulations include the following:
   a. proper packaging to prevent leakage during normal transport conditions and during potentially dangerous conditions,
   b. identification of characteristics and dangers of waste being transported through appropriate labeling, marking, and placarding of packaged waste, and
   c. a generator may accumulate hazardous waste on-site for 90 days or less provided that specific requirements are met concerning proper storage, emergency planning, and personnel training.

3. The manifest. The Uniform Hazardous Waste Manifest (see Appendix A for sample form) is the key to managing hazardous waste from "cradle to grave". Through use of the manifest, generators track the movement of hazardous waste from the point of origin to the point of ultimate treatment, storage, or disposal (T/S/D). Information required on the manifest includes name and EPA identification number of the generator, the transporter, and the T/S/D facility; it requires DOT description of waste being transported; it requires a determination of the waste quantity being transported; it requires the address of the T/S/D facility to which the waste is being sent; it requires certification that the generator has in place a program to reduce the volume and toxicity of waste generation at his facility to the degree economically practicable; and finally, it requires that the T/S/D method chosen by the generator is that practical method currently available that minimizes the risk to human health and the environment to the greatest extent possible.

   It is important to note that the generator is responsible for seeing that any waste shipped from his facility arrives at its intended destination. This is confirmed by his receiving the generator copy of the manifest from the owner or operator of the facility to which waste is transported. If the generator does not receive his copy, he must report that fact ("exception report") to the EPA within 45 days of transporter acceptance of the waste.

4. Recordkeeping and Reporting. Generators who transport hazardous waste off-site must submit a biennial report to the Regional Administrator of EPA by March 1 of each even-numbered year. Many states also have annual or more frequent reporting requirements. These reports detail the generator's activities with regard to hazardous waste transportation during the previous calendar year or reporting period. Generators who treat, store, or dispose of their own hazardous waste on-site must submit a biennial report that contains the description of the type and quantity of hazardous waste being handled during the year and the method of treatment, storage, or disposal used. The generator must also keep a copy of each biennial report and any exception reports for a period of at least 3 years from the date the report was submitted.

3.2.3 EPA REGULATIONS APPLICABLE TO HAZARDOUS WASTE TRANSPORTERS

Transporter regulations were developed jointly by EPA and DOT to avoid contradictory requirements. Even though regulations are integrated, they are not included under the same act. A transporter of hazardous waste must comply with regulations under 49 CFR Parts 171 to 179 (the Hazardous Materials Transportation Act), as well as those under 40 CFR Part 263 of RCRA.

EPA standards apply only to off-site shipments of hazardous waste, and the transporter must comply with the following requirements:

1. Notify EPA. Each transporter must obtain a unique identification number from EPA and use it in the handling of any hazardous waste.
2. Carry the Proper Manifest in the Proper Form. The transporter is required to deliver the entire quantity of waste which he accepted from either the generator or another transporter to the designated facility listed on the manifest. If this cannot be accomplished, the transporter is required to inform the generator and receive further instructions. Before transferring waste to a T/S/D facility, the transporter must obtain an authorized signature from the T/S/D facility and date the manifest. Transporter must retain a copy of each manifest of waste hauled for 3 years from the date the hazardous waste was accepted by the initial transporter.
3. Report and Cleanup Spills. RCRA regulations require that transporters take immediate action to protect health and the environment in the event of an accidental release. If a federal, state, or local official with the appropriate authority determines that immediate removal of the waste is necessary to protect human health or the environment, he can authorize waste removal by a transporter who lacks an EPA ID and without the use of a manifest.

3.2.4 EPA REGULATIONS APPLICABLE TO OWNERS AND OPERATORS OF HAZARDOUS WASTE TREATMENT STORAGE AND DISPOSAL FACILITIES

EPA has established minimum national standards which define acceptable management of hazardous wastes under RCRA, 40 CFR Part 264. The provisions of the EPA standards are quite extensive and apply to owners and operators of all facilities which treat, store, or dispose of hazardous waste, except as specifically provided otherwise by EPA. The standards are designed to address the following areas:

- Who is Subject to Regulations (Subpart A);
- General Facility Standards (Subpart B);
- Preparedness and Prevention (Subpart C);
- Contingency Plan and Emergency Procedures (Subpart D);
- Manifest System, Recordkeeping, and Reporting (Subpart E);
- Ground water Protection (Subpart F);
- Closure and Post-Closure of Facilities (Subpart G);
- Financial Requirements (Subpart H);
- Use and Management of Containers (Subpart I);
- Tanks (Subpart J);

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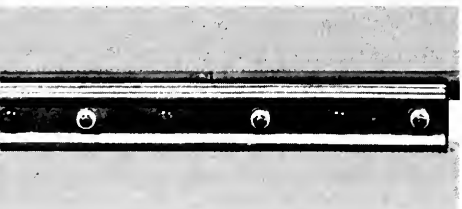

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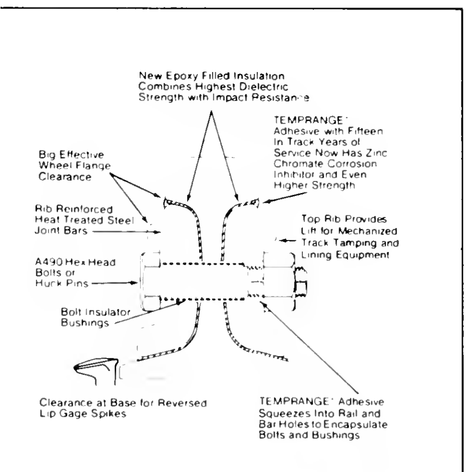

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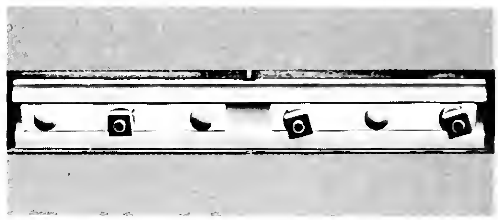

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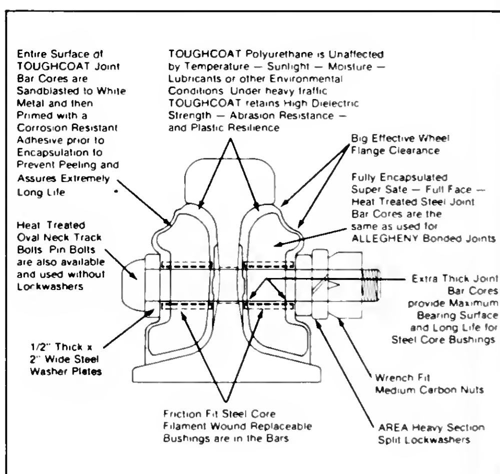

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- Landfills (Subpart N);
- Incinerators (Subpart O);
- Thermal Treatment (Subpart P);
- Chemical, Physical, and Biological Treatment (Subpart Q); and
- Underground Injection (Subpart R).

3.2.5 EPA PERMITS FOR TREATMENT, STORAGE, AND DISPOSAL OF HAZARDOUS WASTE

Provisions have been made by EPA for owners and operators of existing hazardous waste treatment, storage, and disposal facilities to obtain "interim status" under the regulation. These standards are presented in 40 CFR Part 265 and cover those areas identified above in Section 3.2.4. For new hazardous waste land disposal facilities, EPA has promulgated regulations for interim standards under 40 CFR Part 267. Additionally, individual state standards have been established and should be thoroughly reviewed for applicability.

3.3 PROVISIONS APPLICABLE TO SMALL QUANTITY GENERATORS

3.3.1 DEFINITIONS.

Those who generate between 100 kilograms (220 pounds) and 1,000 kilograms (2,200 pounds) per month of K-List, F-List, U-List or "characteristic" waste or any combination thereof and those who generate more than 1 kg. of P-List waste per month are regulated as "Small Quantity Generators". Those generating less than the amounts given here are not regulated under current programs. It is important to note that regulation as a "small quantity" generator does not mean reduced liability. While different management requirements apply as outlined below, responsibility for proper identification, registration, storage, transportation, and disposal lie with the generator; and penalties for improper management can be severe.

3.3.2 WASTE IDENTIFICATION AND REGISTRATION

Responsibility for determining whether specific wastes are hazardous or non-hazardous lies with the generator, and requirements for small quantity generators are the same as those for other regulated generators (see Section 3.2.1 of this document). Regulated small quantity generators are required to register their wastes with EPA and obtain Federal Generator Identification Numbers using EPA Form 8700-12.

3.3.3 STORING AND LABELING HAZARDOUS WASTE

Storing and labeling requirements for small quantity generators are also similar to those for other regulated generators. (See 40 CFR 265.170 - 265.177.) Containers must be DOT-approved, in good condition, and free of rust, damage or leaks. Special epoxy or plastic linings are required if the waste is acid or caustic. Reactive wastes may not be stored in the same container. Separate containers with reactive wastes must be stored in such a way that no hazard is created if they should leak. Containers must be closed except when adding waste. Reactive or ignitable waste should be stored no closer to property lines than 50 feet.

The storage area and storage containers must be inspected weekly for evidence of leaking and/or deteriorating containers. Each container must be clearly marked as to the date storage began and must also clearly show the label "Hazardous Waste". Furthermore, all applicable DOT warning labels such as "flammable" or "poison" must be applied.

Obviously, storage which complies with regulations summarized above can be achieved only with specific training of and instructions to operating personnel regarding what goes into each container, when it was placed there, detailed shipping records clearly referencing manifests, etc.

Specific regulations also apply to storage of hazardous waste in tanks (see 40 CFR 265.190-265.199). Applicable provisions for freeboard or secondary containment with uncovered tanks, waste feed cutoff or bypass, daily and weekly inspections must be researched and observed.

3.3.4 ON-SITE ACCUMULATION

Regulated small-quantity generators may accumulate up to 6,000 kilograms of hazardous waste on-site without a RCRA permit for up to 180 days (compare 90 days for other regulated generators). Regulated small-quantity generators who must transport waste over a distance of 200 miles or more for off-site treatment, storage or disposal may accumulate up to 6,000 kilograms of waste without a RCRA permit for 270 days or less. Generators are strongly recommended to contact their state regulatory agency to determine whether stricter or other provisions may apply to on-site accumulation.

3.3.5 SAFETY/CONTINGENCY REQUIREMENTS

Regulated small-quantity generators are required to meet certain minimum safety measures. An "emergency coordinator" must be available on-site or on-call at all times. The coordinator must be thoroughly familiar with the plant/facility operations as well as all emergency procedures. The coordinator may designate someone to act in his/her place.

Basic information must be posted next to telephones available to operating personnel:

- name/telephone number of Emergency Coordinator
- name/telephone number of local Fire Department
- location of all fire extinguishers and spill control equipment.

Other useful information may include Chemtrec (Chemical Manufacturers Association response network) or similar group telephone number, emergency response contractor telephone number (if applicable), key instructions or other useful reminders from spill response and contingency plans, access to computer-aided safety information, etc.

Each generator must ensure that operating personnel are trained and thoroughly familiar with proper waste handling and emergency procedures. Generators must investigate and comply, if necessary, with the "Hazard Communication Standard" established by the Occupational Safety and Health Administration (OSHA) and described in 29 CFR 1910.1200. Generators must also determine what, if any, state hazard communication standard or "right-to-know" regulations are applicable.

Other safety/contingency provisions which apply to small quantity generators include emergency alarm systems, available spill-control and fire fighting equipment, unobstructed aisle space, and written arrangements with local emergency response agencies.

3.4.6 SPILLS

If a spill of hazardous waste occurs, the emergency coordinator must contact the EPA National Response Center at 1-800-424-8802 if either of the following occurs:

- A spill endangers surface water, human health or the environment.
- A spill requires response by the fire department.

In addition, the generator must file a report of the incident with the applicable EPA regional administrator.

3.3.7 TRANSPORTATION

Generators must ship hazardous waste only with haulers having valid EPA transporter identification/registration. It is the generator's responsibility to complete the manifest accurately and completely (see Appendix A). Copies of manifests must be retained at the generator's place of business for at least 3 years.

3.3.8 WASTE MANAGEMENT/DISPOSAL

Since small quantity generators rarely dispose of their own hazardous waste, this report will not cover regulatory or engineering aspects of waste disposal. Generators are reminded that regulations concerning waste disposal are contained in 40 CFR 264. However, the following suggestions and reminders are made to small quantity generators regarding disposal.

- Septic tanks and similar systems may not be used for hazardous waste disposal.
- While many wastes cannot be discharged to publicly owned treatment works, under certain conditions, this option may be available. Under no circumstances, however, should any discharge take place without full coordination with and official permission from the pertinent agency(ies).
- Waste recycling is highly acceptable, may be economical for the generator and should be explored by contacting recycling firms, regulatory agencies or consultants familiar with these options. Similarly, waste exchange programs should be explored on a regional basis.
- In choosing a waste treatment/disposal firm, it is strongly advised that the generator verify the permit status of each candidate firm with EPA and perti-

nent state agencies. It is also strongly advised to visit each facility under consideration and obtain detailed, first-hand information regarding its capacity, status, operating procedures, and audit results if available. In this regard railroad personnel may benefit from a report by AREA Committee 13 entitled "Guide For Evaluation of Hazardous Waste Treatment, Storage and Disposal Facilities". Persons wishing copies of this report may contact the Chairman, Committee 13, c/o AREA Headquarters.

APPENDIX A

"Uniform Hazardous Waste Manifest"

(Note: The manifest form is state-specific;
the example shown on the following page is that used by Illinois.)

STATE OF ILLINOIS

ENVIRONMENTAL PROTECTION AGENCY DIVISION OF LAND POLLUTION CONTROL

2200 CHURCHILL ROAD SPRINGFIELD ILLINOIS 62794 9276 (217) 782 6761
P O BOX 19275

IL 532 0610
LPC 62 8 81

Please print or type

EPA Form 8700-22 (Rev. 9-86)

UNIFORM HAZARDOUS WASTE MANIFEST

1 Generator's US EPA ID No	Manifest Document No	2 Page 1 of
Information in the shaded areas is not required by Federal law but is required by Illinois law		
3 Generator's Name and Mailing Address		A Illinois Manifest Document Number IL 1924706
4 Generator's Phone ( )		B Illinois Generator's ID
5 Transporter 1 Company Name	6 US EPA ID Number	C Illinois Transporter's ID
		D ( ) Transporter's Phone
7 Transporter 2 Company Name	8 US EPA ID Number	E Illinois Transporter's ID
		F ( ) Transporter's Phone
9 Designated Facility Name and Site Address	10 US EPA ID Number	G Illinois Facility's ID
		H Facility's Phone ( )

GENERATOR

11 US DOT Description (*Including Proper Shipping Name Hazard Class, and ID Number*)	12 Containers No	12 Containers Type	13 Total Quantity	14 Unit Wt Vol	I. Waste No
a					EPA HW Number XX; Authorization Number
b					EPA HW Number XX; Authorization Number
c					EPA HW Number XX; Authorization Number
d					EPA HW Number XX; Authorization Number

J. Additional Descriptions for Materials Listed Above	K Handling Codes for Wastes Listed Above In Item # 14: 1 = Gallons 2 = Cubic Yards

15 Special Handling Instructions and Additional Information

16 **GENERATOR S CERTIFICATION** I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified packed marked and labeled and are in all respects in proper condition for transport by highway according to applicable international and national government regulations

If I am a large quantity generator I certify that I have a program in place to reduce the volume and toxicity of waste generated to the degree I have determined to be economically practicable and that I have selected the practicable method of treatment storage or disposal currently available to me which minimizes the present and future threat to human health and the environment **OR,** if I am a small quantity generator I have made a good faith effort to minimize my waste generation and select the best waste management method that is available to me and that I can afford

Printed/Typed Name	Signature	Date Month Day Year

TRANSPORTER

17 Transporter 1 Acknowledgement of Receipt of Materials

Printed Typed Name	Signature	Date Month Day Year

18 Transporter 2 Acknowledgement of Receipt of Materials

Printed/Typed Name	Signature	Date Month Day Year

FACILITY

19 Discrepancy Indication Space

20 Facility Owner or Operator Certification of receipt of hazardous materials covered by this manifest except as noted in item 19

Printed Typed Name	Signature	Date Month Day Year

"24 HOUR EMERGENCY AND SPILL ASSISTANCE NUMBERS" OUTSIDE

DISTRIBUTION PART 1 GENERATOR ... EPA PART ... FACILITY PART 4 TRANSPORTER PART ... IEPA ... GENERATOR

REV

GENERATOR COPY PART 1 DO NOT REMOVE PART 1 FROM SET UNTIL COMPLETED

This Agency is authorized to require pursuant to Illinois Revised Statutes Chapter 111 1/2 Section ... that this information be submitted to the Agency. Failure to provide the information may result in a civil penalty against the owner or operator not to exceed $25,000 per day of violation. Falsification of this information may result in a fine up to $50,000 per day of violation and imprisonment up to 5 years. This form has been approved by the Forms Management Center.

COMMITTEE 22—ECONOMICS OF RAILWAY CONSTRUCTION AND MAINTENANCE

Chairman: W. C. Thompson

Report of Subcommittee 9

Subcommittee Chairman: N. C. LaRocco, Jr.

ECONOMICS OF UTILIZING VARIOUS TRACK FIXATION SYSTEMS ON WOOD TIES

In today's environment of high speed, high frequency, high tonnage train traffic, railroad engineers have had to move beyond relying solely on the traditional work horse of the industry, the cut spike and double-shoulder plate to fasten rail to wood ties. A myriad of fasteners have evolved which range from simple adapations of the more traditional components, to systems which incorporate technology exclusive of the double-shoulder plate and cut spike. These various fixation systems are utilized to different degrees throughout the industry. The type of system, the installation location, the conditions encountered, the benefits gained and the installation and maintenance costs are all factors which are considered when making the decision to install conventional, modified or new fixation systems.

The American Railway Engineering Association Committee 22, Subcommittee 9, was assigned the task of studying the "Economics of Utilizing Various Fixations of Rail to Wood Ties, Other Than Cut Spikes and Conventional Plates." In order to accomplish this task, a questionnaire was developed, approved by the Committee membership and sent to the AREA headquarters for distribution to various railroad engineering departments. Eleven railroads responded. However, only six of the responding railroads presently utilize fixation systems in lieu of, or in addition to, cut spikes and conventional plates.

The fact that five of the responding railroads utilize the conventional system only is not insignificant (these railrods ranged in size from 200 main track miles to in excess of 6,000 main track miles exclusively dedicated to freight operations). It was evident from this initial observation that, in considering the subject question, many factors indigenous to individual railroads governed the decision to utilize various fixation systems. Although not stated, factors such as; satisfaction with the conventional system, lack of capital, low tonnage hauling, etc., may have contributed to the absence of modified or new fixation systems on these railroads. However, the reasons must be left to speculation.

On the other hand, the six railroads with positive responses gave clear reasons for utilizing the alternate fixation systems. The criteria used to determine fastener application was as follows:

Railroad 1:

This railroad utilizes plate hold down devices other than cut spikes on all curves 4° and over, and in areas of abnormal rail wear and short tie life. These fasteners were installed to improve track lateral stability, to improve rail change out and improve tie life. Once installed, gage widening and the need to regage was drastically reduced. Spiking during rail change out was eliminated, thus reducing the spike killing of ties, which, in turn, increases tie life and reduces maintenance costs.

The labor costs expended during installation are comparable to the cost of installing the conventional track plate and cut spike. The material costs, however, ran approximately 30 to 40 percent higher. One the other hand, rail change out is faster and easier, while ties are installed slower but less often. The overall cost of installation on existing track for this particular railroad, was found to be equal

NOTE: For purposes of this report, *conventional system* refers to cut spike, double-shoulder plate, and rail anchors; *hybrid system* refers to any of the aforementioned components in combination with another fixation component (i. e., lock spike, screw lag, lock in shoulder and clip, etc.); *direct fixation* refers to a system which afixes rail to plate and plate to tie with components other than the conventional components.

to that of installing conventional components, and the cost of installation on newly constructed track has proven to be much less. In addition, no new machinery or tools were required to install the fasteners.

The Engineering Department concluded that; the fifty track miles of non-conventional fasteners on wood ties are a vast improvement over the conventional cut spike design and are performing better than expected.

Railroad 2:

Railroad 2 utilizes a hybrid fastener system in a test installation intended to prevent rail turnover in a retarder yard where long cars, historically, passed knuckles and derailed. Since the installation two years ago, derailments have ceased.

The system utilized existing tie plates with a hook in shoulder and clip, and was more costly than the conventional system. The benefits realized are; less frequent maintenance, extended rail life, reduced rail replacement costs, and, of course, the primary one, the reduction in derailments and their negative effect on service. It was concluded that the additional costs were offset by the benefits.

Railroad 3:

Railroad 3 utilized two direct rail fixation systems to prevent longitudinal rail movement and reduce ties being cut by rail anchors. Ten-thousand fasteners were installed as a test to compare the performance of the direct fixation fasteners against the performance of the more conventional cut spike, tie plate and rail anchor. They concluded that the two test systems performed better than the conventional components. The additional benefits gained are; elimination of gage widening, reduced maintenance, extended tie life, reduced rail replacement costs, and reduced gage face wear. However, the cost of installation of the two fixation systems being tested was greater than the installation costs of conventional plate and cut spike. Material costs were approximately twice the cost of the standard cut spikes and plate, and labor costs were one and one half times as much.

In answer to the question: did the extra cost of labor or material justify the installation, Railroad 3 stated; due to the special handling, the extra cost will not be recovered in extended life and reduced maintenance. However, if it becomes an accepted standard and more adaptable to mass production techniques the extra cost will be justified.

Railroad 4:

This railroad utilizes a direct fixation system on wood ties as its standard on high volume track, and any new installations. Fifteen years ago, the Engineering Department upgraded the rail section for its main track, which required a purchase of new plates and anchors to facilitate the installation. An elastic fastener system was selected. The primary expectations of the fixation system were; greater longitudinal restraint, greater lateral track stiffness, reduced gage widening, reduction in down ties, reduced rail replacement costs and overall reduction in maintenance costs.

The results have been as expected. Gage widening and down ties have been practically eliminated. Rail replacement labor costs are considerably less. Tie life is extended somewhat due to reduced spiking during maintenance operations and reduced plate cutting due to mechanical action. Although tie installation has, historically, been negatively impacted due to lack of effective machinery, new production equipment recently introduced has made tie replacement costs comparable to that of the conventional system.

It must be pointed out, however, that initial installations utilizing cut spikes to affix the elastic fasteners and plates to the ties, experienced accelerated degradation of ties and surface conditions, and developed elongation of the holes in the plate and disintegration of the throat of the spike. This resulted in additional labor and material being expended to correct the problem.

Since direct fixation is the standard for much of the trackage, the initial installation cost versus that of the more traditional system is comparable. Due to economy of scale, the material costs for the direct fixation system are slightly higher than that of the cut spike, double-shoulder plate and rail anchor. However, the benefits gained outweigh the extra costs. The responder concluded: "public safety and one-time performance could not be equated into dollars."

Railroad 5:

Railroad 5 is presently testing three fixation systems on approximately 2.6 miles of wood tie track. The tests are being performed to fulfill the need to test different types of fasteners, to prevent gage widening on curves and to facilitate rail change out.

Two of the three systems tested are complete direct fixation systems, while one is a hybrid system utilizing standard double-shoulder tie plates. The installation costs range from 2-1/2 to 3 times more expensive for labor, and material costs range from 6 to 8 times more for the clips and screw lags or lock spikes, than the cut spikes they replaced. The fasteners did produce very positive results.

The fasteners were given credit for extending tie life by reducing mechanical wear and the need to spike during relay operations. On a 9° curve application gage widening due to mechanical wear associated with the cut spike, has been eliminated. In addition, rail change out production has been considerably increased in the test locations.

In all three locations which utilized three different rail hold down devices and three different plate to tie fasteners, the systems have performed as they were intended. As far as justifying the additional costs, this railroad stated: "In one case the rail is replaced every 4 years. Extra labor for the initial installation is off-set after the first replacement of the rail."

Railroad 6:

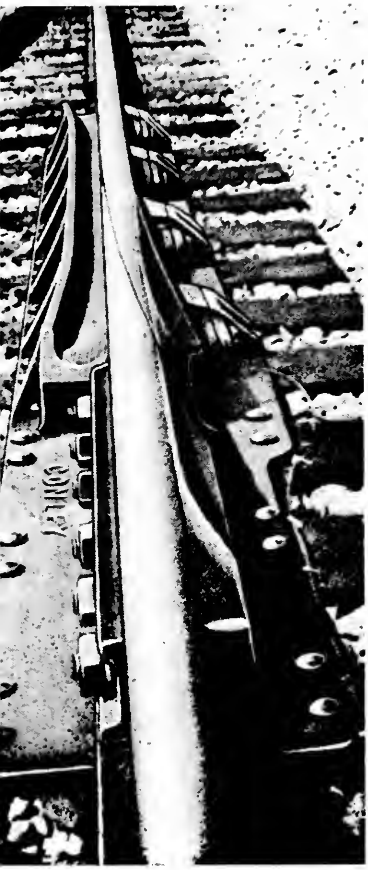
This railroad utilizes eight different fixation systems in addition to the cut spike and double-shoulder plates. Each application location was determined due to unique problems associated with curves, poor subgrade conditions, poor ballast conditions, drifting sand, and any other conditions which affected the cut spikes' ability to perform the function for which it was designed. The applications ranged from test sites one third of a mile long to an application of 100,000 components. The primary reasons for application were; comparison of systems, to resist rail turnover on curves, to develop better rail-plate-tie connection, to eliminate rail lift in sand or soft subgrade, etc.

Seven of the various systems were effective in performing to expectations (one is still being tested). Each site is subject to higher than normal mechanical loadings and was subject to gage widening. All the fixation systems reduced or eliminated the need for regaging. In all cases, the labor costs and the material costs for the systems were substantially greater than conventional systems. In one case, tools had to be modified to facilitate the one-shot application. All but one of the systems had a negative effect on tie installation, resulting in up to 15% reductions in productivity. The four systems, in which the rail hold-down device was independent of the plate to tie fastener reduced rail replacement costs considerably; while one had no affect; and the two which utilizes rail hold-down devices driven into the tie increased costs. Surfacing cycles were increased by the four direct fixation fasteners in varying amounts based on geographical location, while three hybrid systems had no effect.

All but one system is considered cost effective. Each has performed as anticipated, and savings from reduced maintenance and the elimination of derailments have offset the original installation costs.

Conclusion:

The various fixation systems other than the more conventional double-shoulder plate, cut spike, and standard rail anchor are not in wide use in the North American railroad industry. The reasons for



this vary. However, more engineering departments are looking for something better than the traditional system for use in specific trouble areas.

Research has shown us that elastic fasteners: (1) provide better longitudinal restraint than conventional systems; (2) prevent gage widening and rail rollover; and (3) provide increased resistance to lateral shifting or track buckling. These fixation systems, in combination with hard wood ties, have demonstrated their ability to provide savings due to reduction in derailments, increased tie life, reduced rail installation costs, reduced need for gauging, and to some extent, surfacing.

Although no economic calculations were performed, it was apparent from the responses that positive experiences and cost savings in the majority of cases warranted or justified the use and additional costs of the various fasteners. The data supplied demonstrated that utilizing the standard plate with a lock spike or screw lag for plate anchoring is demonstratively better than the conventional cut spike. Savings in tie life and gaging can be realized from this one component change. The use of an elastic or spring spike (vs. cut spike) has proven better in providing increased tie life, longer surfacing cycles, and elimination of gage and rail rollover problems, however, are offset by increased tie and rail installation costs. The use of a hook in shoulder with conventional plates and lock spike or screw lag provide all the benefits of the previous system as well as the reduction in rail installation costs. The complete elastic fixation systems provides all the benefits of the other fasteners however, on a greater scale.

Railroads will continue to investigate these various fixations and find them to be economic alternatives to existing maintenance of way practices. The decisions to change from one system to another will be based on sound economic analysis for each application.

When making this economic evaluation, the railroads should utilize a cost benefit analysis similar to the following:

ADDITIONAL INSTALLATION COST/TIE		ESTIMATED SAVINGS/TIE	
Material Cost	- $ ________	Transposing Rail (____ Yr.)	- $ ________
Labor Cost	- $ ________	Relaying Rail (____ Yr.)	- $ ________
Machinery Cost	- $ ________	Rail Wear/Year	- $ ________/Yr.
Total Additional Cost	- $ ________	Tie Life Savings/Year for ____ Yrs.	- $ ________/Yr.
		Maintenance Savings/Yr. for ____ Yrs	- $ ________/Yr.
		Surfacing Savings	- $ ________/Yr
		Derailment Savings	- $ ________/Yr.
		Total Estimated Savings/Tie	- $ ________/Yr.

Whether a railroad uses net present value, discounted cash flow, payback period, or any other economic analysis methodology, the aforementioned table can be utilized to compare the savings and the additional costs, resulting from the application of a non-conventional fixation system.

COMMITTEE 24—ENGINEERING EDUCATION

Chairman: C. E. Ekberg, Jr.

Report of Subcommittee No. 1—Recruiting

Subcommittee Chairman: J. W. Orrison

A survey of MW&S Chief Engineers concerning college graduates hired in 1987 has been completed. Replies were received from 20 of the 20 railroads of which information was requested. Eight graduates were employed during 1987, compared to 44 during 1986.

Table 1 summarizes the type of degree and major courses of study for 8 newly employed graduates. Table 2 shows a summary of schools represented by the graduates employed.

Four of 20 responding railroads employed at least one graduate in 1987. Three graduates were employed by one railroad, 2 graduates by 2 railroads and one graduate by the fourth hiring road. The average number employed by hiring railroads was two.

Only one of the graduates hired had prior experience. Employment of electrical engineering graduates decreased from 12 in 1986 to 6 in 1987, while hiring of civil engineers dropped from 23 in 1986 to 1 in 1987.

The average monthly salary of the 8 graduates employed is provided in Table 3. Salaries reported by U.S. railroads included a high of $2,375 per month and a low of $2,100 per month. Of the railroads hiring graduates, one paid all graduates the same salary regardless of experience.

Co-op student programs were provided by three railroads with the companies sponsoring 27 students in 1987. The sponsoring railroads paid salaries ranging from $1,270 per month (new co-op students) to $1,690 per month. Table 4 lists schools of railway-sponsored co-op students. All railroads sponsoring more than one co-op student selected from two or more universities.

Table 1.

Degrees and Major Courses of Study of College Graduates Employed by Railroads

Degree		Number of Graduates					1987 Distribution	
		1983	1984	1985	1986	1987	US	CA
B.S.		30	84	45	43	7	4	3
M.S.		1	5	4	0	0	—	—
B.A.		—	1	1	1	1	1	—
	Total	31	90	50	44	8	5	3

Major Course of Study

		Number of Graduates					1987 Distributions	
		1983	1984	1985	1986	1987	US	CA
Civil Eng.		22	57	45	23	1	1	0
Electrical Eng.		3	15	1	12	6	3	3
Business		—	4	1	1	0	—	—
Eng. Tech.		1	3	1	1	1	1	—
Construction Eng.		2	3	1	3	0	—	—
Transportation		—	1	1	1	0	—	—
Other		3	7	—	3	0	—	—
	Total	31	90	50	44	8	5	3

Table 2.

Schools of College Graduates Employed By Railroads During 1987

McGill University	2
New York Institute of Technology	2
Bucknell	1
University Manitoba	1
University Pittsburgh	1
Southern University	1

Table 3.

Average Monthly Salaries

Categories	America—US $		Canada—CA $	
	1986	**1987**	**1986**	**1987**
Overall Average	2223	2231	2447	2387
Bachelor				
w/Prior RR Experience	2297	—	2387	2387
w/No Experience	2220	2231	2573	2387
Civil Engineering	2137	2100	3153	—
Electrical Engineering	2380	2301	—	2387

Table 4.

Schools of Co-op Students by Railroads During 1987

School	Number of Co-ops
North Dakota State	4
Georgia Tech	3
Nebraska	3
University of Tennessee	3
University of Waterloo	3
Alberta	2
New Mexico	2
U.T.—Chattanooga	1
Alabama	1
Clemson	1
University of Calgary	1
University of British Columbia	1
University of Sherbrooke	1
University of Wisconsin	1

DIRECTORY OF CONSULTING ENGINEERS

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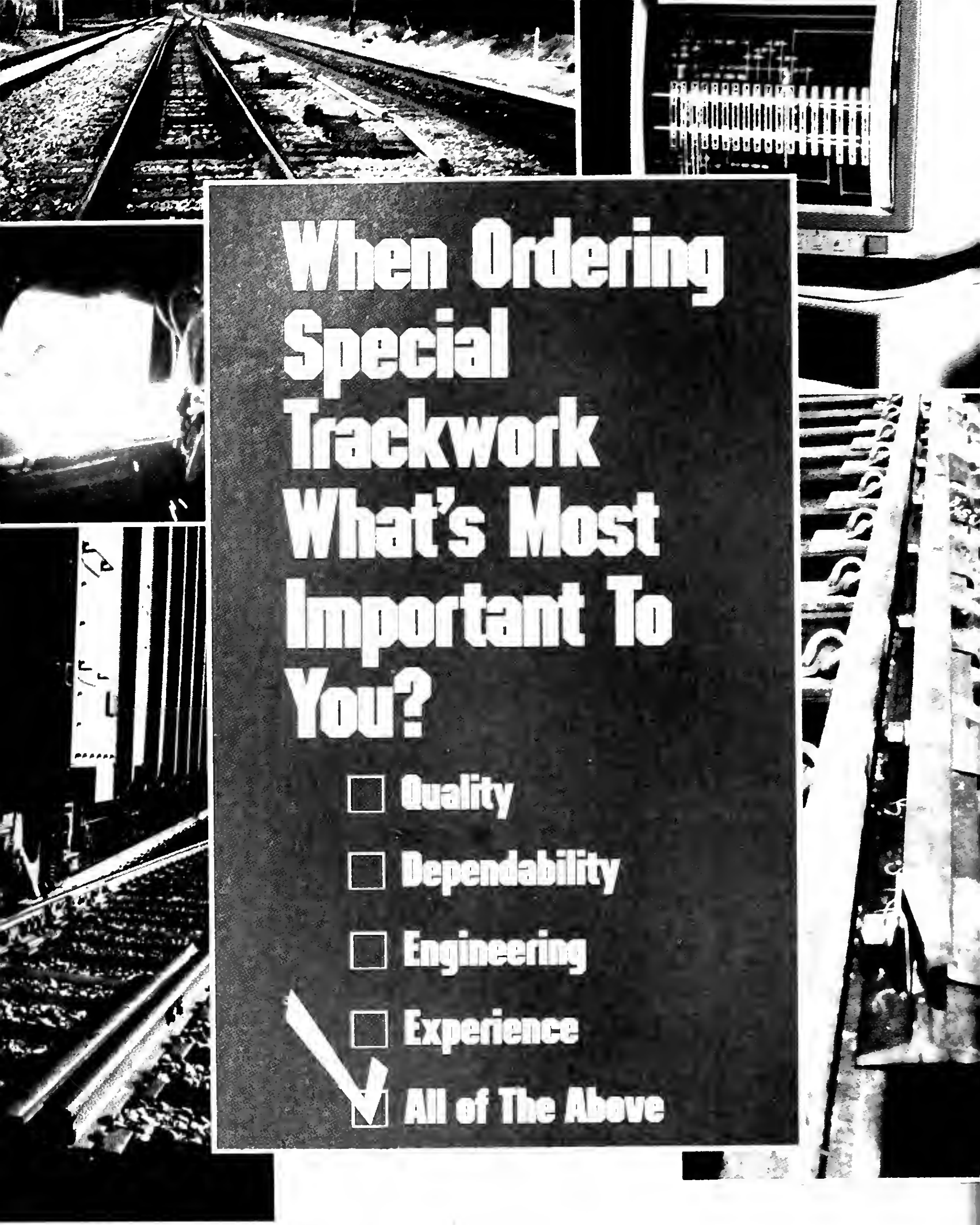
When Ordering Special Trackwork What's Most Important To You?
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Experience
All of The Above

AMERICAN RAILWAY
ENGINEERING ASSOCIATION

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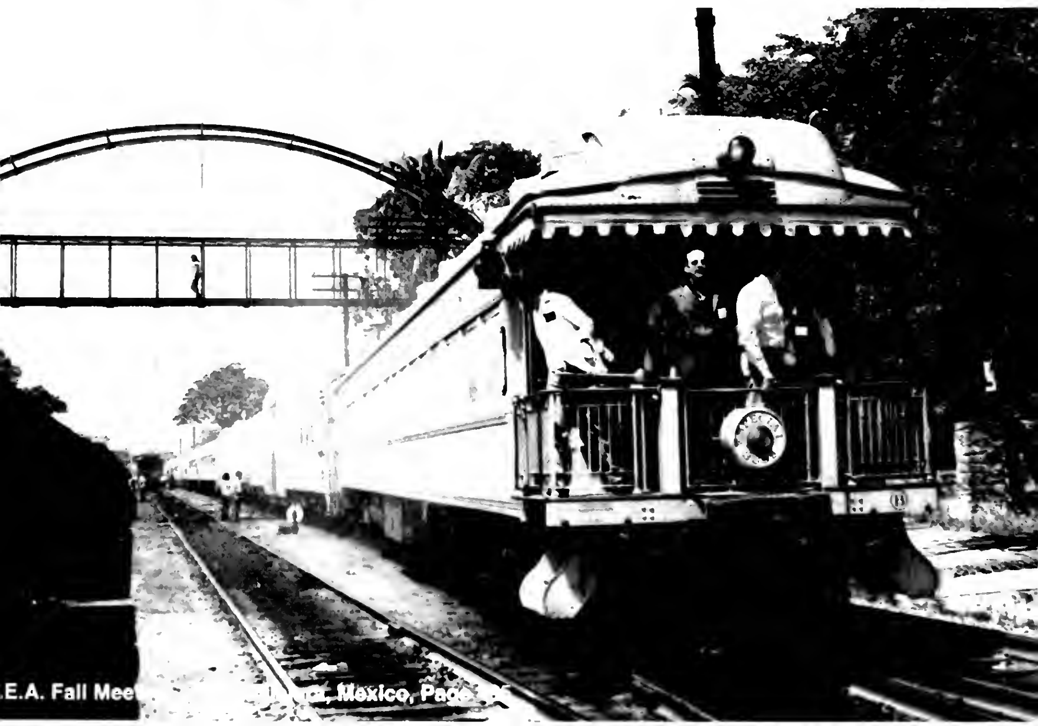

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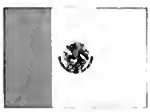


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DEDICATION

This A.R.E.A. Bulletin is Dedicated to
ANDRES CASO LOMBARDO
Director General Ferrocarriles Nacionales de Mexico
in acknowledgement of Mr. Caso's outstanding leadership of the Mexican Railways and his support of the A.R.E.A. and its 1988 meeting in Guadalajara, Jalisco, Mexico, October 6-8

Scenes From The 1988 Fall Technical Conference October 6-8 Guadalajara, Mexico Technical Session on October 6

Andre Caso L., Director General of the Ferrocarriles Nacionales de Mexico and Stan McLaughlin, A.R.E.A. President and Assistant Vice President-Engineering of the Union Pacific.

Below: At the table of honor at the Thursday luncheon are L. to R. Stan McLaughlin, Andre Caso L., Alfonso Hernandez L., Advisor to the Director General and moderator for the AREA conference, and Francisco Sandoval D., Manager of the Pacific Region.

Some of Those Making Presentations at the Guadalajara Meeting

E. J. Rewucki, Deputy Chief Engineer, C.P. Rail

L. T. Cerny, Executive Director, A.R.E.A.

J. W. Walsh, Associate Administrator for Safety, F.R

G. Rivera D., Budget and Technical Coordinator, Track and Telecommunications, F.N.M.

R. Ruiz C., Assistant General Director—Track and Telecommunications Dept., F.N.M.

E. Ramirez C., Assistant Commissioner—Bridges, F.N.

P. Jimenez G., Chief of Department of Planning and Urbanization of State of Jalisco is introduced at head table.

Heading south from Guadalajara, the special Ferrocarriles Nacionales de Mexico train traversed verdant farmlands before heading into the rugged Tuxpan Canyon area, shown below.

Conference attendees enjoyed dome car (above) on inspection train trip as well as a rear end observation lounge and two dining cars, plus brand new luxury coaches provided by the railway.
Photo below shows A.R.E.A. special train pulling out of station at Colima en route to Guadalajara.

Photo above shows seaside luncheon near Manzanillo provided to trip participants by the railway.

Light Rail Inspection in Guadalajara
Oct. 8

Photo below shows construction in progress near south end of new light rail line in Guadalajara—meeting attendees visited this location on Saturday.

PRESENTATIONS TO THE
A.R.E.A. FALL TECHNICAL CONFERENCE
GUADALAJARA, MEXICO
OCTOBER 6, 7 and 8, 1988

The Mexican Railway Network: Recent Achievements and Outlooks

By: Ing. Gonzalo Rivera D.*

Objective

The purpose of this presentation is to present to our distinguished visitors from the United States and Canada, and also the Mexican assembly, the general conditions of the Mexican railways. Also, what has been done in the recent years to improve it and the actions that must begin on a short and medium term as to achieve maximum results in these procedures.

History

The Mexican Railway Network consists of 24,590 km. of operating tracks of which 20,110 km. are main lines and 4,480 km. are secondary lines. It is considered that 14,970 km. constitute the basic and strategic network that transports 90% of the commercial cargo, and links the principal regions of the country.

Eight five percent of the network was constructed between the years of 1873-1910 through the concession of more than 20 different companies that employed different specifications, only sharing the criterion of minimum cost of construction. In this way, 45% of the original tracks were narrow with crossties of 914 mm., and 55% of the tracks were built with crossties of 1,435 mm. All the previous mentioned was achieved with the difficult topography of the Mexican territory. This favored the fact that the greater part of the lines resulted in quite pronounced profiles, being that sections in mountain areas had curves up to 14° metrics, and slopes that in some cases surpassed 4%.

In reference to bridges and other works, the Mexican Railway Network has 10,400 bridges, 23,950 sewages and 302 tunnels. Before 1910 there were already 8,000 functioning bridges and 18,000 sewages with extremely heterogeneous characteristics and capacity that depended firstly on the type of track they were situated on, narrow or wide, and also upon the variety of critera and construction specifications that were established by the concession company. The tracks and constructed structures of the final decades of the last century, and the first decade of this century, satisfied in general the operating conditions of the times. But with the passing years needs increased, principally axle loads, the operatives were pressed needing to correct the most urgent requirements to permit the traffic of trains.

In the post-periods of the Armed Revolution of 1910 till the 70's, due to the continued lack of resources, the required attention to the railways was not given. The rehabilitation works having to be chosen in a selective way without covering the needs gave way to rapid deterioration that consequently affected the operatives. In fact, for many decades the government of Mexico gave priority to the development of the highway network and designated almost all resources to the system of road transportation leaving the railway system almost forgotten. It was not until 1977 when the need was felt to have an efficient railway system that the government began to support this system of transportation designating greater resourses than before. Our present government, with its policy for modernization, has wanted the railways in Mexico to be a priority enterprise in the national context, and to occupy the place they deserve in the ground transportation system. Because of this policy, the railways have maintained a vigorous effort through the last 6 years, even with the difficult economic situation the country has felt. As a very important chapter in the modernization, in 1987 an administrative reorganization was effected, integrating former Railway Enterprises, Ferrocaril Del Pacifico, Chihuahua-Pacifico Sonora Baja California and Nacionales de Mexico into one, Ferrocarriles Nacionales de Mexico (National Railways of Mexico), that was divided into 5 regions: Pacific, central offices in Guadalajara: north, central offices in Chihuahua; northeast, central offices in Monterrey; center, headquarters in Queretaro; and southeast, central offices in Veracruz.

Line Classification

Considering the density of traffic and the operative speed of the trains, we have defined the

*Financial and Technical Coordinator, National Railways of Mexico

Regions of the Mexican Railway Network

importance of different railway lines in our system, classifying them into 6 groups. To this end we have adopted the same critera as the Canadian National Railways, determining the importance of the line by the empirical formula:

$$I = T \times (1.01)^v$$

"I" is the index of importance, and it defines the hierarchy of the line in the system.

"T" is gross annual tonnage that is hauled over the line, and is expressed in millions of tons.

"v" is the highest speed on a train route in km/hr.

In this way our railway system is composed of the following categories:

Line Classification	*I*	*Length of Main Line*
A	65 or Higher	246 KM.
B	40-64.9	1,384 KM.
C	20-39.9	4,980 KM.
D	10-19.9	2,745 KM.
E	3.5-9.9	5,150 KM.
F	0-3.4	5,605 KM.

Depending upon the category, a series of parameters have been established for the structure and characteristics of the tracks that must be followed in construction, reconstruction and maintenance, to withstand the demands of the type of line classified. The most important parameters are: alignment, gage, crosslevel and the physical conditions of the elements of the track.

The most important lines are: the new line Queretaro-Mexico with classification "A". Then, followed in order of importance with a "B" classification, the sections Mexico-Queretaro (new line), Queretaro-Guadalajara and Mexico-Saltillo. Next, are the "C" classification lines Irapuato-Ciudad Juarez-Guadalajarasan Blas, Guadalajara-Manzanillo, Mexico-Veracruz (via Jalapa), Saltillo-Nuevo Laredo, Monterrey-Torreon, Saltillo-Piedras Negras and Tierra Blanca-Medias Aguas, Vera Cruz. Classification "D" has 31 sections, among them: Monterrey-Matamoros, San Luis Potosi-Tampico and Mexico-Cordoba-Tierra Blanca; under the "E" classification there are 32 sections, and finally 86 sections of the "F" classification which includes all branches and lines with very low traffic.

Our railway network consists principally of lines directed to marine ports or toward border points, connecting to the north with important railways in the United States and to the south with the railways of Guatemala. The very particular configuration of our railway system now affords us a great opportunity for exportation. The railway terminals in the north are: Matamoros, which connects with the Union Pacific in Brownsville, TX.; Nuevo Laredo with the Union Pacific and the Texas Mexican in Laredo, TX.; Piedras Negras, in Eagle Pass, TX. with the Southern Pacific; Ojinaga in Presidio, TX. with the Santa Fe; Ciudad Juarez in El Paso TX. with the Santa Fe and Southern Pacific; Agua Prieta in Douglas and Naco; Sonora in Naco, AZ. with the Southern Pacific; Nogales Sonora in Nogales, AZ. with the Southern Pacific; Mexicali in Calexico, CA. with the Southern Pacific; Tecate and Tijuana with the San Diego and Imperial Valley Railroad; on the southern border it is the city of Hidalgo, Chiapas that connects with the railways of Guatemala in Tecun Uman.

There is a magnificent relationship with the our neighboring railway companies. This was proved once again on the 17th of last September by the action of Hurricane Gilbert. The most important line in the country, Mexico—Nuevo Laredo, suffered great damages to the north and south of Monterrey. Fortunately, thanks to the emergency program that was followed, traffic was reestablished quickly in a period of 9 days. The valuable help by our neighbouring railways was put to good use by way of Nuevo Laredo in sending ballast and wood. We are deeply grateful for this assistance. The damages to other lines that meet in Monterrey were also overcome.

Characteristics of Present Day Mexican Tracks

Of the 20,110 km. of track, only 90 km. are narrow gage and practically the entire network, or 99.5% of the tracks, is of standard gage. All our railways are single line, with the exception of the 245 km section Mexico—Queretaro, and other short sections of the Mexico—Cordoba—Veracruz route that are double track. Sixty one percent of the total length of the tracks have curves between 0° and 3° metric degrees. This curvature corresponds to chords of 20 meters or 65′ 5″. Twenty three percent of the tracks have curves between 3° and 6° and 10% between 6° and 9°. The other 6% have more than 9° of curvature, and in some cases up to 14° which makes for difficult operations. Fifty nine percent of the tracks have slopes between 0 and 1%. Thirty three percent have slopes of 1 to 2%, and 8% are made up of sections of more than 2% to 3.8%. In the last two decades some new connections have been built to rectify old tracks, diminishing the curvature and slope. But, these have not been enough with 710 km. being the required length needed of new track lines, so that in the lines of higher category than "F", there will be no curvature more than 10° and slopes of more than 2.5%.

The base of the track for approximately 200 km., which represents almost 1% of the total length of the network, requires geotechnical treatments to improve the conditions for cargo capacity and stability.

Eighty seven percent of the tracks have ballast of ground stone and 13% are slag. To date, the lack of ballast is approximately 9,500,000 cubic meters, which is required to bring the tracks up to standard. Since the year 1958, concrete crossties were beginning to be used with the installation of a French design, two-block reinforced concrete crosstie. In 1967, the use of a German design monoblock crosstie was adopted. At the present moment, there are installed in operating tracks 9,650,000 concrete crossties, of which 7,820,000 crossties are monolithic and 1,830,000 are two-block crossties. The remaining ties in the main lines (28,600,000) are wooden crossties.

The caliber of the rails which the main tracks are made with go from 136 pounds/yard to 50 pounds/yard. The predominant rail on the lines classified A, B and C is of 115 pounds/yard or 112.3 pounds/yard, of which 9,165 km. of tracks are built. With rail of 100 pounds/yard, we have 5,550 km. of tracks, and with rail of 90 pounds/yard there exists 1,126 km. The remaining 4,253 km. of main tracks are built with inferior calibers.

At the present there is welded rail on 8,872 km., of which 6,375 km. are on concrete crossties and 2,497 km. are on wooden crossties. The remaining 11,238 km. of mainline track are of standard track on wood crossties with spikes and bar joints. The fastener that has been adopted in the elastic track sections is of a French type. Recently, we have been using a Mexican designed clip for curves, and being installed more than a year ago, has given good results. This fastener was used for the first time in test segments in the Guadalajara—Manzanillo line of km. 322 and 462.

In reference to bridges, 58% are of adequate capacity to withstand without restriction the heavy traffic operations. Forty two percent are of less capacity than E-60, which imposes restrictions for the handling of trains with heavy locomotives of 3,000 hp or 3,600 hp, and in cars of 100 tons or more.

Recent Achievements

Under the present government, the investment in railway lines has been more important than in past decades and particularly in the years 1986, 1987 and 1988. The effort that has been done in the area of tracks has been intense because a great demand of traffic must be satisfied. Being installed into operations are 15 new unit trains, 10 express trains for cargo called The Star Service and 12 new services of passenger trains between the principal cities of the country.

During this period of 1986-1988, 1,850 km. of track have been reconstructed in the sections classified B and C. In this reconstruction 2,300,000 concrete crossties have been used, 3,650 km of 115 pounds/yard and 40 km. of 136 pound/yard rail, and also 3,300,000 cubic meters of ballast. The renovation methods for tracks that have been used are semi-mechanized, and have as a primary source the machinery acquired in recent years being track cranes, crosstie replacers, tool and machines, plus Mexican manual labor. With this, some fronts have been able to produce up to 80 km of track per year, with the maximum produced in a day being of 1,046 m. The renovation program of tracks with new rail for this year was achieved with 21 work fronts, and there has been a completion of 480 km., or in other words, 80% of the total program. Seventy five percent of the works are done directly by the Mexican railways and 25% are done by contracted companies.

In the last 3 years, 710 km. of tracks of E and F classification have been rehabilitated, using reclaimed rail of 100 pounds/yard or of greater caliber. This rail came from the renovation of the principal lines, and using new wood crossties and traditional fasteners, substantially improved the quality index of these tracks, especially in the caliber of rail.

In 1987, 210 km of track were widened so as to almost finish the unification of our gage on the tracks. Now, only 90 km. of the branch to Teziutlan are of narrow gage track and is under study for a new section.

The total length of rehabilitated track during 1986-1988 is of 2,220 km., highest of all past periods. The maintenance works have also been intensified due to the urgency to withstand adequately the new services. A total of 4,800,000 wooden crossties have been replaced, which includes those in the rehabilitation program.

To increase productivity, and searching to progressively mechanize maintenance work and rehabilitation of the track, in 1986-1987 80 large track machines were purchased. These included a ballast cleaner, 3 mobile welding plants, 20 tampers, and other machinery along with lesser equipment. With the use of machinery, in the last 3 years, 12,200 km. of track have been aligned and leveled, giving preference to lines with tracks of concrete crossties and other types of track under the classification A, B, C, and D.

In early periods, the inspection of the rails in the tracks through electronic methods have been limited due to the lack of economic resources. In the last 3 years 27,900 km. were tested, covering the basic and strategic lines with a Sperry detector car for internal defects in rails. This has contributed greatly to the avoidance of accidents on the main lines and permits a control upon the fatigue of the rails, to better the renovation program in the tracks.

To be able to maintain traffic of trains upon the railway network has been a difficult job for many years due to the low capacities of the bridges. Because of this, the weight of cars was limited to 109.1 tons/car or 27.3 tons/axle for much of the Mexican lines. The most severe limitation of 80 tons was given for the Pacific Coastal Line from Ixtepec to the border with Guatemala, due to the E-30 capacity of a great number of bridges. Also, a program was begun for increasing the capacities of the bridges through reinforcements or substitutions on all lines. Up to now, more than 2,800 bridges have been replaced with those in small clearances mostly using box-type reinforced concrete spans of E-80 capacity, and those of long clearances with steel spans of E-72 capacity. More than 1,300 bridges have been reinforced, the most outstanding being metal trusses. This increased the necessary capacity required for the structures, and also changed the old appearance to a more modern one.

After the most urgent problems on routes were corrected, a program was instituted to follow up and upgrade routes, so that in 1988, the following lines were open to heavy traffic cars of 119 tons gross weight, and even to greater demands. The routes were Vera Cruz—Coatzacoalcos, Monterrey—Matamoros, Piedras Negras—Ciudad Frontera, Ciudad Valles—Tampico, Saltillo—Monterrey, Coatzacoalcos—Salinas Cruz; the route Irapuato—Manzanillo is about to be finished and work is being done intensely to open up four more routes at the end of this year, and to have all lines classified A, B, and C without restrictions to heavy traffic.

The present administration has instituted a program to change the deteriorated image of the

Replacement span installed

railway for a new and more dignified one. As a complement of the services to the users, a program is under way for renovation of the stations. Until now, 45 of the most important stations have been rehabilitated, as Queretaro, Irapuato, Uruapan—Toluca, Oaxaca, Monterrey, Nuevo Laredo, Saltillo, and Colima in the Guadalajara—Manzanillo route. In the process are more than 60, including the Guadalajara and Manzanillo stations.

At the end of the present year, the work on signalization with a CTC system for sections Irapuato—Guadalajara and San Luis Potosi—Benjamin Mendez will be completed. And this with the double track line signalization of Mexico—Queretaro—Irapuato will convert all these lines of A, B class into signalized routes.

Perspectives for the Coming Years

Even though advances in the area of rail lines have been important the last 3 years, the difference in earlier years maintenance make it necessary to intensify the rehabilitation of the tracks, so that in the next 6 year period, differences can be completely eliminated. Starting from 1995, the works in the lines will become of a normal cyclical character so that the most important job should be maintaining, and leaving for rehabilitation only those sections having reached their useful lives, which depends on the traffic and geometry of each.

For the next government, an ambitious program has been elaborated that renovates 7,212 km. of track with new rail and concrete crossties at a rate of 1,200 km. per year. Also, it has been proposed the rehabilitation of 3,060 km. of track with selected reclaimed rail and wooden crossties be of 510 km. per year. The total program contemplates rehabilitating 1,712 km. of track per year.

We are conscious of the magnitude of the program that imports 3.2 billion pesos ($1,400,000,000), and that implies the acquisition of 830,000 tons of rail, 11,815,000 concrete crossties, 7,742,000 wooden crossties, 17,890,000 cubic meters of ballast, plus the fasteners and accessories for the tracks. Without a doubt, one of the hardest tasks shall be the logistics, and within this, the supply of ballast. For this, more equipment for supply is needed, reducing journeys to quarry cities, and also improved coordination within the operations area.

The capacity of the railroad to renovate tracks with its own resources is 1,100 km. per year, plus 500 km. yearly with reclaimed rail. But, to ensure the fullfilment of the programs, it is necessary to increase the participation of outside contracting companies which must be given greater percentages of the jobs than to date. To complete the program of track renovation, the automation of some fronts has been proposed with the employment of 2 track renovation trains of the type used in European countries and the U.S.A.

In the aspect of bridges, it is important to increase the capacity of the 3,000 bridges of low capacity that still exist in the lines class A, B, C, and D, and to work upon the substitution and reinforcement of more than 5,000 small sewages on these lines.

To supply the fronts with welded rail, it is necessary to acquire a rail welding plant to help the 3 stationary plants that exist in Ciudad Frontera, San Luis Potosi and Tierra Blanca, and the other 4 mobile plants in use.

Proposed jobs for the tracks are to replace 5,700,000 wooden crossties, apply 6,700,000 cubic meters of ballast, and a minimum of 7,000 km. of track to be surfaced and lined with machinery each year. To such an end, the assistance of contracted companies have been solicited to complement the railway labors, because on a short term basis, the railway machinery will not be sufficient.

In reference to new tracks, it is necessary that the country increase its lines by 1,500 km. so that the operation can be more efficient, and potentially productive areas can be included. For instance, like the coast line of the Mexican Gulf, and projects that are in progress be finished, like the short route Guadalajara—Monterrey of which the Guadalajara—Aguascalientes portion is already being executed.

It is also necessary to put into effect the relocation of lines to overcome slopes and curvatures, which will permit substantial improvement of the operations. There are 50 sections programmed, for a total of 1,200 km.

It is estimated that by the year 1994, the traffic on the network will increase 50%, for which there will be a need to construct double track lines in the heaviest sections like Irapuato—Guadalajara and Queretaro—Saltillo, totalling 1,200 km. of double tracks. It will be also necessary to finish the electrification in the double track Mexico—Queretaro line.

As a complementary measure to improve the operation and increase the traffic capacity on the lines, in the new governments program there has been included the signalization with a CTC system of 2,970 km. of the heaviest lines like Monterrey—Nuevo Laredo, Mexico—Cordoba—Coatzacoalcos and Guadalajara—Manzanillo.

Conclusion

The Mexican National Railways, in the present administration, has given the first important step towards the modernization that is required by the industrial development and demographic growth of the country.

The railway track is the basis of the railway operation, and because of this it is necessary that in the next 6 years the rehabilitation of the lines be achieved and the network completed. Then the operation can reach the excellence that is required so that the railways in Mexico will fulfill its corresponding function as the backbone of ground transportation.

We do not doubt that the next administration of the republic will give all its support to the development of railway transportation. It will be role of the next administration of the Mexican National Railway to put forward all its capacities and dedication to face the challenge of the achievement of great programs that will place the Mexican railways on level with the big railway enterprises of the U.S.A. and Canada.

FRA TRACK SAFETY RESEARCH

By: J. W. Walsh*

Introduction

During the past eight years, the Federal Railroad Administration has been conducting a very practical and effective Research and Development program directed toward improving the safety of railroad operations. As you all may know, the FRA Office of Safety has a strong program of safety regulation and enforcement on the railroads. In 1985, the Office of Research and Development was made part of the Office of Safety. Although some of the R.&D. work has been in the area of improved and rational safety regulations, much more has produced results that are of an advisory and informational nature. This work can be a direct safety benefit to the railroads that incorporate our findings into their standards and operations, and will directly benefit the public by reducing the risk of casualties from railroad accidents.

The Office of Research and Development has also done its share to reduce the Federal budget deficit, greatly reducing its level of spending during the same eight years. The cooperation of individual railroads, the Association of American Railroads, and particularly the individual members of the A.R.E.A., has been invaluable, not only in reducing the expenses of our research work through cost sharing on research projects, but in the technical knowledge brought to the work by the railroaders with whom we cooperate.

Our research work is divided generally into two categories: Equipment and Operating Practices Safety, including Hazardous Materials; and Track and Structures Safety. I would like to talk today about the work we are doing in the area of track safety research.

Track Lateral Stability

Buckled track causes some of the most serious train accidents, because it often occurs on well maintained, high speed track with heavy traffic levels, and the problem is difficult to predict. FRA and our sister agency, the Transportation Systems Center at Cambridge, Massachusetts, have been working for several years in cooperation with the A.R.E.A. to find a way to detect incipient track buckling, and to prevent its occurrence. We have been conducting tests at the Transportation Test Center in Pueblo, Colorado, and on several railroads to help us better understand this problem.

We realize that a practical method to accurately determine the stresses in rails and the lateral strength of the track would be a major breakthrough in the solution of this problem. We don't have a solution yet, but there are a couple of different concepts that might have some promise.

Vehicle-Track Systems

FRA is working closely with AAR in the Vehicle-Track Systems Program, the replacement for the former AAR/RPI Track-Train Dynamics Program. One of the valuable projects in this area is the study of vehicle-track interaction, with the objective of reducing the number of train accidents caused by the adverse response of certain cars to track geometry conditions. Another is the study of fatigue properties of car-building materials and components, to determine ways to prevent their premature or unsafe failure. This program has contributed much information on the stresses imposed on cars by the track in the actual operating environment.

Gage Restraint Measuring System

Ever since the Federal Track Safety Standards were first drawn up in 1971, we have known that the section concerning crossties was subject to widely varying interpretation, depending largely on the experience of the inspector to determine the quality of a tie condition. To enable us to better measure and understand the safety margin of track from excessive gage widening under moving trains, we have worked with the Transportation Systems Center to develop a Gage Restraint Measuring System.

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*Associate Administrator for Safety, Federal Railroad Administration

The Gage Restraint Measuring System is a prototype device designed to measure the strength of track in holding its gage under lateral and vertical loads. The principal feature of the system is the "split axle." The whole system is commonly referred to as the "split axle car." The split axle is a common freight car wheelset with the axle separated at its center. The missing axle section is replaced with a sleeve containing two bearings so the two wheels can be pushed apart, or drawn together. The pressure is supplied by a set of hydraulic actuators, and the two wheels are instrumented with strain gauges to continuously measure the lateral loads on both wheels. The loaded gage is measured by the distance between these wheels. The car is also equipped with a separate system to measure the unloaded gage.

The split axle wheelset is mounted in a more-or-less conventional three-piece freight car truck under a 100-ton open-top hopper car. When we operate it, we couple it to our T-6 instrumentation car, which supplies power to the system and carries the instrumentation and crew. The train is pulled by a locomotive at 15 miles per hour when testing, and at track speed when traveling. We replace the split-axle truck with a conventional truck when we ship the car or move it over a long distance.

The system places a combination of a controlled lateral load and a fixed vertical load on both rails, and then measures their relative lateral deflection. From this, we predict the eventual deflection under the most severe lateral load that the track is likely to see in actual service.

The original purpose of the system was to identify those locations which might cause a derailment from wide gage, and quantify those conditions more precisely than do the Federal Track Safety Standards. Essentially, we would be instituting a performance standard for the gage restraint property of the track. That purpose was and still is directly related to the safety function of the FRA. We believe that the GRMS would also be useful in characterizing the overall strength of longer track segments for track maintenance planning.

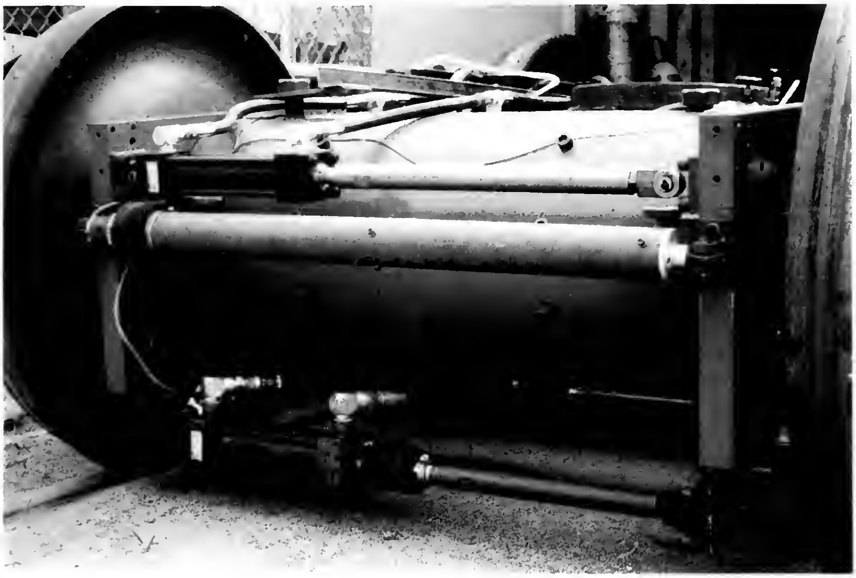
The system has been successfully operated on four major railroads, on track that was very strong and on some that was not. The reliability of the system has improved with each test. It is presently capable of surveying about 60 to 80 miles per day, depending on traffic levels and similar factors.

Track Degradation Study

Last winter we began a cooperative project with Conrail to try to quantify the actual rates of degradation of specific track geometry conditions. The objective is to develop information that will support the development of rational track inspection programs, and a method to accurately predict future problems, based on time histories of individual track locations.

The study is concentrating on six segments of Conrail track, each about 2000 feet long, that have displayed particular problems in the past. We survey these sites with Conrail's own excellent track geometry car when it passes over them on its regular schedule. An FRA computer on board the car is connected to the regular instrumentation when the car is at a test site, and we read gage and crosslevel at three-inch intervals. The car's location within the test zone is determined precisely using an automatic location detector system so data from successive tests can be overlaid and compared. Conrail is providing us with information on maintenance work performed on the study segments so we can account for those particular changes.

We have already found some interesting phenomena that were not expected. For instance, at one location on a ten-degree curve laid with continuous welded rail, we found gage in June averaging two-tenths of an inch tighter than at the same location in the previous March. The March survey was conducted in cold weather, but the one in June was during the heat of the day, and we think now that the change in rail temperature was affecting the gage of the track. Upon investigating, we found the same differences from morning to late afternoon of the same day, in the same track, dependent on



Split Axle Assembly

rail temperature. We have also found small but measurable differences in gage in curves at intervals corresponding to the spacing of the ties, and the existence of this phenomenon also appears to be related to the rail temperature.

Development of Track Geometry Indices

We are all aware that a serious threat of derailment is posed by the "rock-and-roll" problem, when a series of low joints causes a particular car to roll from side to side, lift a wheel, and possibly derail. We have worked with the people at Transportation Systems Center to develop a method to measure continuously along the track and predict the possibility of a rock-and-roll situation. The equipment to take the continuous measurements, and the mathematics to analyze them, are fairly complex.

It is not likely that most track maintenance personnel would have access to the equipment or be able to do the mathematical analysis in the field as part of their normal day's work, so we have developed a simplified measuring system that we call the "CLIM Bar;" "CLIM" standing for "Crosslevel Index, Modified." This little device is the size of a regular level board and has an electronic pendulum and a small computer chip. The actual crosslevel can be read directly from a digital display. The crosslevel index, or "CLIM," is summed automatically by the device over a series of joints, and can be read directly after eight crosslevel readings have been taken. It gives a good indication of the possibility of a rock-and-roll condition at any location on the track. The components of the "CLIM Bar" are not expensive, and we think that it will have a useful place among your tools once the final development is complete.

CLIM Bar

Heavy Axle Load Program

The Association of American Railroads and FRA are conducting tests to determine the effect of 120-ton cars on the track, compared with 100-ton cars. This program, the Heavy Axle Load Program, is being run at the Facility for Accelerated Service Testing (FAST Track) at the Transportation Test Center near Pueblo, Colorado.

Until this year, the test trains at FAST consisted normally of 100-ton cars with 33-ton axle loads, but the Heavy Axle Load test train running now is made up of cars with 39-ton axle loads. We are looking at the effect of the heavier cars on rail life, and how that in turn is affected by lubrication. We are also evaluating the effect of the heavier loads on degradation of track geometry, ballast, turnouts, ties, fasteners, subgrade, and the track structure as a whole.

We are also conducting experiments on dynamic track buckling on FAST during this test, with particular emphasis on the effects of heavy axle loads on ballast consolidation and other factors affecting track lateral stability.

This test program began in June, 1988 and is scheduled for completion in December, 1989, when 160 million gross tons of 39-ton axle traffic will have been accumulated. This should allow completion of all proposed experiments related to this test program. The test data will then be analyzed.

This program is jointly funded by FRA and AAR. Nearly all of the equipment and track material has been donated by several railroads and the railroad supply industry. Overall direction of the test is provided by a steering committee of representatives of the railroad industry, railroad suppliers, AAR, and the FRA.

The nature of the interaction between track and trains, and the performance of the various components, is complex. However, the results of the FAST Heavy Axle Load Program should go a long way toward providing the answers to the performance of track and vehicle components under 39-ton axle loads.

Conclusion

The Research and Development programs of the FRA cannot live in a vacuum; we could not justify the expense of doing it all ourselves, and we could not operate without the advice and wealth of knowledge that you, the representatives of the railroad industry, provide. Your cooperation is essential; we welcome it, and we appreciate it very much.

Reconstruction of Bridge Near KM 127 on Mainline from Coatzacoalcos to Salina Cruz

By: Ing. Eduardo Ramirez C.*

Introduction

Techniques, especially in this century, have gone through such impressive changes that human beings seem to have lost the capacity for amazement. The present work is located in the present and looks toward the future. What is today a reality, tomorrow will be a pleasant memory that left the basis for development.

The setting of 3 thru-spans through the isthmus zone, show that even when living today during a time of accelerated changes, there still exist some needs, but this has not surpressed the human will in its constant struggle to excel.

Preface

Among the branch lines of the National Railways of Mexico, this one stands out for strategic importance since it crosses from the Gulf of Mexico to the Pacific Ocean through the Sierra Madre of Oaxaca. This line originates in the vigorous port of Coatzacoalcos in the estate of Veracruz, site of the most important petroleum complexes of the Mexican Republic. It terminates in Salina Cruz, another port in the estate of Oaxaca that also stands out for its importance in petroleum and fishery. This narrow portion of land is known as the Isthmus of Tehuantepec.

This line is designated under the code name "Z" and runs along 303 km. It ascends from sea level up to 300 meters at its highest point and proceeds again to sea level. The geometric line includes maximum curvature of 12 degrees and slopes of 2.24% in very short stretches. The present administration, firm in its intention to modernize the national railway system, has backed up the intensive rehabilitation work in the infra-structure, as in the equipment and services that it furnishes.

Facts

In the rehabilitation of the infrastructure, the "Z" line of course stands out because in a relatively short period of time it has modified its image in relationship to bridges and sewages. Of the 273 existing bridges and 622 sewages, in the last 3 years 120 works have been rehabilitated. This leaves of a balance of 841 works to Cooper E-72 capacity, 54 works yet to be rehabilitated.

Within the rehabilitation of bridges and sewages, two activities can be differentiated:

1) the rehabilitation proper of bridges that require a minimum of intervention to upgrade to a Cooper E-72 capacity, even when its structure is of a provisional character, and
2) to rehabilitate those bridges that require immediate attention of being upgraded, in which case there are prefabricated structures that are being substituted for the existing ones to achieve this objective. The setting of the spans that we are involved with now on this section, are within this second group of activities.

Due to the fact that all of the isthmus zone of Tehuantepec, especially from the outfluent of the Gulf of Mexico, is highly corrosive because of the influence of the petroleum complexes in Coatzacoalcos and the chemical industries close to the port, the metal structures of railways in this zone suffer accelerated deterioration. Because of this, the rate of maintenance has not been able to keep up to their deterioration, so that at the present, 60% of the metal structures are being replaced and 40% have already been reinforced.

The Jaltepec River runs along the side of the bridge at Z-127 + 61 km. and is an effluent from the river Coatzacoalcos and empties into a port of the same name. It collects the waters of the outfluent of the Gulf of the Sierra Madre of Oaxaca along with the rivers Sarabia and El Chachilapa, passes through the town of Jesus Carranza, Veracruz, the limit between the states of Veracruz and

*Assistant Commissioner Bridge Section, National Railways of Mexico

Oaxaca, contributing numerous benefits to the regions agriculture and livestock aside from its rich fishing productiveness.

The bridge located at Z-127 + 61 km. is called "El Rompido". This is probably because more than 40 years ago the river Jaltepec, broke at this point its right margin where the railway track was located. Since then, simple concrete cylinders were installed, over which 4 riveted thru-truss "pony" type spans of 88′ length each were placed.

This old structure was able to accept loads equivalent to Cooper E-50, and its physical state demanded priority attention. The "El Rompido" bridge is located is located on a right curve of 5° with an elevation of 4″. Because of this bridge's location and characteristics, the preparation and it's replacement were of special interest.

Preparations

Due to the geometric conditions of the bridge's tracks, its location next to the river, and the possible season in which to do this job, it was determined that the following steps would be followed: place the new structure on the dry side of the river upon a false setting, lift out the old truss, laterally shift the new span underneath and then place the old structure on the false setting. The preliminaries for the project were begun in the month of May, 1988 and consisted overall of the following:

1) Construction of false settings to receive the 3 new spans. These false settings, because they must remain from the beginning until the setting has taken place, were constructed on a base of wooden crossties, not impregnated, and were set on the left side of the bridge to avoid any growth of the river that may provoke settlement.
2) Setting up the 3 metal thru-spans upon the false settings. The 3 structures were left 100% riveted, using hot rivets.
3) Putting in place new wood for the ties covering the 3 spans, needing a total of 210 pieces of impregnated pine wood of 10″ by 10″ by 10″.
4) Placing the metallic brackets upon the outer side of the new spans, to permit lateral shifting using lifting-jacks.
5) Eliminating the anchors of the old trusses to be able to move freely during the rest of the resetting.
6) Placing rails of bearing under the new spans so that they serve as a "path" at the time of lateral shifting.
7) Preparing rails of the adequate length for mounting and cutting of track, so that the cranes can come up to the edge of each side of the bridge.
8) Other preliminaries in materials, tools and equipment.

The setting of the spans was programmed estimating a rate of one per day, to be done from August 17–19. (Note: Only 3 of 4 spans were programmed) The time before the settings was not good because of intensive rains that provoked the overflowing of neighboring rivers, endangering the false settings and the project itself because of the difficulties of working in the rain and the handling of the spans being 4 meters in height.

Development

The sun raised to a clear day on the 17th of August and the gangs of riveters, bridgers and the one of tracks prepared the last details of the setting by: lubricating the rails for lateral displacement; putting "Tirfors" (a French design pulling tool) in strategic locations to be able to pull the spans, and preparation of the bridge approaches for the cranes, to eliminate over-elevation.

Old truss span is lifted for sliding of new thru girder span.

At 8 in the morning, formal setting was begun of the first span. Located on the edges of the old truss No. 1 were great cranes of 35 tons of capacity to elevate the 40 ton span No. 1.

First, track was unnailed on No. 1's span to remove the long rails and to connect the sections of rail previously prepared for providing for the close proximity of the cranes. Next, all the rail on No. 1 was unnailed, the material of the track was piled up outside of the exchange site and removal of the cross-ties was begun which lasted until 9 hr 35 min.

One of the important problems that had to be solved was to eliminate the over-elevation of the curvature affecting the cranes. Forced by the method of setting, the cranes would unavoidably turn toward the left side of the bridge to place the No. 1 truss upon the false setting once the new span was in place. Two possibilities existed: One, to eliminate over-elevation of the whole bridge by placing blocks to prop up the trusses and installing an order for precaution at least two days before and two days after the setting so that trains reduced their velocity upon passing through the bridge. The other possibility, the one used, was to install wooden jackets exclusively where the cranes would be blocked at each point of span lifting, which could be done in a very short time without affecting train traffic.

After the 1 hr 35 min. used to dismount the track on truss No. 1, the over-elevation was removed from the south approach of the bridge, and also from truss No. 2. Then, the cables of the cranes were held upon each end of the truss to be in a position to lift it. At the same time, the correct blocking of the cranes was done, especially the one on truss No. 2, for it was not easy to find enough space for the blocking. The track itself was propped up from the concrete cap, and for this part the track gave support to the blocks that secured the crane.

There was no other protection for truss No. 2, even though it had to support the weight of the crane (105 tons) and ½ of truss No. 1 (20 tons). But, because the load was static, there was no impact effect.

Once the cranes and cables were secured for the lifting, the elevating of the old truss to a height of at least 95″ that would allow the passage underneath of the new span was begun. Two hours later, the lateral shifting of the new span was ready to begin. At 11 hrs. 30 min. the shifting towards the right was begun using 3 ton "Tirfors" and 4 step jacks of 15 tons each. The 50 ton pressure camera jacks, which had been planned to be used, were not because of problems with the compressor. In this way, after one hour the new span was shifted 17′. The new span weighed 50 tons plus 6 more from the weight of the wood already in place, so that 56 tons were shifted laterally. Because of the tools used, the expertise of the bridge crew and the generous amounts of lubricant used to reduce friction, the sliding of the new span into position went very smoothly.

Until that moment, the cranes were anchored to the turnbuckles of the cabin to avoid the risk of unintentional rotations. At 12 hrs. 40 min. the anchors were removed to permit the rotation toward the left side of the bridge and put the old truss onto the false setting.

After another hour, truss No. 1 was completely resting on the base of the false setting. The cables were removed from it and were placed on the new span to lift it to remove the rails that were used as guides for the lateral shifting. After this, the inverse procedure was followed: unblocking the cranes, removing props to leave the original over-elevation, placing the tie plates and setting the rails.

Because of the intense heat registered that day, there were difficulties in the setting and aligning of the rail curvature, a problem that was solved at 16 hrs. In 8 hours of work, and with difficulties encountered, we were able to resecure traffic on this span and the bridge for the regular passage of trains.

Comparatives

In the setting of span No. 2 the next day, there were some advantages that improved the operation and reduced the setting time. The advantages were:

1) The personnels previous day experience which lead to better team work.

2) The compressor was in working condition to feed the two 50 ton pressure camera jacks, enough to act upon the brackets placed on the edges of the span for the lateral shifting. The jacks were backed up by the "Tirfors" on the other side.

The most outstanding disadvantage was that this time both cranes had to be blocked. On the day before only one of them had been, for the other crane was upon firm ground.

Work on the 18th was begun at 8 hrs. 0 min. The passenger train having passed, the time used to cover the day's work was the following:

1) Dismantling the track over truss No. 2, including the elimination of the over-elevation for both cranes over the bridge. (2 hrs., 30 min.)

2) Blocking the cranes, grasping truss No. 2 and its lifting. (1 hr. 30 min.)

3) Lateral shifting towards the right of the second metallic thru-span, until located in its proper site. (55 min.)

4) Lateral freeing of the cranes and lowering of the removed truss until perfectly supported by the base of the false setting. (20 min.)

5) Unblocking the cranes, removal of blocks to leave original over-elevation of the track in place, placing tie plates and setting rail. (1 hr. 35 min.)

Train traffic was renewed at 14 hrs. 50 min.

Thru girder span is jacked into position from false settings.

The 19th of August, just like the other days, began with a clear sky, without threats to the days work. This time, passage for two passenger trains was allowed before interrupting traffic for setting procedures, so that work was begun at 8 hrs., 50 min.

This time, the decisive factor for success was the personal motivation of the workers; on one hand only one third of the work was left to be done, and on the other, the 19th of August was a Friday, only a day away from their weekend rest. So the time employed for this last part of the setting was the following:

1) Dismantlement of the track on truss No. 3, including the elimination of the over-elevation for both cranes over the bridge. (50 min.)

2) Blocking the cranes, grasping truss No. 3 and its lifting. (1 hr. 10 min.)

3) Lateral shifting towards the right of the third metallic thru-span until located in its proper site. (35 min.)

4) Lateral freeing of the cranes and lowering of the removed truss until perfectly supported upon the false setting. (15 min.)

5) Unblocking the cranes, removal of blocks to leave original over-elevation of the track, setting tie plates and placing rail. (2 hrs. 10 min.)

Trains were allowed passage again at 13 hrs. 50 min.

Supplementary

For this job, 55 specialized workers were required in riveting, bridge and track work. The new spans that were set were given a base for epoxy resin, having been first cleansed completely of residues of dirt and surface rust.

It is expected that with the new impulse that has been started by the modernization of the Mexican railway system to keep in optimum condition not only this bridge but all of the ''Z'' line, who as a silent witness, has seen the passing of the hundreds of millions of tons of products that have benefited Mexicans and foreigners alike.

Conclusion

At the end of the 20th century, the Mexican railway is preparing itself to receive the 21st century, with a new, renovated and worthy image before the world. The jobs, like the one described today, will be modernized and human and economical resources will be improved. Human beings are capable of adapting to the new needs of the times, and are avid to give their best effort to the progress of all humanity. It rests upon all of us who have witnessed this example today, to give the best of our capacities to the achievement of a better tomorrow.

Ventilation System for Mount MacDonald Tunnel

By: S. S. Levy*

Good morning ladies and gentlemen. Before we look at the ventilation system designed for Mount MacDonald Tunnel, I would like to first present some background on the general subject of ventilation for diesel rail operation through tunnels. We'll look at the basic requirements a ventilation system must satisfy, the manner in which ventilation is created, the variables which impact it, and some of the analytical techniques used in its evaluation. From there, we'll shift to Mount MacDonald Tunnel. We'll look at the major components of the system, how the system would operate when serving a heavy laden westbound coal train. We'll then look at the major components of the system in more detail.

The primary functions of a ventilation system servicing diesel operation in relatively long tunnels are twofold: 1) to provide a sufficient air flow relative to a moving train to prevent its locomotives from overheating; and 2) to remove the residual smoke and diesel pollutants emitted by a train so that the succeeding train can be exposed to a relatively clean environment. In addition, the ventilation system should be capable of controlling the direction of smoke movement during serious emergencies involving smoke and fire. Furthermore, the system must be able to provide sufficient ventilation for tunnel maintenance.

When a train is moving through a tunnel, ventilating air required for locomotive cooling is generated by the "piston effect" of the train. The velocity of the air ahead of the train is in the direction of train movement, but at a speed which is less than the speed of the train. The air flow generated relative to the train is equal to the difference between these speeds multiplied by the tunnel cross-sectional area. The steady-state speed of the air ahead of the train is primarily a function of the train and tunnel cross-sectional areas, and the length, skin friction coefficient, and speed of the train.

To increase the ventilation rate relative to a moving train, most of the long tunnels in the western hemisphere employ a tunnel door and a fan system at one end of the tunnel. Ventilating air for locomotive cooling is generated by the piston effect of the train moving toward or away from the closed portal door. The air flow rate generated relative to the train in this case is equal to the product of the speed of the train and the tunnel cross-sectional area. This effect often permits a sufficient flow of air past the train for "self-cooling". Under certain conditions when the train piston effect cannot provide the required air flow, a fan is operated to supplement the piston effect. This mode of fan operation is commonly referred to as "cooling". The air flow rate relative to the train in this case is equal to the product of the train speed and tunnel cross-sectional area, plus the fan air flow rate.

When the train leaves the tunnel, the tunnel door is closed and the tunnel is purged by having the fans either supply or exhaust air from one end of the tunnel to the other. The tunnel is cleansed by displacing the polluted air with fresh outside air. Approximately 1.25 air changes are required to clean the tunnel. The operating time of the fans to purge the tunnel in this manner is referred to as the "purge time."

To determine the supplemental air flow and pressure a fan must deliver in cooling to prevent the locomotives of a designated design train from overheating, Parsons Brinckerhoff has developed a number of computer programs.

One of these programs is used to predict train speed and pressure drop over the length of the tunnel as a function of available tractive effect, mechanical and grade resistance, and the air drag on the train.

Figure 1 shows the relationship among train speed, supplemental ventilation, and the required fan delivery pressure to the tunnel. The results are for a 6700 foot-long, 15K trailing ton coal train powered by either 5 or 6 EMD SD40-2 units in Mount MacDonald Tunnel. The results show the effect on train speed of added train drag due to increased supplemental flow. As can be seen, the law of diminishing returns comes into play as more and more supplemental flow is introduced into the

*Parsons Brinckerhoff Quade & Douglas, Inc.

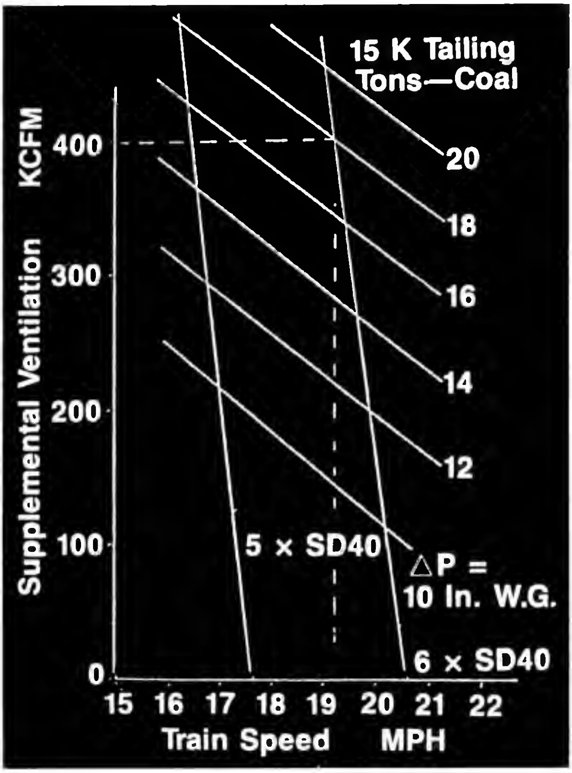


Figure 1.

tunnel causing the train to slow down. It should be noted that more than two-thirds of the air flow relative to the train is generated by train piston action.

With train speed, locomotive heat release and the supplemental air flow delivered to the tunnel as input, a second computer program is used to compute the steady-state temperature of the air surrounding, both vertically and longitudinally, a series of successive locomotives to determine the inlet air temperature to the locomotive radiators. This variable determines whether overheating of the locomotive will occur. By varying the amount of supplemental air delivered to the tunnel and evaluating the resulting radiator inlet air temperatures, the air flow required to be delivered by a fan is determined.

Another parameter which is critical in the evaluation of locomotive cooling requirements is the wall surface temperature, since it controls the temperature of the air approaching the train for the majority of time the train is in the tunnel. For the design coal trains for Mount MacDonald Tunnel, which have a remote consist, this parameter is also used in the prediction of the drop in tunnel air temperature as it moves from the head end to the remote consist. The wall surface temperature analysis was carried out for the MacDonald Tunnel using specially modified versions of the Subway Environmental Simulation program, also developed by Parsons Brinckerhoff. The wall surface temperature profile is obtained by superimposing the independent solutions for each of the three components comprising the ambient air temperature, i.e., the daily variation, the annual variation, and the annual average.

Now that we know a little more about ventilation, let's look at the system designed for Mount MacDonald Tunnel.

The site of the new tunnel is the Rogers Pass area of Glacier National Park, British Columbia. At the present time, CP Rail's main line operates through the park via the 5-mile Connaught Tunnel, a 0.95% grade single-track tunnel serving bi-directional traffic. However, the westbound approach grades to this tunnel are on the order of 2.2%, and require the use of locomotive pushers to move heavy laden coal and freight trains through this portion of the park. This procedure is costly and time consuming. With increased traffic forecasted for the mainline, the tunnel and its approach grades would become a bottleneck. Consequently, CP Rail decided to build a second tunnel. Westbound traffic will run through the new 9-mile-long, 0.7% grade MacDonald Tunnel. Eastbound traffic will run through the existing tunnel. The new tunnel is also part of the railroad's over-all grade reduction program. At its completion, trains will be able to run from Calgary to Vancouver over grades not higher than 1.0% and this, in turn, will reduce the required hauling capacity to approximately 1.0 horsepower per trailing ton, considerably less than is currently required.

Due to the projection of traffic through the new tunnel, the railroad established a maximum time interval between trains passing through the tunnel of no more than 40 to 45 minutes. Due to the tunnel's length and the speed of the design trains, the standard portal-to-portal ventilation concept could not be applied without restricting the frequency of traffic. Accordingly, a unique system had to be developed to meet the railway's traffic operating requirement.

The tunnel overburden permitted the location of an economically feasible ventilation shaft near the mid-point of the tunnel. The opportunity to use mid-tunnel ventilation provided the solution to ventilating such a long tunnel without unduly delaying entering trains.

The schematic (Figure 2) features the major components of the vent system which includes a tunnel gate system at the east portal, a tunnel gate system at the mid-tunnel, a 1200-foot-deep, 28-foot diameter vent shaft which is partitioned and connects to the tunnel on opposite sides of the mid-tunnel gate, a series of dampers, and a system of five fans. One fan is housed in a vent building at the east portal and the remaining four fans are housed in a vent building atop the shaft. The combination of the partitioned shaft and the mid-tunnel gate serve to divide the tunnel into two segments, east and west, each having its own ventilation system. The system will purge one-half of the tunnel while a train is passing through the other half.

Figure 3 illustrates how the system would be operated to serve a train requiring supplemental cooling.

As a train enters the east portal, the mid-tunnel gate is closed, the intake dampers at the top of the shaft serving the east tunnel are closed and one of the two fans serving the east tunnel are operated in cooling.

When the rear of the train enters the east portal, the east portal gate is closed, the fan at the top of the shaft is put into idle (which is a non-delivery mode), the by-pass dampers at the top of the shaft are opened, and the fan at the east portal is operated in exhaust.

As the train nears the mid-tunnel area, the mid-tunnel gate is opened and the intake dampers at the top of the shaft are sequentially closed. During this period, the source of air for the fan at the east portal transitions from the top of the shaft to the west portal, thus providing continuous cooling as the train moves from the east to the west segment of the tunnel.

When the rear of the train passes the mid-tunnel gate, the gate is closed behind it, the fan at the east portal is set to idle, the east portal gate is opened, and the fans at the top of the shaft for the east portion of the tunnel are operated in parallel for 15 minutes to purge the east segment. While this is

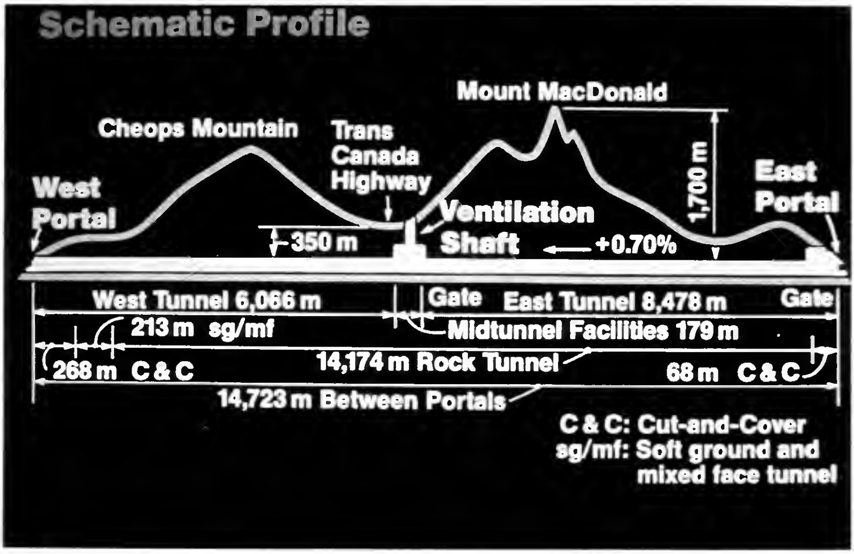


Figure 2. Profile of Mount MacDonald Tunnel

occurring, either of the two fans at the top of the shaft for the west portion of the tunnel are operated in cooling to provide supplemental ventilation while the train is in the west segment. Air is exhausted from the west portal across the train and up the shaft.

When the rear of this train leaves the tunnel, the two fans for the west portion of the tunnel are operated in parallel for 13 minutes to purge the west segment. Once the purge cycle in the east tunnel has ended, a train can now enter the east portal while purge of the west continues.

Now let's take a look at the major components of the system in more detail.

Each tunnel gate system contains two vertical-lift, independently operating gates. However, only one gate is operational at any given time. The inoperable or standby gate is de-energized and held in its up position by the force of its counterweights. The gates are of steel construction except for its center wooden frangible panel which is designed to break away when hit by a train. Each gate is powered through a 5 hp motor/clutch/reducer arrangement located high above the gates. Upon loss of power, the counterweight system is designed to fully open a gate within 15 seconds. When a train passes under a gate, the gates are de-energized and held open by their counterweights. During this period, the gates are maintained de-energized through independent relays controlled by adjacent track circuits, the CTC, and the ventilation system control system.

The prime movers of the vent system are five identical vane-axial, controllable pitch in motion, fans fabricated by Flakt. The fan is single stage, has a wheel diameter of approximately 9.5 feet, and is powered by a nominal 2250 hp, 1200 RPM squirrel-cage induction motor. The motor, floating shaft, and fan shaft are all outside the air stream. A unique feature of this fan is its anti-stall ring which prevents the fan from going into surge. Surge is a dangerous operating condition and occurs when the fan is operating in the unstable portion of its characteristic curve. The anti-stall ring eliminates this portion of this curve.

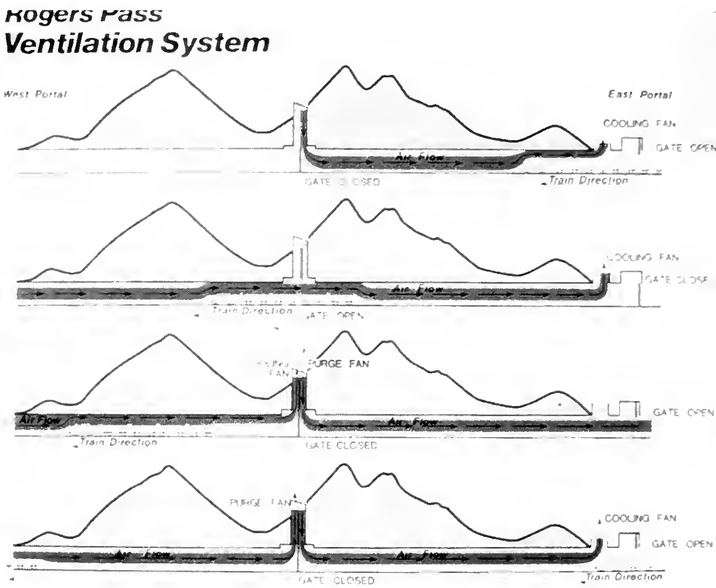


Figure 3.

During peak traffic periods, the fans are required to cycle (cooling off, purge-off, cooling-purge). Because the size of the fan motors preclude frequent starting, the motors will run continuously during these periods. The fan flow is varied by changing the pitch angle of the fan blades through a hydraulic blade pitch control mechanism. This system also includes a programmable controller which allows specific blade angles to be pre-set, such as the idle position where the blades are in the closed position and no air is delivered, and allows the rate at which the fan blades are opened and closed to be varied in order to minimize air hammer.

Each fan is equipped with an isolation damper. The damper is 14 × 14 feet. The blades are made of stainless steel. The damper is hydraulically controlled. The damper actuator includes a spring return mechanism which automatically closes the damper upon loss of power.

The vent system is controlled through a computer-based central control system. The system was designed to operate fully-automatically with only minimum dispatcher interface. For a train approaching the tunnel, the dispatcher need only enter one of the sixteen available fully-automatic cooling modes. The system then executes the mode automatically through the monitoring of track circuits.

This concludes my presentation. If there are any questions on the system, I will be glad to answer them at the completion of this session.

Rail Profile Maintenance Programming

By: J. R. Janosky*

I think we all recognize that the 1980's have been a time of outstanding progress in many areas of railroad engineering. Now, we are preparing to enter the last decade of this century, when, it seems to me that we will see an even greater growth in both new engineering concepts, and in the application of engineering progress to the problems of rail. But, I think we must also face the sometimes uncomfortable fact that virtually nothing in our past experience will go unchallenged or unchanged. Rail maintenance concepts and procedures will be no exception.

When Vin Terrill came to this company three and a half years ago, we knew that things were going to be different. One of the most significant changes we are about to see will be reflected in the fundamental reason why we will grind the surface of rail in the future. If we are correct, this basic change in approach will require all of us to re-examine everything we know about rail grinding. We are convinced that in future rail maintenance grinding programs, the removal of rail surface defects will decline in importance to the degree that for many, it will represent as little as 10 percent of all grinding. In fact, defect removal will become a secondary effect of the primary application of our rail grinders. That application will be *railroad profiling*.

To make our case for that statement, let me review, for a moment, the reasons why we have spent the last thirty or more years grinding a part of our very expensive rails into steel dust along the right of way, and why we have invested so much effort and money in designing bigger and faster equipment to do it with. A wide variety of defects have plagued our rail over those past thirty years as speeds increased and loads went up. It began with primary and secondary batter at the ends of jointed rail, that could develop very quickly into extremely severe conditions. In the early days, until after World War Two, steam locomotives left engine burns that started a similar progression of additional defects. Diesel electrics with their automatic controls have improved but not eliminated the problem. In the sixties, heavier loads and traffic contributed to an epidemic of corrugations, particularly on the field side of the low rail. These also remain a problem, but a preventable problem today. There has been a series of other defects that have been addressed by rail grinding. Flaking defects that can lead to shells at the gage corner of the rail must be removed, once started, or they progress from the micro crack stage to heavy shelling and eventually can result in detail fractures. These are the reasons that rail grinders have been put to work, because these defects can propagate and lead to greatly shortened rail life. But, notice that this approach is a matter of deciding to settle for continuously playing a "catch-up" game.

We allow the rail defects to get a head start and then grind away enough metal to remove them. We wait for fifteen or twenty million gross tons of traffic to start the growth process all over, and then we grind them away again. The rail defects lead and we follow. A by-product of this approach to defect management is a significant amount of metal is removed each time the rail is ground. Then, there is the matter of rail wear. Grinding has the proven ability to extend wear life. Early condemnation of rail or early transposition because of wear can be a significant cost to the railroad. In recent times, we have used rail grinding more and more to relieve the gage corner of the high rail to prevent excessive gage corner wear, and we have ground the field side of the low rail to avoid stress-causing false flange contact. In doing this, we have actually taken a first and important step toward a new and more productive approach to rail grinding. We have used the rail grinder to prevent rail problems, even though in these cases the prevention usually came after the problem had already become serious. The important point here, is that this type of grinding recognized the fact that when wheel contact is allowed to take place anywhere but on the top of the railhead, trouble follows. Stresses are not delivered through the railhead, the web and base and into the track structure. These stresses cause both surface and sub-surface defects.

Looking at Photo 1 we can see a polarized view of wheel applied stress at the proper place on the railhead, where it follows the design path down into the track structure. In Photo 2, because of a worn

*Manager Customer Service, Speno Rail Services Co.

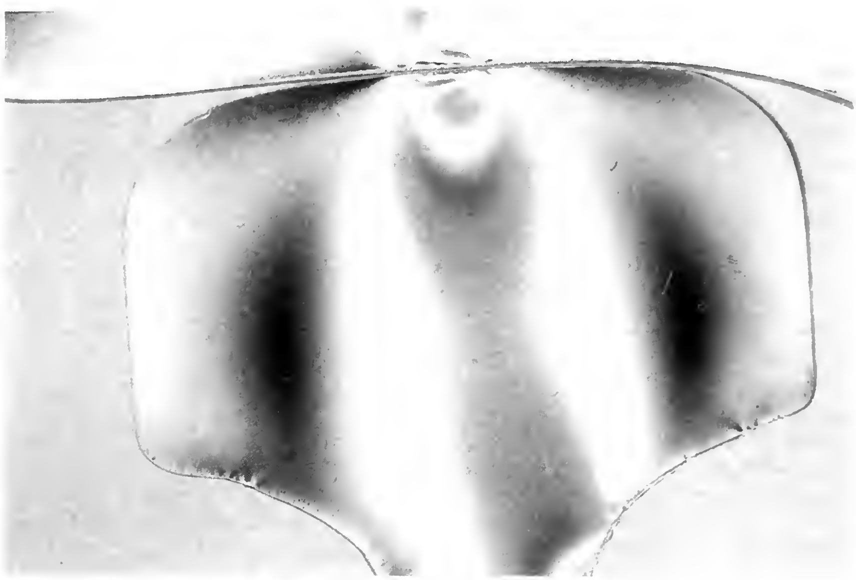


Photo 1

rail profile, the worn wheel makes a false flange contact. We can see the stress lines being contained within the field side of the railhead where fatigue damage and accelerated plastic flow will follow. In Photo 3 the same kind of problem results from flange throat contact in rail that has lost profile and allowed flange wear to take place. Properly profiled rail enhances the steering process and maintains wheel contact in the desired tread area. The result is minimal gage corner wear and the elimination of gage corner stresses that can produce micro-cracks, flaking and eventual shells. The significance of this kind of stress in causing shelling was only recently brought out by R. K. Steele, PhD Metallurgy, in his report on the progress of the AAR research into the causes and failure mechanisms of shelling. Some of you may have already seen the report. The reoccurrence of shelling has been demonstrated in this research, to literally stop when a proper grinding program is instituted. The grinding of the gage corner to relieve flange throat contact eliminates the stresses that cause the process.

All of this does not mean that we have been wrong in our approach to rail grinding application all these years. Far from it. Millions of dollars have been saved by defect and wear management, under the original application philosophy of grinding as the problems became more acute. The reality of the situation was, we had no other good option. For one thing, the equipment of the day was limited by the available control technology. These rail grinders, as early as the first units built after World War Two, had 96 motors. That was enough to develop some sophisticated patterns on the railhead, but the electrical, mechanical and hydraulic controls of the day limited progress in the selective application of the grinding patterns. The grinding angles had to be set manually, requiring considerable time to change while on track. But, the real barrier to developing a better application approach to rail maintenance was really the lack of adequate measurement techniques and equipment. The main tool was a taper gauge and straight edge. The decisions on grinding patterns and metal removal were made on the very subjective judgment of the rail grinding supervisors. Many were very

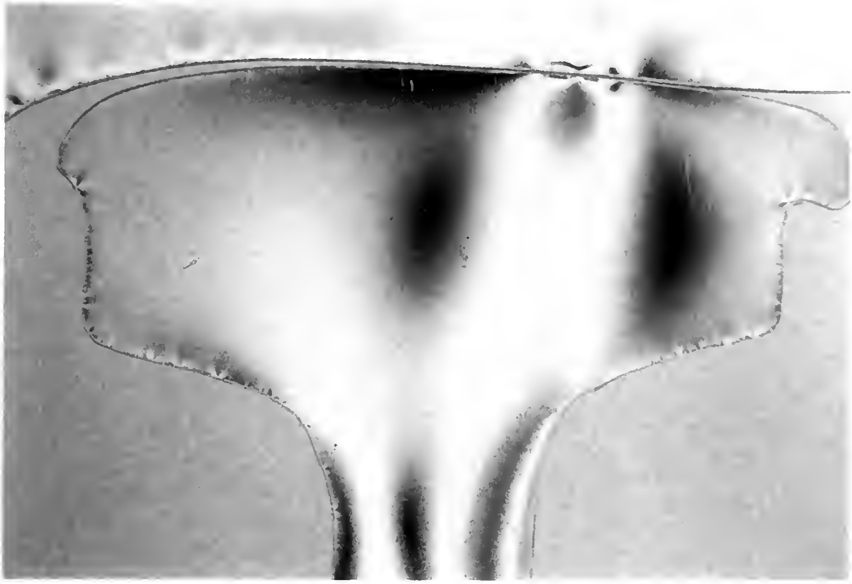


Photo 2

good at it, but remember, the objective was corrective not preventive. The advanced defect condition of the rail was reasonably apparent and the number of passes usually required made it possible to make adjustments during operation. To be sure, some railroads made significant efforts in researching the effectiveness of grinding patterns, and of metal removal approaches. It was largely through those labors that we have come to this turning point in rail maintenance. However, progress was slow. The lack of the kind of computer technology that we have today made an impossible task out of handling, processing and the application of the volumes of data that the rail would yield. Yet, profile grinding was alive and well in the seventies and early eighties, but it was a different kind of profiling approach than the technique we are talking about for the future. Some continuous programs have taken place for the past ten years, and they not only have worked well, they have also proven that the next generation of profile maintenance methods will work exceptionally well.

That next generation will take full advantage of all the progress and technology that has been built into today's rail maintenance units. These machines were designed and built with the power and control to handle the metal removal requirements of today's remedial grinding, but they also have the speed to begin to execute the light metal removal high speed profile maintenance grinding that is beginning to be used on the North American railroads. But, even more importantly, these are intelligent machines. They not only use computer technology to conduct their ordinary operations, but they have the capacity to communicate with other computer sources and to act in concert with them. Machine intelligence will be a key to achieving the cost effectiveness and optimum results of a profile maintenance program.

To see what kind of role machine intelligence will play in this emerging concept and, to get a better overall picture of the way it will work and the benefits we can expect, allow me to speculate a bit on how we think the idea will be applied. It is an idea we call *Rail Profile Maintenance*

Photo 3

Programming (RPMP). We have already talked about the importance of profile maintenance to control wheel generated stresses in rail. The last word in our phrase, programming, is a critical element in achieving that result. Programming of the maintenance of the profile will have to be an ongoing and multi-stage effort. It will require the latest in instrumentation technology and computer utilization. Also, we believe it will require and encourage a new level of cooperative effort and partnership between the rail maintenance contractor, the maintenance of way engineer and the operating departments of the railroads. It is still early in the development of a true RPMP system, but rail grinding contractors are working with the railroads in formulating the requirements of the system. From this work, we will be able to extend the development of the hardware and software needed to make it a reality. This is how RPMP will probably work. There are three components that will share in the implementation of the program: First, the rail grinder with the machine intelligence to make it a highly efficient system; second, the railroad's central maintenance management computer, the data base of information on rail condition and the program support utilities; and third, a rail surface and profile analyzer, a vehicle capable of high speed monitoring to provide continuous, objective data on rail profile and surface condition.

Again, with some obvious speculation about the future, this is how the system might work. A ten step progression of activity that is actually performed in a closed loop configuration, with each step leading to the next and repeating in turn.

STEP 1: The main computer selects a profile that best meets criteria in the data base for rail in similar circumstances. The intelligent rail grinder is given patterns and metal removal specifications from the central computer. The computer may call for little or no profile change or may make significant changes depending on conditions.

STEP 2: The grinding unit performs the initial profiling of the rail using on-board, intelligent control systems that respond to the directions given it by the central computer.

STEP 3: The grinding unit will record the new profile given the rail. This data will be used first, to perform a quality control check on the job and then, the data will be down-loaded to the railroad central computer to become a permanent file on that section of rail.

STEP 4: The file now becomes a part of the main data base held in the central computer. Information about the continuing performance of the rail can be used to program future grinding and also to become part of the over-all performance standards of all the rail in the data base.

STEP 5: From the very beginning of the life of the rail, a two-stage monitoring program will be maintained in the computer. One stage will record the environment of the rail. Because it is tied to the operations as well as the maintenance information sources, the computer will maintain a record of the life of the rail in terms of passing tonnage, consists, speeds and any maintenance that can have an effect on the life cycle of the rail.

STEP 6: The second stage of monitoring of the rail will be conducted by on-track equipment. This will include the normal internal structure testing of the rail and also analysis of the rail by surface and profile measuring equipment. The surface and profile measuring will be conducted at relatively frequent intervals, depending on track conditions. Since this will be done at or near track speeds, it will not interfere with traffic. This data describing the rail will be fed into the data bank as it is generated.

STEP 7: Maintenance management programming in the central computer will compare the environment conditions of the rail in the section and the wear and surface condition of the rail from the test vehicles reports, to the overall rail records in its data bank to determine how well this section of rail is performing and to identify the rate of change it is experiencing. From this, the computer can use historic information in the data base to predict the progression of rail profile condition and to set priorities for the next profile grinding. Since this is to be high speed, light grinding, these grinding programs will be more frequent than corrective programs and will need to be done before defects start.

STEP 8: The computer will be programmed with economic data on which it will make recommendations for the earliest and latest the rail profile can be re-ground for the best cost efficiency. It will not only consider this section of rail, but it will do the same thing for all contiguous sections, because it will be programmed to build a recommendation for an area wide program for best utility of the rail grinder.

STEP 9: Given the "go ahead" by management on the program recommendations, the computer will produce schedules for grinding operations, and most importantly, it will generate the grinding values that will program the intelligent machine for each section of track.

STEP 10: Finally, with the program for patterns and metal removal requirements in its own computer, the rail grinder will proceed at very high speeds with the program. It will again record its own performance and relay that information to the data base and describe the new profile of the rail. And, the process will continue, through the life of the rail . . . a life that will be longer and more productive than anything we have known in the past.

The type of grinding we would anticipate in this mode of maintenance would probably require no more than about five thousandths of an inch of metal removal on any segment of the rail, and often as little as two thousandths will be enough. Therefore, single pass, high speed grinding will cover many miles in one day. This speed will reduce cost three ways. First, the cost per mile for the machine will be low since it will be on track, only briefly. Secondly, the light cut will minimize the cost of metal removed. And, third, the traffic delay time for the track will be minimal. As I said at the outset of this description, this represents some speculation about the methods and procedures that will be used. And of course, each railroad will have its own systems to follow. But, if we are correct in the prediction of the future, most of what I have described will no doubt, come to pass. Given this tight control over the profile of the rail, we believe that a very high percentage of the defects we now find in rail will never get a start. With wheel contact maintained in the selected tread area of the rail, a large measure of the present wear problems in curves also will not take place. We will be on our way to a far more effective and economical way to extend rail life.

We don't offer this approach as a trip to Utopia. We understand that many other variables affect rail and that many conditions influence how maintenance of rail and track must be conducted. Budgets will never be the full amount needed, and other programs such as wayside lubrication will have to be maintained, if the full results are going to be achieved. Wheel maintenance will have to become a priority program in cooperation with maintenance of rail. But, we believe the railroads are, in fact, doing these things and will do more in the future. We of the contract rail maintenance sector will be trying our best to bring this form of progress to you at the same time.

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THE EVOLUTION AND APPLICATION OF RAIL PROFILE GRINDING

By: Allan M. Zarembski*

This report was prepared under the auspices of AREA Committee 4 and its adhoc subcommittee on Rail Profile Grinding. The author would like to thank Mr. A. W. Worth, CN Rail (Committee Chairman), Mr. R. K. Steele of AAR, Mr. B. Sorrels, AT & SF Railway (Previous Committee Chairman), Mr. V. R. Terrill of Speno Rail Services for their comments and suggestions and Mr. Albert Rivoire (Previcus Subcommittee Chairman, Rail Profile Grinding).

Introduction

The elimination of rail surface defects through the use of rotating grinding wheels (rail grinding) has been done by freight railroads since it was introduced by the Pennsylvania Railroad in the late 1930's. That application used the first rail grinder cars for the elimination of corrugations, engine burns, and batter at rail ends. Subsequent applications of rail grinding extended to almost all types of rail surface defects including corrugations, joint batter, weld batter, engine burns, flaking and shelling, as well as for the grinding of mill scale from new rail (1).

This traditional goal of defect elimination, or rail rectification remained the primary use of rail grinding from the 1930's until the 1980's. However, in recent years grinding practice has evolved from the defect elimination approach to the emerging rail maintenance or preventive grinding approach. This new approach does not allow surface defects to develop to any significant extent by attempting to eliminate the defects before they emerge on the railhead. This is of particular interest to heavy axle load environments such as are common in North American freight railways, where unground rail can exhibit a relatively short service life.

This evolution from traditional grinding to the emerging practices of profile control and maintenance grinding has resulted in a significant broadening of rail maintenance, and the potential for increased service life of rail (and thus reduced cost) in severe service track. Rail profile grinding is utilized to achieve this increase in rail service life and this report presents the fundamental concepts behind the technique.

Profile Grinding

Rail profile grinding refers to the method of controlling and maintaining the shape of the railhead (hence the term profile) by grinding the head of the rail (10,17). This represents an evolutionary step beyond traditional defect elimination grinding, where the control of the shape of the rail, either before or after grinding, was not a factor in the grinding process. In fact, as illustrated in Figure 1 (2), traditional defect elimination grinding flattens the railhead (1a), while contour or profile grinding provides a specific contour or profile to the railhead (1b). Contour grinding is used to restore the original shape to the railhead. Profile grinding is used to give the railhead a special profile other than its original shape (18).

However, even in profile grinding the elimination of surface defects, if present, is usually the preliminary step. For rail with surface defects and plastic flow, profile grinding can therefore be a three step process, as illustrated in Figure 2. The initial step, consisting of one or more grinding passes, eliminates any surface defects present. The second step, also consisting of one or more grinding passes, effectively reshapes the deformed railhead. The third and final step (if necessary) grinds the desired railhead profile.

*President, ZETA-TECH Associates, Inc., Cherry Hill, NJ

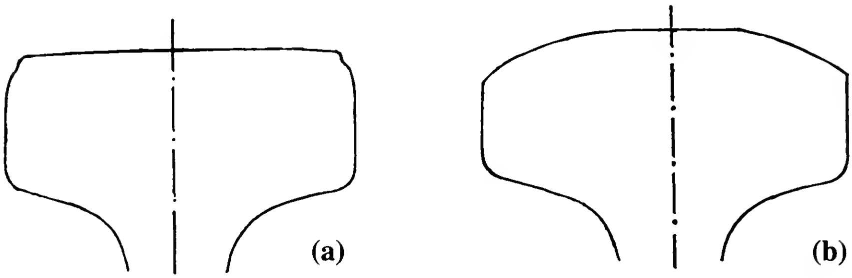

Figure 1. Ground Rail profile (2)
(a) "Flat" profile after defect elimination grinding
(b) "Contour" profile after profile grinding

By determining a profile that is appropriate for a given track location, an optimum rail shape can be designed and then ground into the rail after installation. Through this control of railhead shape the location of wheel/rail contact, and thus the interaction between the wheels and the railhead, can be controlled. This approach could be used in conjunction with wheel profile maintenance, but North

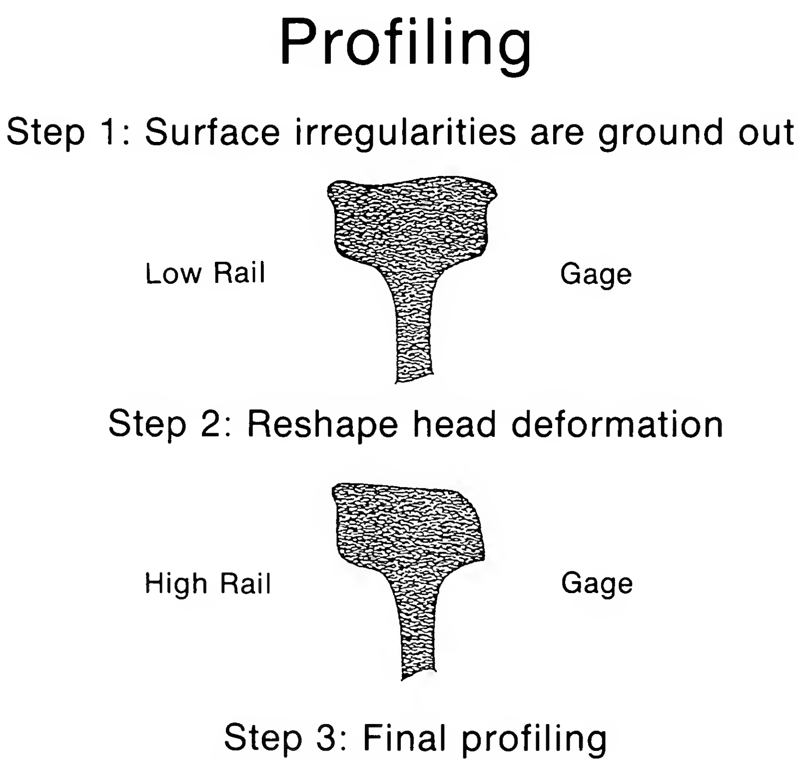

Figure 2. Three Steps of Profile Grinding

American application generally deals with the control of the railhead shape only. This control of rail profile by grinding can be treated independently of the control of wheel/rail contact by wheel profile maintenance.

Rail profile grinding, as currently practiced in North America, encompasses three general purposes of rail maintenance:

a. Control of gage face wear of the high rail on curves and on tangents (as applicable).

b. Control of short wave corrugations on the low rail on curves.

c. Control of gage corner surface fatigue on the high rail on curves to include both spalling and shelling.

While all three purposes can be achieved through the proper use of rail profile grinding, they generally cannot all be addressed simultaneously (3,4). Thus, the profile that is best suited for the control of one of these maintenance areas may not be the best for the other two problem areas, even though it may be possible to derive benefit in all three by proper profile selection. Therefore, to get the greatest benefit from profile grinding it is necessary to prioritize the rail problems for a given track location, and then select the optimum railhead profile for that location.

The evolution of implementating rail profile grinding in each of these three areas is presented in the next three sections.

Evolution of Profile Grinding; Reduction in Rail Wear

Early applications of profile grinding can be traced back to the Pennsylvania Railroad and more recently to the Denver and Rio Grande Western. However, the application of rail profile grinding in the mining railraods of Western Australia during the late 1970's (5) and the reporting of the benefits attributed to this grinding, has resulted in renewed interest and activity. These Western Australia mining railroads operate at North American axle loads and in similar operating conditions, so as a result, their problems and the subsequent solutions are directly applicable to North American railroading.

The original development work was aimed at reducing the gage face wear on low and moderate curves by optimizing the steering of conventional three piece freight car trucks. First, this optimization was analyzed using freight car curving models to help define the optimum railhead profile, and was then tested in actual service application (5). The result was the development of a set of asymmetric railhead profiles (i.e., asymmetric about the center line of the railhead), with a separate profile for the high and low rails of the same curve. In addition, for tangent track where hunting wear was noted, special tangent profiles were developed to control this form of railhead wear.

The initial profile grinding concept, designed to use the steering of the freight car generated by the conicity of the wheelset (3) (illustrated in Figure 3) which shows the shifting of the wheelset outward towards the high rail of the curve. This results in the outer wheel riding on the larger radius portion of its tread and the inner wheel riding on the smaller radius portion of its tread. The difference between these radii, known as the rolling radius differential, compensates for the difference in length around the curve of the high rail and the low rail. In addition, the rolling radius differential generates a longitudinal creep force (which is, in fact, a partial wheel slippage in the longitudinal direction), which tends to align the axles into a radial position. With equally distributed misalignment of the two axles the result is a degree of self-steering that reduces flanging on relatively shallow curves and has the potential to eliminate flanging on curves less than 3 degrees (5).

To maximize the rolling radius differential and still maintain sufficient wheel/rail contact area to avoid excessive contact stresses, the profile presented in Figure 4 was developed (5). This profile results in a shifting of the wheel/rail contact patch on the high rail toward the gage side of the rail head, while still avoiding contact on the gage corner to prevent surface fatigue at that location. On the low rail the contact zone is moved towards the field side of the rail head to avoid any false flange

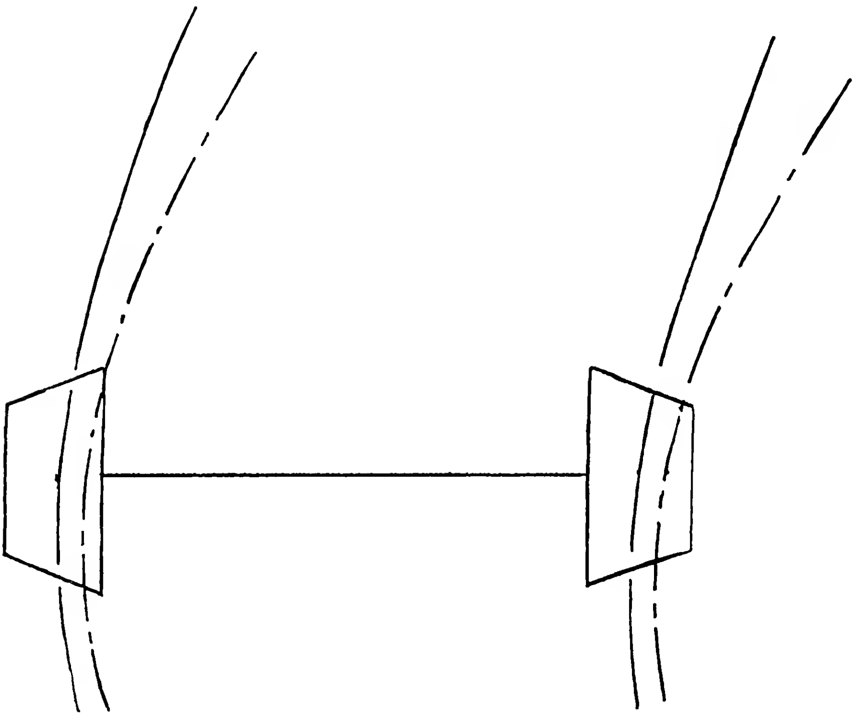

Figure 3. Curving Path of a Wheel Set (3).

contact. In this manner the rolling radius differential is emphasized and the lateral forces generated by the truck while curving are reduced. In addition, lateral gage face wear is also reduced. In fact, for shallow curves (in the Australian case for curves less than 3 degrees) gage face wear is all but eliminated, as illustrated in Figure 5.

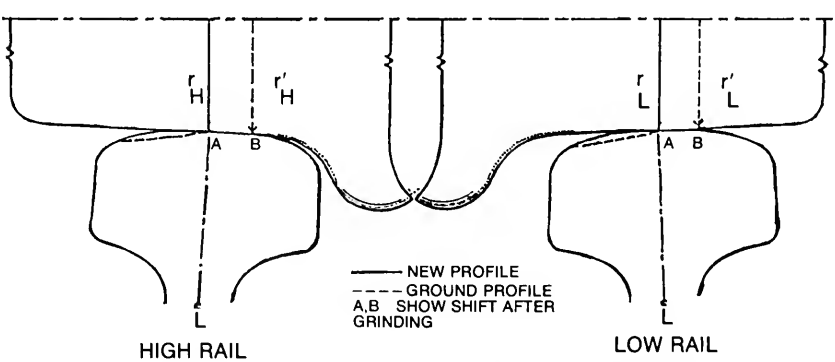

Figure 4. Effect of Grinding on Wheel/Rail Contact Positions (5)

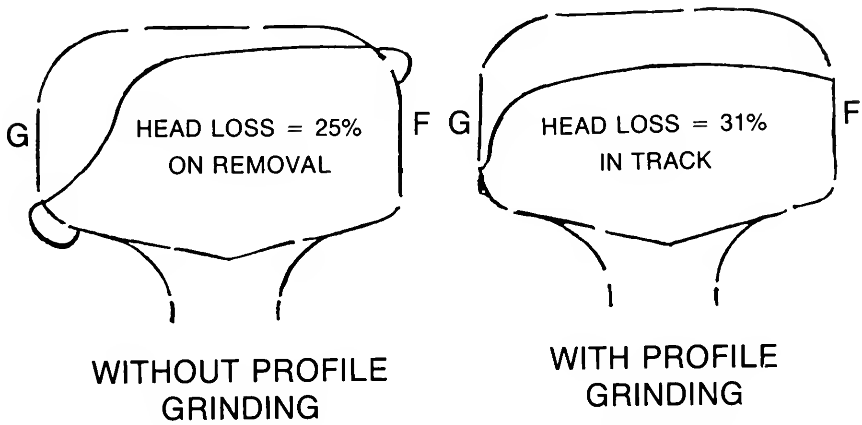

Figure 5. Worn Rail Sections, with and without Profile Grinding

Subsequent field tests of the effect of profile grinding at FAST (6) measured the reduction in both lateral flanging forces and gage face wear for several different railhead profiles. In these tests, lateral force measurements were taken on a 4 degree test curve with three different railhead profiles and a control (non-profiled) railhead. Figure 6 presents the results for operations above, below and at bal-

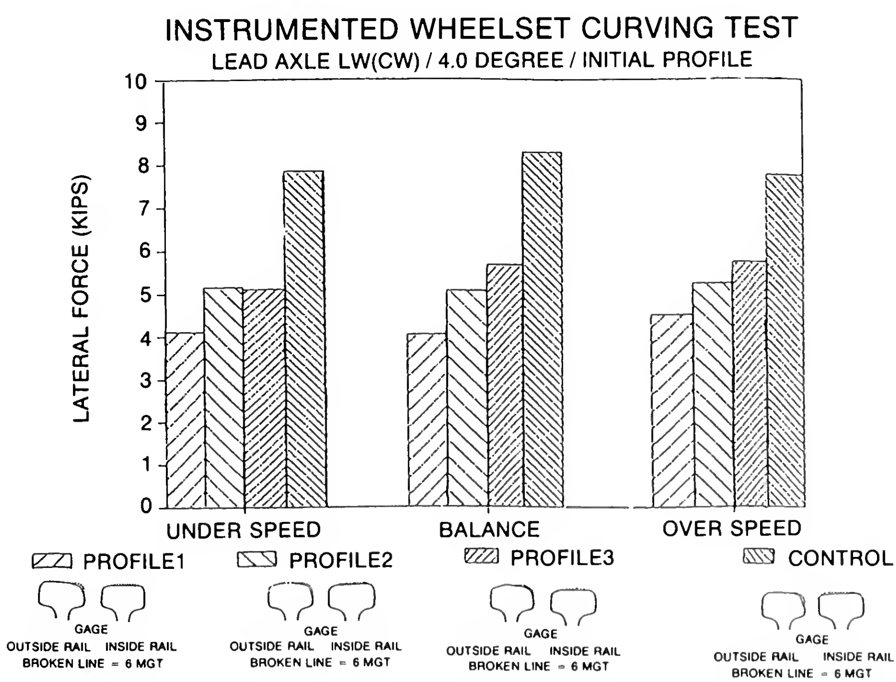

Figure 6. Lateral Wheel Forces—4.0° Curve. (6)

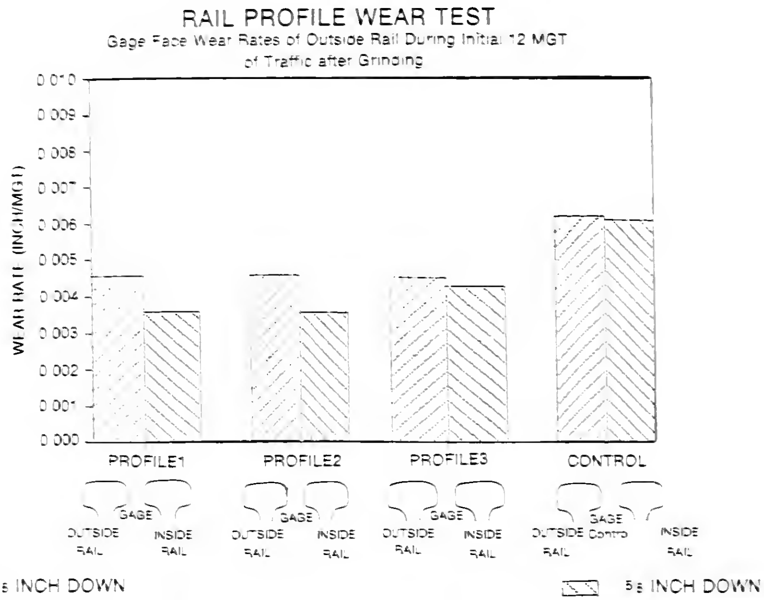

Figure 7. Outside Rail Gage Facewear—12 MGT. (6)

ance speed for the curve. In all cases, profile grinding significantly reduced the measured lateral forces.

Please note that the profiles tested at FAST lasted only 10 MGT (in non-lubricated operations) and were completely gone after 20 MGT of traffic. Therefore, the beneficial effects of profile grinding started to disappear after 10 MGT of operations and were eliminated after 20 MGT.

This reduction in lateral force translates into a reduction in gage face wear. Even for curves where flanging is not eliminated, such as the 4 degree curve presented in Figure 7, a reduction in the rate of gage face wear was measured.

In the Australian case, where flanging was almost completely eliminated, significant increases in rail life were recorded (5). These are indicated in Table 1.

In fact, the use of profile grinding as a means of controlling rail wear resulted in a dramatic reduction in the projected rail requirements during the early 1980's (see Figure 8).

Table 1.

Increase in Rail Life by Profile Grinding

Curvature (Degrees)	Rail Life (MGT) No Grinding	Rail Life (MGT) Profile Grinding	Theoretical Increase (%)
1.5	255	465	82
2	225	390	73
2.33	195	330	69

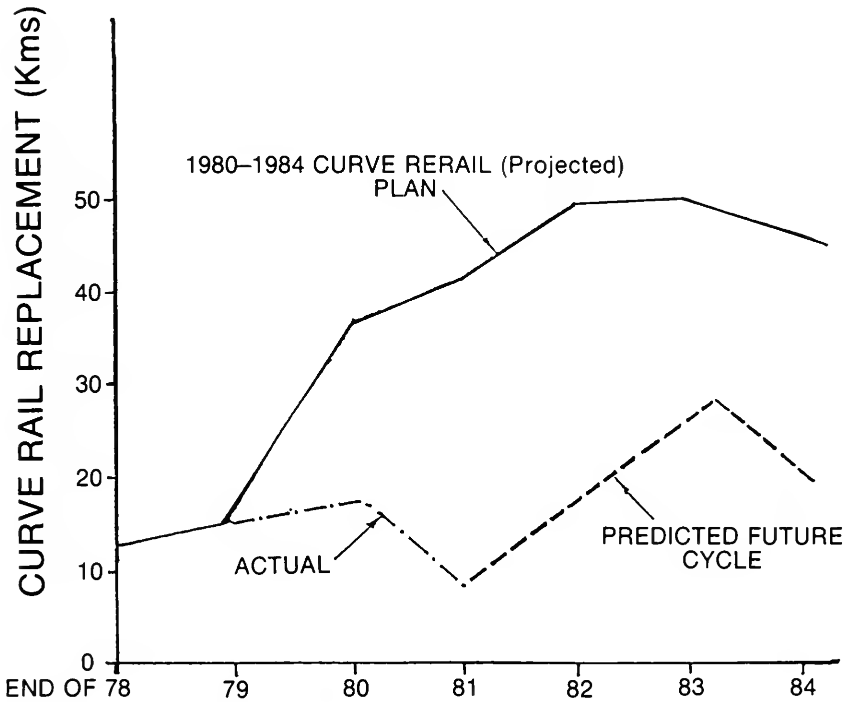

Figure 8. Effect of Profile Grinding on Curve Relay Requirements (5)

The use of profile grinding has been extended to North American railroads with their more severe curvatures and greater variability of wheel conditions. This has resulted in a shift in emphasis of profile grinding away from wear reduction and towards first corrugation elimination and then towards fatigue control.

Control of Short Wave Corrugations

The second area of benefit to be derived from profile grinding is of corrugation control. In North American applications this refers to the control of heavy axle load, short wave corrugations found on the low rail of curves. These corrugations generally have wavelengths in the range of 12 to 24 inches on wood tie track (7).

These freight railroad corrugations are generally associated with the high contact stresses generated when the false flange of a worn wheel runs on the field side of the low rail, as illustrated in Figure 9. This contact, which is counter-formal (i.e., the curvatures of the two bodies in contact are opposite to each other), causes significantly higher wheel/rail contact stresses than the normal, conformal, wheel/rail contact configuration (3).

When this high contact stress is located near the field side of the low rail (i.e. where there is little unstressed rail steel to constrain the overstressed material), severe plastic deformations and corresponding short wave corrugations can result (8). These corrugations can be of significant depth (over 0.6 inches, (4) and give rise to severe wheel/rail dynamic impact forces in the track structure.

Control of these corrugations has been considered by at least one North American railroad (3) to

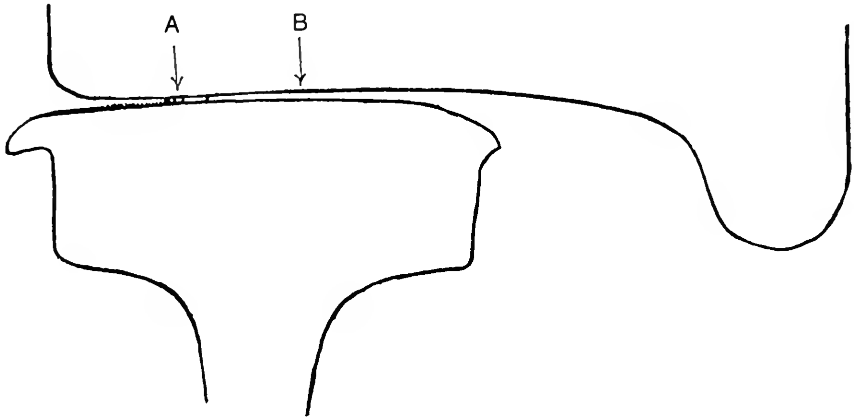

Figure 9. False Flange Contact on Field Side of Low Rail (3)

be the most important aspect of profile grinding of the rail. This is true as long as significant corrugations remain. Once the corrugations have been eliminated other aspects of rail maintenance emerge as being most important. Therefore, several other techniques (such as control of wheel profile and of track gage) should be employed to control corrugations, either alone or in conjunction with profile grinding. However for the purposes of this report, the primary mechanism to be discussed is rail profile grinding by itself.

By grinding the field side of the low rail to shift the contact point towards the center of the railhead (such as from point A to B in Figure 9), the high stress producing false flange contact is avoided. Rather a more tolerable conformal contact condition is established near the center of the wheel hollow and at the top of the railhead.

The grinding pattern used for this type of profiling maximizes metal removal on the extreme field side of the low rail. Thus, it can be used in conjunction with the wear control profile described in the previous section and illustrated in Figure 4. However, the percentage of grinding motors used and the amount of metal removed must once again be determined by the railroad with respect to the site conditions of the rail being ground.

In the case of a test application by one major North American railroad (3,4), the use of profile grinding to control the regrowth of corrugations was evaluated for several different types of grinding pattern. By measuring and recording the average depth of corrugations for periodic intervals after grinding, the development of a corrugation regrowth curve was possible (see Figure 10). For both profiles used in the test, corrugation regrowth was significantly slower than it had been using conventional (defect elimination) grinding patterns. This reduced growth rate could be used to extend the grinding cycle from the previous 6 month interval to a 8 month interval, an extension of 33% (4).

Alternately, it was observed during this test that more frequent grinding passes could reduce the overall amount of grinding by eliminating the corrugations while they are relatively shallow. This comes about because of the non-linear nature of the corrugation growth curve (Figure 10). By grinding frequently, fewer grinding passes are required over the life of the rail (9). This concept, which is illustrated in Figure 11, is discussed in the later section on light grinding.

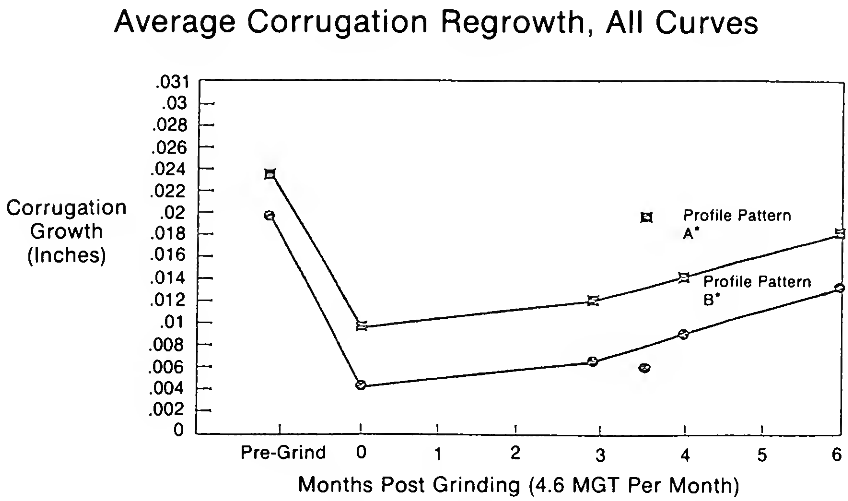

Figure 10. Corrugation Regrowth After Profile Grinding (4)

In the more recent applications of rail profile grinding, this specific grinding strategy is generally incorporated as part of the overall grinding activity. By controlling the contact zone on the field side of the low rail, the undesirable false flange contact can be eliminated without effecting the other profiling objectives.

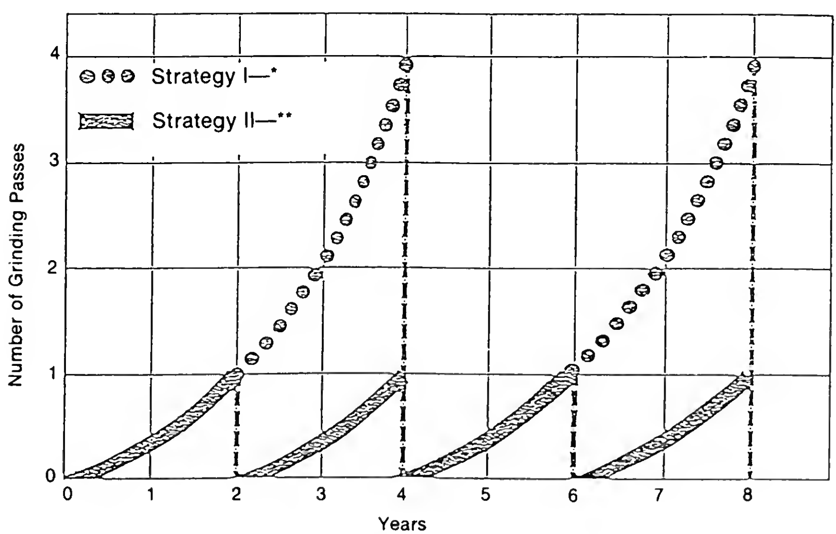

Figure 11. Corrugation Growth Rate Effect on Grinding Strategy (9)
***4 passes after each 4 years (8 passes over 8 years)**
****1 pass after each 2 years (4 passes over 8 years)**

Control of Gage Corner Fatigue

The third area of benefit associated with rail profile grinding is in the control of rail surface fatigue; in particular fatigue defects at the gauge corner of the railhead. This includes both surface fatigue defects, such as spalling, and sub-surface fatigue defects, such as gage corner shelling.

In a severe flanging condition, such as on a sharp curve, single point contact between the throat of the wheel and the gage corner of the rail frequently occurs. This type of contact, which is illustrated in Figure 12, generates very high contact stresses in the region of the gage corner of the high rail. These high stresses, can result in gage corner fatigue problems, including cracking and spalling (10,11,19). Two point contact, when flanging in curves, can also produce very high combined gauge corner contact stresses in the high rail if the two contact points are close together. This occurs when certain wheel profiles are run on certain rail sections. A notably bad case is the combination of 136RE rail and Heumann or similar designs based upon a worn wheel configuration such as the AAR1 profile. The sort of damage that results is depicted in Figure 13.

Table 2 presents calculated wheel/rail contact pressures for combinations of wheel and rail profiles. These contact pressures were calculated using the AAR curving model (16). Note the extremely high contact stresses associated with the new (unworn) 136RE rail and the AAR 1 wheel profile. Since most wheels in service are worn and therefore similar to AAR1 or Heumann profile, the new 136RE profile may not be compatible with most of the wheels running on it.

In order to relieve these high contact stresses, grinding of the gage corner of the rail can shift the wheel/rail contact points away from the corner and into a more central location on the railhead. This shifting of the wheel/rail contact point is analogous to the two other aspects of rail profile grinding discussed previously. The grinding required to shift this contact away from the gage corner is illustrated in Figure 13, from which it can be seen that grinding is required on the gage corner of the high rail.

This grinding of the gage corner can result in a decrease in both surface fatigue spalling and sub-surface fatigue shelling, by wearing away the surface fatigue damaged rail steel. The point of maximum rail stress is relocated before fatigue damage can initiate a failure. Figure 14 shows such a decrease in transverse defects (due to shells) as well as overall fatigue defects for one major North American railroad that utilized rail profile grinding to control gage corner fatigue from 1982 onward (12). Other instances of the control of rail fatigue defects by profile grinding have also been reported in Australia (13).

In the case of sharper curves, where flanging takes place, a second contact point between the flange of the wheel and the gage face of the rail can occur, thus generating "two-point" contact between the wheel and the rail. This change in wheel rail contact, from one point to two-point contact, can result in a deterioration in truck curving performance and a corresponding increase in the wheel/rail flanging forces. This has been demonstrated in recent field tests on a major freight railroad (3). The result can be an increase in gage face wear, if no other action is taken. Therefore, this type of gage corner profile grinding should be used primarily in areas where rail fatigue, and not rail wear, is the dominant rail failure mode.

However, it is noted that a limited amount of gage corner grinding, when combined with compensatory grinding to maximize the rolling radius differential, can be used as part of an overall profile grinding strategy to control gage corner fatigue without increasing gage face wear (3,4). In fact, grinding of the gage corner of the high rail can be incorporated into the wear control pattern, previously illustrated in Figure 4. As in the case of corrugation control, this type of profile grinding can be combined with the previously defined profiles.

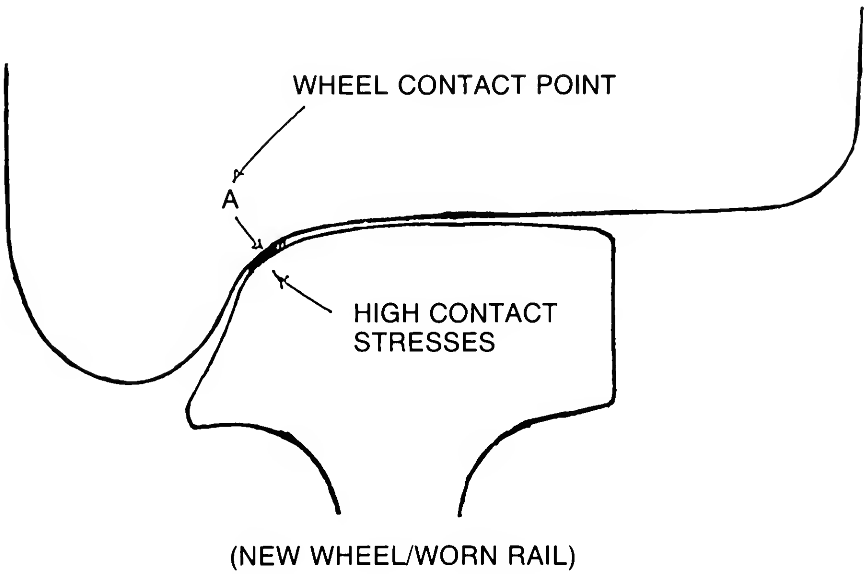

Figure 12. Single Point Contact between Gauge Corner of Rail and Wheel Flange Throat.

Table 2.

Contact Pressure Determined from Exercise of the AAR Curving Model

W/R Profile	Curvature 2°	4°	6°	8°
AAR1:20/132RE	191ksi	170ksi	160ksi	154ksi
flanging?	yes	yes	yes	yes
AAR1:20/136RE	182ksi	154ksi	134ksi	123ksi
flanging?	yes	yes	yes	yes
AAR1:20/Curve Worn	142ksi	127ksi	118ksi	113ksi
flanging?	yes	yes	yes	yes
AAR1/132RE	460ksi	329ksi	240ksi	220ksi
flanging?	no	no	yes	yes
AAR1/136RE	448ksi	421ksi	813ksi	224ksi
flanging?	no	no	no	no
AAR1/Curve Worn	327ksi	101ksi	92ksi	87ksi
flanging?	no	no	yes	yes

AAR1:20—Standard Wheel Profile
AAR1—"Heuman" Design Profile

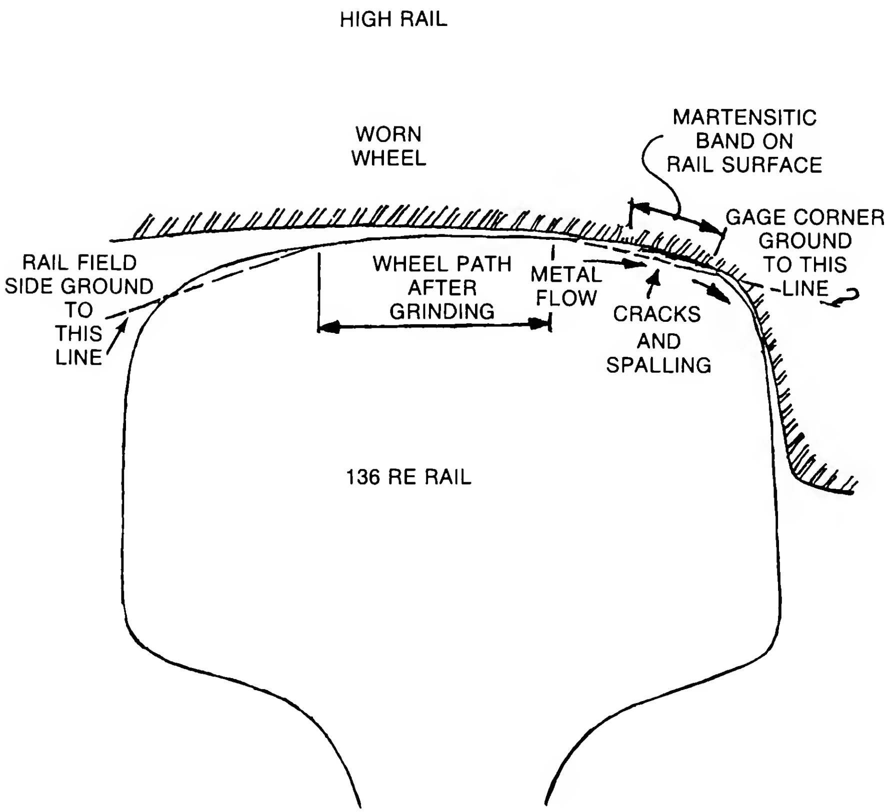

Figure 13. Gauge Corner Spalling and Profile Grinding to Relieve it.

Light Grinding

As the concept of maintenance grinding becomes more widely used (and in fact it is used by most major North American railroads), the benefits of more frequent grinding, i.e. the resulting elimination of rail surface defects at an early stage, become increasingly apparent. This has already been observed in cases of corrugation regrowth. When the grinding of corrugations is done at an early stage in their growth (and on a shallow portion of their growth curve), a decreased rate of regrowth results, i.e., there is a longer interval before the corrugations grow to an undesirable depth.

This concept has also been applied to rail surface fatigue types of defect (2). As can be seen in Figure 15, grinding of the surface defects (such as fatigue defects) while they are still relatively shallow requires significantly less metal removal than when the surface cracks have grown to a significant depth. In fact, grinding at this early stage can avoid the formation of corrugations or other surface defects entirely, provided that the grinding is carried out on a regular, ongoing basis. This concept, which has been referred to as preventive grinding, suggests that very light grinding passes (0.002 to 0.005 inches in depth) made at very frequent intervals (5 to 10 MGT for sharp curves) can prevent the emergence of these defects, and thus extend the life of the rail. The corresponding profile

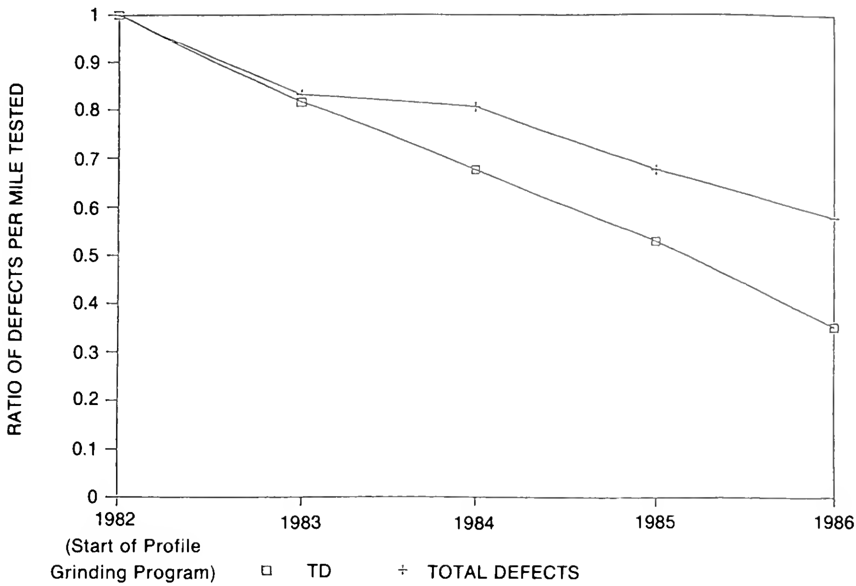

Figure 14. Rail Defects on Major North American Railroad (defects normalized by actual miles tested) (12)

required to maintain this rail condition is once again established by profile grinding. Note, in this case, rather than using heavy grinding to achieve the proper profile, light, frequent grinds are used to provide and maintain (with an emphasis on maintenance) the profile.

It should be noted, however, that frequent light grinds do not address miscellaneous phenomena such as corrugation starting from rail welds or engine burns (20). And there still may be problems with corrugations coming back in old carbon steel rail that has been severely corrugated in the past. Every so often, a heavier grind to remove surface irregularities and restore profile is likely to be needed.

Economics of Rail Profile Grinding

The final issue to be addressed in this report is the economics of rail profile grinding. While rail profile grinding is still relatively new in its application, particularly in North America (having been introduced in the early 1980's), the question of the relative economic benefits of this technique of rail maintenance have only recently been addressed.

The economics of conventional rail grinding, such as corrugation grinding, have been established, with some analyses displaying a return on investments (grinding costs) of over 400% (14).

Recent analyses of the economics of rail profile grinding (9,12) have calculated the benefits associated with grinding aimed at extending the fatigue life of rail in heavy axle load, mainline service. In such an environment, particularly in sharp curves, rail wear is the traditional cause for rail replacement. However, increasing use of rail lubrication (12) has resulted in a shift in failure mode from rail wear to fatigue, and in particular, rail surface fatigue such as spalling. Rail profile grinding can be used to extend the fatigue life of rail in these cases.

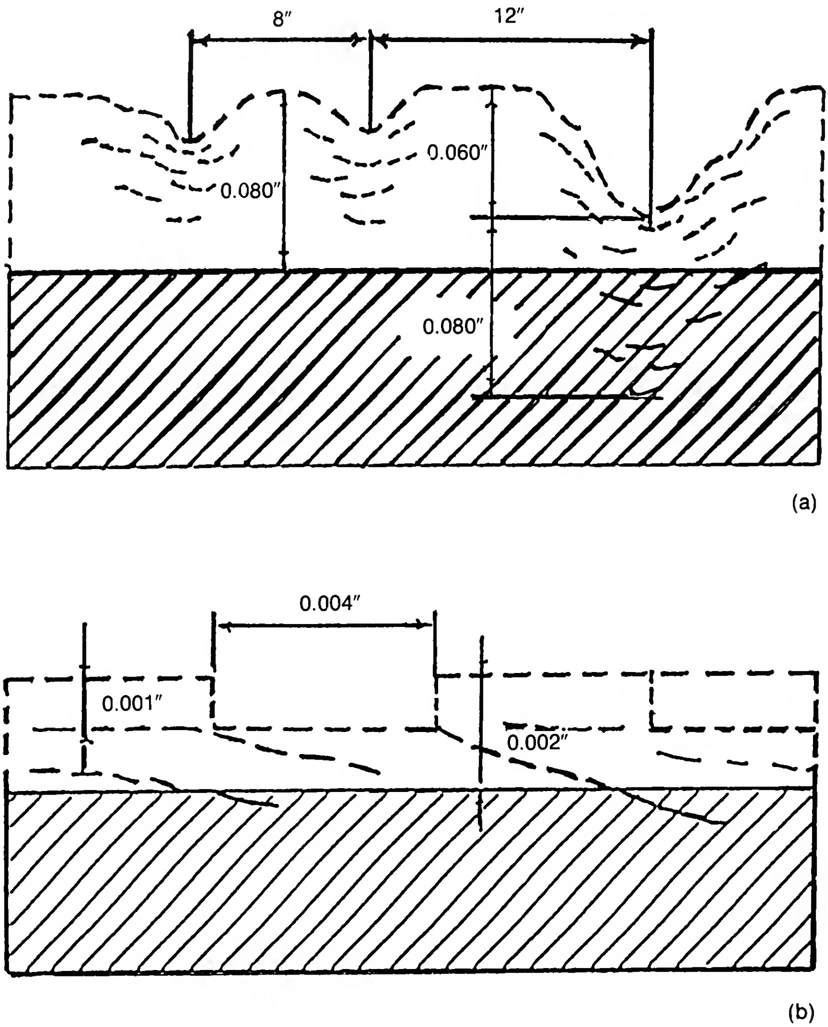

Figure 15. Rail Surface Cracks before
(a) Corrective Grinding
(b) Preventive Grinding (2)

In the analysis of heavy axle load traffic on a well lubricated 5 degree curve (12), the cost of frequent rail profile grinding (one profile pass every 15 MGT) was compared with the corresponding extension in fatigue life. This analysis, which is summarized in Table 3, indicates that under moderately heavy traffic conditions (25 MGT annual traffic), the return on investment (for rail grinding) was approximately 50%. For heavy traffic conditions (50 MGT annual tonnage), the return on investment (for rail grinding) was over 85%. In both cases, rail profile grinding and its associated extension of rail life, were found to be economically viable.

An alternate analysis of rail profile grinding (15) suggests that for a major North American freight railroad, adoption of rail profile grinding can result in an overall cost savings of over $2 Million per year, due to a reduction in replacement rail requirements from 135 miles per year to 120.5 miles per year.

In both cases, analysis suggests that profile grinding is economically viable, as well as a technically feasible approach to rail maintenance.

Conclusion

Rail profile grinding has emerged in the last 10 years as an effective approach for the control of rail fatigue and wear. After initial application in the heavy haul mining railroads of Western Australia it has been quickly adopted by several North American freight railroads. Since the mid 1980's, rail profile grinding, in some form, has been tried by all the major freight railroads. In many cases it has been adopted as the primary rail grinding technique.

As noted in this report, rail profile grinding can be used to address several different classes of railhead problems, including rail wear, corrugation control, rail shelling and rail surface fatigue. While benefits can be obtained in all three areas by proper design of a rail profile, they may not necessarily be obtained to an equal degree in all cases. In addition, the relative benefits in each area will differ as a function of the relative emphasis and effort placed in that area. This is readily evident by the differing effects of rail profiling, e.g., the trade off between gage corner grinding and lateral flanging force. Thus, it is extremely important that the rail problems to be addressed by profile grinding be defined and prioritized. In this manner the profile patterns can be optimized to fit a railroad's particular needs.

Table 3.

Cost vs. Benefits for Rail Profile Grinding (12)

Equivalent Annual Cost Per Mile (Based on Installed Rail Cost of $165,000 per Mile):

	25 MGT	50 MGT
Annualized Cost of Grinding:		
Replace Both Rails:	$10,000	$30,840
Replace High Rail Only:‡	5,000	15,420
Annualized Cost, Profile Grinding:		
Replace Both Rails:	4,169.	16,616.
Replace High Rail Only:‡	2,085.	8,313.
Net Benefit, Profile Grinding:		
Replace Both Rails:	5,831.	14,224.
Replace High Rail Only:‡	2,915.	7,100.
Net Cost Profile Grinding		
(One Profile Pass Every 15 MGT) per Mile:	1267	2533
	1900	3800
‡Annual Savings:	$1015	3300
Return on Rail Grinding Investment	53%	87%

An appropriate trade off between differing rail problems and a corresponding application of profile grinding techniques can result in a customized grinding pattern. This customized grinding pattern is not only for each railroad, but potentially for each location on that railroad. The flexibility of the new generation of computerized rail grinders permits the pre-programming of a large number of grinding patterns, and the immediate selection of those patterns at a grinding site. This permits a railroad to develop specialized profiles to address a series of rail problems, allowing each problem to be treated with its own optimum pattern.

A comparison between three such optimum rail profiles, each of which is geared toward a specific rail problem, is presented in Figure 16 (4). Profile A addresses corrugations as its highest priority, Profile B treats gage face flanging force (and thus wear) as its greatest concern, and Profile C considers gage corner fatigue as its highest priority. Note the difference in grinding emphasis (and thus metal removal) between these three profiles.

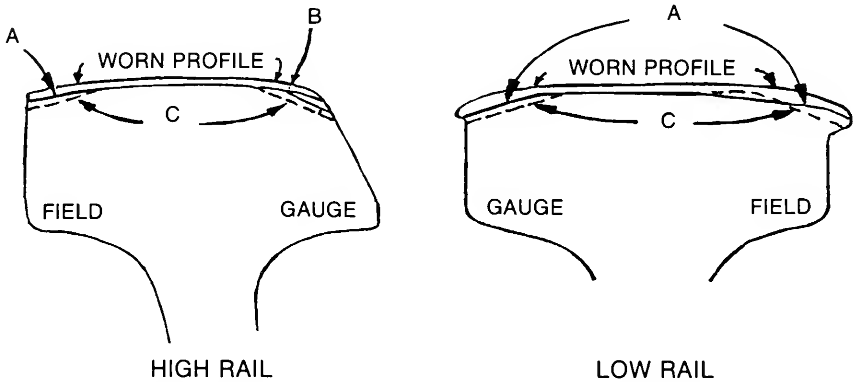

Figure 16. Conceptual Differences between Three Sets of Profiles (4)

It must be noted that any rail profile deteriorates under traffic. This applies to the newly rolled rail profile, as well as to any ground profile. As a result, the desired railhead profile cannot be simply ground into track and forgotten. Rather, it is necessary to periodically monitor the profile and to regrind the railhead when the profile deteriorates to the point where it is no longer functioning properly. This deterioration has been reported to occur between 15 and 20 MGT of heavy axle load traffic (4,6).

If this profile maintenance is not carried out, i.e. if the profile is allowed to deteriorate and is not restored, then the benefits of the ground profiles will no longer continue. Consequently, profile grinding must be considered an ongoing maintenance activity, with periodic maintenance grinding required to retain the optimum railhead profile. By employing such an ongoing program of profile maintenance, the full benefits of the profiles can be achieved, while at the same time the total level of grinding required can be significantly less than that needed if the profiles are permitted to deteriorate completely, thus requiring extensive profile restoration.

It can therefore be concluded that rail profile grinding is an effective and economical technique for the control of rail deterioration and can extend the life of the rail in track. Economical analysis of the benefits of profile grinding have shown that a properly designed and executed program of rail profile grinding can result in significantly reduced rail replacement costs and a strong economic benefit for the railroad.

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COMMITTEE 7—TIMBER STRUCTURES

Chairman: D. C. Meisner

Report of Subcommittee 3—Specifications for Design of Wood Bridges and Trestles

Subcommittee Chairman: A. S. Uppal

CURRENT DESIGN PRACTICES OF THE RAILROAD TIMBER TRESTLE

INTRODUCTION

One of the outcomes of the American Railway Engineering Association's Committee #7 meeting in the spring of 1985 was the development of a questionnaire entitled "Current Design Practices of the Railroad Timber Trestle". After approval by the A.R.E.A. a copy of this questionnaire was distributed to all Class 1 Railroads in North America.

From them a total of seventeen responses were received. Of the seventeen respondents, two were unable to answer the questionnaire as they were no longer involved in the design of and/or the operation over timber trestles. Another one stated they no longer rebuild timber trestles. Fifteen respondents answered the questionnaire as completely as was possible in each case.

The purpose of the questionnaire was threefold:

1. To establish what constitutes the standard or common practice in comparison to the design procedures as laid out in Chapter 7 of the A.R.E.A. Manual.
2. To examine areas where further research and development may yield answers to common problems.
3. To determine where and to what extent further clarifications and/or improvements could be made to Chapter 7 of the A.R.E.A. Manual.

The following is a general summary of the information received. For added reference a tabulation of all the data received has been included in the Appendix of this report.

1.0 GENERAL INFORMATION

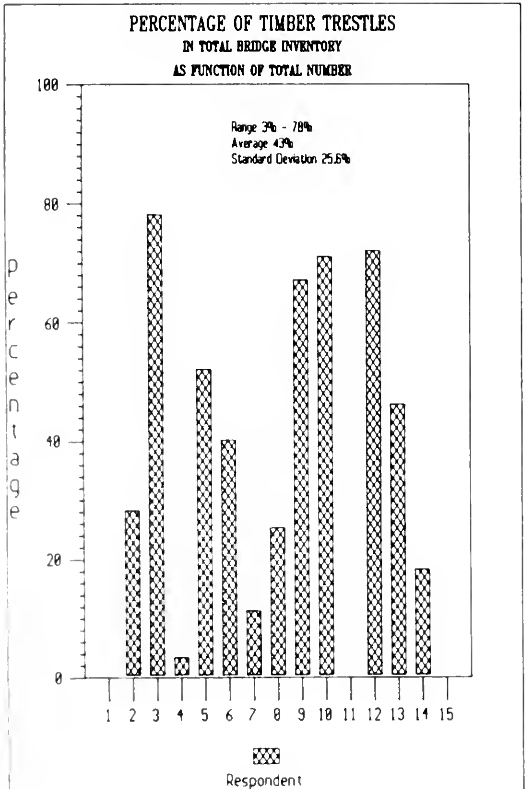
It appears that over the last several decades the types of bridges receiving the most attention (i.e. research and development) have been constructed in steel and/or concrete. Obvious advantages to these types of structures include increased operating life, additional load carrying capacity, longer spans and reduced fire susceptibility, etc. However, upon reviewing the information received it was apparent that the timber trestle still represented a significant portion of the railroad bridge inventory.

1.1 Timber Bridge Inventory

When compared with the total number of bridges across twelve Class 1 Railroads, the timber trestle accounted for roughly 43 percent of the total. Putting it another way the timber trestle made up an average of 33 percent of the total lineal footage of railroad bridges in North America. This somewhat lower percentage when related to total lineal footage was consistent with the shorter length bridges, which in general is where the timber trestles are best suited. Refer to Figures 1 & 2 for graphical analysis of the responses received.

1.2 Bridge Types

The timber trestle is a broad term made up of several bridge types. They include open deck, ballast deck, pile bent, frame bent, single-storey, multi-storey and within each several variations including timber species, component sizes, spacing etc. From the information received, the most common timber trestle in operation today can be described as an open deck (11 of 15) single-storey (13 of 15) pile bent (13 of 15) structure.



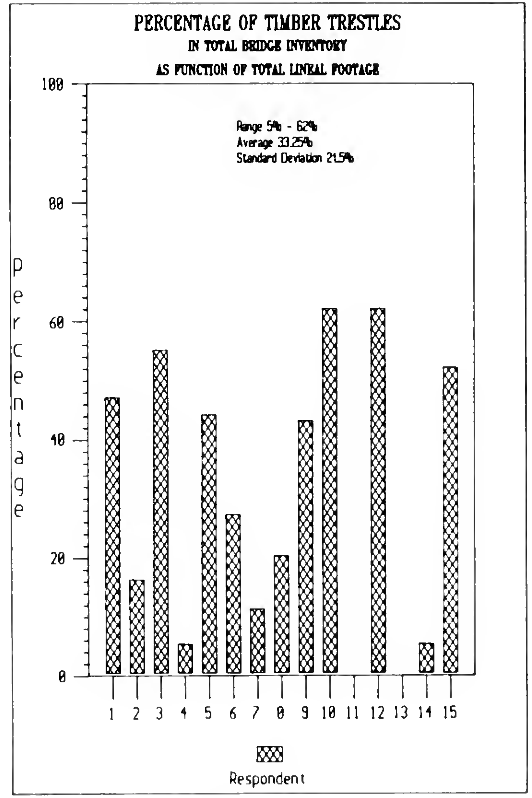


Figure No. 1 **Figure No. 2**

NOTE: Blanks indicate respondent did not give quantities as a percentage

1.3 Timber Species

The most common bridge material being used today is select structural Douglas fir. However the breakdown for the various bridge components using different species in order of preference were as follows:

TIES: Douglas fir (7 of 15), southern yellow pine (6 of 15), oak (2 of 15) and western hemlock

STRINGERS: Douglas fir (10 of 15), southern yellow pine (3 of 15) and oak.

CAPS: Douglas fir (7 of 15), southern yellow pine (4 of 15), oak (2 of 15) and western hemlock

PILES: southern yellow pine (7 of 15), Douglas fir (3 of 15), cedar, larch, tamarac, spruce and oak

POSTS/MUDSILLS: Douglas fir, southern yellow pine and oak

2.0 DESIGN

The design of railroad timber trestles is covered in depth in Chapter 7 of the A.R.E.A. Manual. The main variations across the railroads polled were in the Cooper's E-loading being used and in the values of allowable unit stresses.

The Cooper's E-loading was found to range from E-60 to E-80 with an average value of E-72. The most common value (4 of 10 responses) was E-80. It should be noted that only one of the railroads included a factor for impact loading.

Some railroads no longer design new timber bridges, while others restrict their use to branchlines or industrial spurs.

2.1 Allowable Unit Stresses

A wide range of values were found to exist with respect to the allowable unit stresses used in design calculations. This can be rationalized to some extent in that these figures are probably dependent on species, grading, treatment process, moisture content (as stipulated in the grading rules used), etc. The responses received are in general for select structural Douglas fir although oak and southern yellow pine are also used.

Allowable Unit Stress	# of Responses	Weighted Avg.
1. Flexure 1000–1200 psi	2	
1200–1400 psi	4	
1400–1600 psi	2	1497 psi
1600–1800 psi	6	
>1800 psi	1	
2. Longitudinal shear		
<100 psi	5	
100–125 psi	7	104 psi
>125 psi	3	
3. Compression		
a. Parallel to grain		
<1000 psi	1	
1000–1500 psi	9	1151 psi
>1500 psi	1	
b. Perpendicular to grain		
<300 psi	2	
300–400 psi	6	408 psi
400–600 psi	5	

The grade governing bodies referenced to were:

WCLIB—West Coast Lumber Inspection Bureau #16 (6 of 15 responses)
SPIB—Southern Pine Inspection Bureau (5 of 15 responses)
NLGA—National Lumber Grades Authority (2 of 15 responses)
AREA—American Railway Engineering Association
NHLA—National Hardwood Lumber Association
WCLA—West Coast Lumbermen's Association

3.0 CONSTRUCTION DETAILS

The construction details as provided either on the questionnaire or from accompanying standard plans varied among railroads but all were very much consistent with the details shown in Chapter 7 of the A.R.E.A. Manual. The following is a breakdown of the information received.

3.1 Guard Rails

Most of the railroads use guard rails, 4 of 12 respondents basing their practice on various criteria. The distance in from the running rail ranged from 9.5″ to 20.25″ with an average of 10.6″.

3.2 Bridge Decks

Criteria for providing walkways on one or both sides of bridges (OS–one side, BS–both sides)

—as required by operating conditions

—OS near switch, BS near yards

—OS old std. when within 1.2 miles of switch on switch side,

—BS new std. all rebuilds or redecks

—OS within yard limits

—BS within yard limits

Refuge bays often not used (5 of 11 responses). Usage is generally governed by length of bridge (eg. if bridge length >150 ft.)

3.2.1 Open deck

Ties:

Width	×	Depth
9 of 15 = 8″		9 of 15 = 8″
2 of 15 = 9″		1 of 15 = 6″ & 8″
3 of 15 = 10″		1 of 15 = 7″
1 of 15 varies 8″ to 10″		2 of 15 = 10″
		1 of 15 = 9″–16″
		1 of 15 = 6″

Tie Spacing:
1 response—13″ c/c
4 responses—12″ c/c
1 response—16 7/8″ c/c
1 response—14 to 16″ c/c
6 responses—14″ c/c

The proper spacing is maintained on 9 of 12 railroads with guard timber, 4 railroads utilize spacer bars. Guard timber is not notched for this purpose.

Lining spikes for alternate ties:
- 8 replies—yes
- 1 reply—every tie spiked, every 6th bolted
- 1 reply—every tie spiked
- 1 reply—every other tie
- 2 replies—every 3rd tie

3.2.2 Ballast deck

Ties—Most use 9" × 7" × 8'-6" or 9'-0" with c/c spacing averaging approx. 20.5". Ballast under ties ranged from 7.5" to 12" in depth (9 of 13 responses were for 8" depth). Several variations in curb timber sizes were recorded:

- 3 replies—8" × 10"
- 2 replies—8" × 6"
- 2 replies—6" × 12"
- 2 replies—8" × 14"
- 1 reply—8" × 16"
- 1 reply—steel sides

3.3 Spans

Majority use 6 to 12 stringers of various sizes including: 8" × 16", 10" × 16", 10" × 18" and 10" × 20".

11 of 15 respondents pack stringers in chords under running rail.

Span lengths—(c/c bents)
- Int. spans—12'–15' (avg. 13.5')
- End spans—12'–14.5' (avg. 13.1')

Span supports in general (12 of 15 replies) were continuous over intermediate supports.

For design the outside jack stringer was considered to carry the following load percentages:
- 5 replies—0%
- 2 replies—50%
- 2 replies—100%
- 1 reply—Dead load only
- 1 reply—No jack stringer used

For sizing the ends of stringers, 10 respondents said no, 2 said yes and 1 said only if needed.

3.4 Bents

Two types of caps are currently being used. All of the 15 respondents said they use timber caps. Five of them also use concrete caps. Common size for timber 14" × 14" × 14', one railroad uses split caps made up of 2-8" × 16", and for concrete 14" × 15" or 15" × 15" × 14' are used.

The number of piles/posts per bent ranged between 5 and 6. The majority (7 of 15) say 6 piles, 5 of 15 use both 5 & 6 piles and 3 use 5 piles. The spacing between centre to centre of piles was as follows:

Intermediate piles	–	varies 2' to 3' c/c
Outer piles	–	varies 2' to 3' c/c

Pile batter is generally provided for as follows:

Intermediate piles/posts	End piles/posts
11 replies—1 in 12	8 replies—2 in 12
1 reply—1 1/2 in 12	4 replies—2 1/2 in 12
1 reply—0 in 12 for 5 piles	2 replies—varies
1 reply—varies	1 reply—3 in 12

Nominal minimum pile diameter at top approx. 14" and at the bottom between 8" to 9". Piling driven to provide 15 to 40 tons (on the average 25 tons) minimum carrying capacity. The nominal size of posts used is 12" × 12" except for two railroads, one of which uses 12" × 14" and the other 14" × 14".

4.0 PROTECTIVE TREATMENT

The protective treatment most widely used (virtually all timber trestles) is the application of creosote or a creosote based compound. The creosote, creosote-petroleum mix or creosote-coal tar mix is applied under pressure to the timber components prior to construction.

With the exception of two railroads no one is using any fire retardent agent.

Protective materials between timber components, such as roofing felt, coal tar pitch, galvanized sheets, etc., are used predominantly between the cap and pile cut-offs.

Number of Responses

3—Application of hot creosote and some sort of sealing fabric such as roofing felt or cotton fabric.
1—.0024 zinc sheet between pile and cap
1—1/4" treated plywood or neoprene
1—20 ga. galvanized iron
1—Rubber and/or roofing mastic

5.0 MAINTENANCE PROBLEMS

As expected, the majority of timber trestle maintenance problems are related to timber decay. Responses to this item included:

—Decay and mechanical wear

—Caps splitting and decay between components

—Cap failure on heavy tonnage mainlines

—Bad piles and caps

—Crushing and splitting of timber caps

—Loosened fastenings, deteriorated headwalls, cap decay and/or failure

—Pumping piles on non-standard four pile bents

—Chords shifting on caps, especially on lines with heavy unit coal train tonnage, bridge fires

—Accelerated timber decay adjacent to bolts, drift pins and groundline

—Bolt hole decay, crushed caps

It should be noted that a number of railroads have reduced the cap failure problem by using prestressed concrete caps in place of the standard timber cap. Some accelerated wear and movement was also attributed to the operation of unit trains over timber trestles. The resulting problem is shifting and improper seating of stringers and/or caps.

6.0 CONCLUSIONS

The questionnaire has served its main objectives in providing timber trestle details used by different railroads and a comparison of the same with those given in Chapter 7 of the A.R.E.A. Manual. Also it pin-points areas that require further examination for additional improvement in design both, for greater economy and longer serviceability.

No significant suggestions were made for improvement to the current design practices for timber trestles however, a couple of helpful points were raised. One, to consider the use of corrugated metal pipe around the base of piles to protect against ice and fire, and secondly a general observation to reduce the contact wherever possible between timber and soil and between timber and steel.

Timber trestles have been and are still fairly common within the North American railroad system.

However their numbers have been steadily decreasing as they are being replaced with steel or concrete structures. Some railroads are restricting their use to branchlines and industrial spurs.

As long as timber is available at affordable prices and there are streams which could be bridged with relatively short spans, the timber trestle would remain an alternative to other types of bridges. Even railroads currently replacing their mainline trestles in steel and/or concrete (to reduce fire susceptibility) suggest their continued use on secondary and branchlines.

Consequently increased interest is required to further improve designs for greater economy and serviceability.

7.0 RECOMMENDATIONS FOR FURTHER STUDY

Subcommittee #3 makes recommendations that the following areas be considered for further examination:

1. Decay of Timber

Several factors such as species, grading, moisture content, surrounding environment (weather), type and density of traffic as well as design affect the service life of trestles.

Therefore the existing design details should be examined together with the methods of treatments (both in the treating plant as well as in the field) to seek means of prolonging the service life of trestles.

2. Design and Analysis

Based on the foregoing the following changes to Chapter 7 in Part 2 of the A.R.E.A. Manual are suggested:

a) Article 2.4.4, "Ties" on page 7-2-9 (1988) be revised to include details and graphs to enable readers to use the information contained in Fig. 2.4.4 on page 7-2-10.

b) Article 2.4.5 "Bents" on page 7-2-9 (1988), Fig. 2.4.5a on page 7-2-11 (1988) and Figs. 2.4.5b to 2.4.5g on pages 7-2-12 to 7-2-17 be revised to include information on 7-pile bents as well as information on concrete caps, and to delete 3-pile bents.

c) Tables 2.7.1, 2.7.2, 2.7.8.1 and 2.7.8.3 (1988) be simplified and tables for E-80 loading should be added.

d) Charts for rating the timber trestles be added to Article 2.10.3, "Carrying Capacity" on page 7-2-47 (1988). Also Article 2.10.4, "Inspection" on page 7-2-47 (1988) be revised and expanded.

3. Effect of Train Dynamics

Some railroads are said to have encountered maintenance problems resulting from the operation of unit trains over timber bridges. (Note, currently A.R.E.A. Committee #7 Subcommittee #6 is carrying out some work in this particular area.)

The current design doesn't allow for an independent consideration of the effect of dynamic loads in sizing the components of timber trestles. The reason being that timber as a material has been known to sustain heavier loads for relatively short durations of time and that the allowable stresses used, among many other unknown factors account for the impact as well.

Some experimental work was conducted by AAR in the late 1940's and early 1950's to determine the dynamic load factors, however this work was of limited nature.

Further research into the dynamic response of timber trestles could yield some understanding of the influence of the unit trains as well as the allowance for impact needed in the design of such structures. This might help in the development of the designs which may better withstand the effects of unit trains.

4. Susceptibility to Fire Damage

Loss of timber trestles due to fire and the resulting disruption to operations is one of the reasons cited for replacement with other materials. Research is needed for development of measures including application of coatings which would provide cost effective protection and prevention of fires.

8.0 ACKNOWLEDGEMENT

Thanks to A.R.E.A. Committee #7 members and particularly to R. W. Thompson Jr. the former Chairman for approving the format of the questionnaire. Also thanks to D. C. Meisner, the Chairman and Subcommittee #3 members for reviewing the report.

Special thanks to all those railroad officials who took time to respond to the questionnaire.

Also thanks to J. N. McLeod, Assistant Engineer—CN Rail, Winnipeg for his assistance in compiling the results of this survey.

We trust the data gathered through this effort will provide some valuable information to all those interested.

APPENDIX

AMERICAN RAILWAY ENGINEERING ASSOCIATION
Committee 7 - Timber Structures
Tabulations of Responses to Questionnaire on the Current Design Practices for Railroad Timber Trestles

A) GENERAL

1) What percentage of your bridge inventory consists of timber trestles?

RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
a) By number	-	28%	78%	3%	52%	40%	11%	25%	67%(A)	71%	(C)	72%	46%	18%	
b) By linear footage	47%	16%	55%	5%	44%	27%	11%	20%	43%	62%	(C)	62%	(B)	5%	52%

Note A) Based on each timber trestle approach to a steel span being counted as a bridge
B) By linear footage. 415,000
C) By number 22,318 Spans. By linear footage 290,135

2) Do a majority of your timber trestles possess

RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
a) OD - Open deck	OD	OD	-	OD	-	OD	OD 56%	OD	OD 58%	OD 51%	OD	OD	46%	OD	
BD - Ballast deck	-	-	BD	-	BD	-	BD 44%	-	BD 42%	BD 49%			54%	-	BD
b) PB - Pile bents	PB	PB	PB	PB	PB	PB	PB 90%	PB	PB	PB 95%	PB	PB			PB
FB - Frame bents	-	-	-	-	-	-	FB 10%	-		FB 5%			-	FB	
c) S - Single story bents	-	S	S	S	S	S	S 99%	S	S	S 92%	S	S		S	S
M - Multi-story bents	-	-	-	-	-	-	M 1%	-		M 8%					

3) What Cooper's E loading do you currently design your timber trestles for?

RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	E72(A)	E60(E)	E65(B)	E60(C)	E80	E72	(D)	E70	(E)	(E)	E72	E65	D	E72	E80

Notes A) Have both E72 and E80 designs, E72 generally used except when a temp bridge is needed on a traffic line
B) New timber trestles have not been built since 1969 except on industrial tracks
C) E60 for old trestles, new trestles are steel
D) No longer design new timber trestles
E) Currently not designing timber trestles, but if they did would be E80

4) What species & grades of timber are specified for the following components?

RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
a) Ties	DF (L)	DF #1 Str P&T	(B)	Oak	(E)	(G)	(H)	(E)	Y Pine	DF #1	(J)	DF	Pine(B)	(M)	(B)
b) Stringers	DF (L)	DF #1 Str B&S	DF-SS	(C)	(B)	DF-L57B	DF	(B)	DF	DF - SS	(J)	DF	-	(N)	(E) 60
c) Caps	DF (L)	DF #1 Str B&S	DF-SS	Oak	(B)	DF-L57B	(H)	(B)	Y Pine	DF - SS	(J)	DF	-	(O)	(E) 60
d) Piles & Class of piles	S Pine & DF	(A)	(B)	Oak Class 4	(B) Class A	-	(P)	(E) Class A	Y Pine (Q)	DF Class A	(K)	DF	-	-	AREA Class 1
e) Posts/mudsills	DF (L)	DF #1	(B)	Oak	(B)	-		(B)	Y Pine	DF SS	(J)	DF	-	(O)	-
f) Grading Rules	WCLIB SPIB	NLGA	(D)	AREA	SPIB	NLGA	(I)	SPIB	(F)	WCLIB	(L)	(L)	-	WCLIB NHLA	(E)

Notes A) DF, pine, larch, tamarac, spruce & cedar - class of piles to RR's own spec.
B) Southern yellow pine, Dense Structural 65
C) Longleaf yellow pine or Douglas fir
D) SPIB, PL423, WCLA, Rules 130a, 710b, 714c, for piles, RR's own spec
E) Southern yellow pine
F) Stringers Douglas fir - WCLA Rule 16, Para 130a,710b & 714c, box heart not to exceed 25%
yellow pine SPIB - for Ties Dense Structural 72, Caps Dense Structural 65 and Posts rough yellow pine Dense Structural 65
G) DF & western hemlock, #1 Structural B&S Par 130B
H) Douglas fir or oak
I) WCLIB Book 16 for DF, NHLA for oak
J) DF Select Structural or #1 Structural
K) Southern yellow pine or Douglas fir, Class #1
L) WCLIB Rule 16 130a,130b,131a 131b and in case of respondents #1 & #12 Company's own specs for piling
M) W Coast DF - "Select Structural 130a or red/white oak - Select Car Stock - Select Dimensions
N) W Coast DF - "Select Structural"
O) red/white oak - "Select Car Stock - Select Dimensions"
P) No longer purchased
Q) Railroad's own specification

NLGA National Lumber Grades Authority
SPIB Southern Pine Inspection Bureau
WCLA West Coast Lumbermen's Association
AREA American Railway Engineering Association
NHLA National Hardwood Lumber Association
WCLIB West Coast Lumber Inspection Bureau
DF - Douglas fir
SS - Structural Select

5) What allowable unit stresses in psi are used for sizing the components in:

RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
a) Flexure	OD 1550	1320	-	-	-	-	-	-	-	-	-	-	-	-	-
	BD 1038	(A)	2300	1200	1650	1225	1250	1700		1450	1600	1680	-	1600 Fir 1000 Oak	1600
b) Longitudinal Shear	OD 108	100	-	-	-	-	-	-		-	-	-	-	-	-
	BD 77 (F)	(B)	155	110	110	110	95	150	-	75	80-90 (G)	100	-	85 Fir 110 Oak	130
c) Compression															
i) parallel to grain -	-	960 (C)	1660	1250	1150	-	1250	1200	-	1000	1050-1100	1300	-	1100 Fir 1000 Oak	1050
ii) perpendicular to grain -	-	350 (D)	485	325	275	400	385	400		345	600	375	-	625 Fir 365 Oak	285

d) Any allowance for impact made in addition to unit stresses stated above?
N - No, Y - Yes, If yes, the impact factor used

RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	N	N	Y(E)	N	N	N	N	N	N	N	N	N	-	N	N

Notes A) 1750 psi for overload
B) 105 psi for overload
C) 1275 psi for overload
D) 465 psi for overload
E) 60% Open deck, 40% Ballast deck, stresses given include the impact
F) The above stresses are for E72 Design E80 Design is as follows Flexure - OD 1284 psi Long Shear - OD 88 psi
BD 1136 psi - BD 84 psi
G) Depending on depth

6) Any comments or other pertinent information

RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	(A)	(B)		None				-			None	(C)	(D)	(E)	

Notes. A) Timber trestles are not built on heavy traffic lines except for falsework, emergencies or other temporary use
B) For determining longitudinal shear, first axle is considered to be equally supported over three ties
C) We currently do not design timber bridges to the new timber specifications (1983 AREA Chapter 7)
D) Typical plans furnished to show details of earlier construction
E) We use the NHLA allowable stresses shown in Ch. 7 for Oak & adjust downward for quality of project since original Table was for 1943 & Oak is no longer stress rated

DESIGN DETAILS

1) Track

a) Do you use guard rails on bridges? (Y - Yes, N - No)

b) If yes, how far apart are they spaced from the running rails in inches

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
a)	Y	Y	Y(C)	Some	Y	Y 50'	Y	Y	Y		Y	Y		Some	
b)	10	(A)	(B)	7.5	10 Min	9	7	20 25	(B)		11	(D)		8 Max	

Notes: A) 9 1/2" to 14 3/4"
B) 10" between rail heads.
C) Guard rails not used on all bridges; only those that meet certain criteria
D) 11" between flangeways

2) Deck

a) Open Deck

RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
i) Ties: Width (in)	10	8	9	9	8	10	8	8	7 3/4	10	8	8	8	8 10	8
ii) Depth (in)	8	8	6 3/4	9	6 & 8	10	8	8	7 3/4	8	8	8	8	9-16	6
iii) Length (ft)	10	10	9	10	9 & 10	12	12	10	10	10	10	9	10	10-16	8 5
iv) Spacing (in)	14	14	16.9	14	14-16	14	12	12	12	8	14	12	15	12	13
v) Spacer Bar/Guard Timb	GT	SB/GT	GT	SB	GT	SB	(C)	GT	GT	GT	GT	GT	GT	SB	GT
vi) Is GT notched for ties	N	-	N	-	N	-	N	N	N	N	N(A)	N	N		N
vii) Lining spikes alt ties	Y	Y	(B)	Y	Varies	Y	N	(D)	(F)	(G)	Y(H)	(I)	(E)		Y(H)

Notes A) Unless welded rail is used
B) 5/8" X 10" washer head; drive spike through guard timber into each tie
C) SB when replacing decks, GT for original construction
D) Every tie
E) Every 4th tie drift bolted to stringers
F) Every other tie on curves, every 4th tie on tangent
G) Bolt every 3rd tie and rest spiked all through guard timbers
H) Every 3rd tie
I) Use 1/2" x 10" boat spikes

b) Ballast deck

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
i) Ties. Width (in)	9	9	8	9	9	8-9 5	9	9	9	-	9	9		(D)	9
ii) Depth (in)	7	7	7	7	7	6-7 5	7	7	7	7	[illegible]	[illegible]		-	[illegible]
iii) Length (ft)	8 5	9	9	8 5	8 5	8	8.5	8 5	9	8	8 5	9			8 5
iv) Spacing (in)	Varies	20	19 5	20	21	20.5	21	21	19 5	-	21	19 5			20
v) Bal depth below tie	8	7.5	8	8	8	8	12	8	8	8-12	8	8			[illegible]
vi) Curb Timber: Width	8	12	6	(A)	8	8	8	6	8	4 (C)	8	6	-		8
vii) Depth	14	10(B)	12	(A)	10to15	10	6	8	8	12	16	12			10

Notes: A) Steel sides
B) Plus 2 in. Riser Blocks
C) c/w 2 x 3/8 in steel brace
D) No ballasted timber decks

c) What criteria do you use for providing:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
i) Walkways OS-one side BS-both sides	(L)	(A)	BS(A)	(O)	(C)	(E)	OS	OS ([illegible])	OS	(H)	OS(F	BS(G)	OS	N	L

ii) Refuge Bays	(L)	150 max	(B)	No	No	(I)	None	125' max		(J)	No (O)	None		-	(L)
RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Notes
A) As required by operating conditions
B) Not used
C) OS - All rebuilt bridges; BS - over highways as conditions warrant
D) OS - Near switch, BS - yard
E) OS-Old std Trestles within 1 2 miles of switch on switchstand side
BS-New std All rebuilds or redecks
F) OS within yard limits, within 300 ft of point of switch or if state law requires
G) BS within yard limits or 150 ft of a switch
H) BS only Both sides if near area heavily used by operating personnel
I) One at middle of all trestles 150 -300 ft at 150 ft intervals on alternate sides
Trestles exceeding 300 ft at 150 ft intervals on alternate sides
J) Distance from abutment to refuge and between refuge bays not to exceed 300 ft
Refuges to be located on alternate sides of the track
K) Transportation Dept Requirements
L) Railroad's own Criteria
N) BS in yard limits, all others OS, Determined by Transportation Operations
O) Depends on what Division feels it needs

3) Spans

i) Stringers

Number	(A)	8	12	6	12	(F)	6	6	8	(D)	8	8	6	4	(G)
Width (in)	10	9	(B)	10	(C)	10	8	8	8	8	8	8	9	10	7
Depth (in)	18	17.5(H)	(B)	16	(C)	20	16	16	16	18	16(E)	17	16(E)	16	16
Stringer chords	5-0	-	-	-	-	OD 5-0	-	-	5-0	5-0		4-11	5 3	-	(G)
(distance between ft-in)						BD 4-7									

Notes
A) OD E72 6-10 X 18, E80 8-10 X 18
BD Not used, E80 10-10 X 18
B) BD. 12-7 3/4 X 14, OD 12-6 3/4 X 16 1/2
C) Number & size vary
D) OD. 8-8 X 18, BD 10-8 x 18
E) Size to 15 3/4 in
F) OD 6-10 x 20; BD- 8-10 x 20
G) 8-7 x 16 chord centers : 5'0"
10-7 x 16 spaced
H) dressed

RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Length (centre to centre of bents)															
Intermediate bents (ft)	13 8	15	14	12	12 5	14 8	12	12	14	15	13	15	13	12-14	13
End spans (ft)	13 2	14 5	13 3	12	12 5	14 3	12	12	13 4	14 4 & 13-10 for SS	12 4	14 4	12 4	12-14	13
ii) Do you closely pack stringers in chord under each rail	Y	Y	Y	Y	-	Y	(B)	N	Y	Y	Y	N	Y	N	Y
If not, spaced how far apart? (in)	-	-	-	-	Varies	-	-	(F)	-	-		(G)	-	(E)	-
iii) Are stringers on every span simply suported or are alternate stringers continuous over intermediate supports?															
SS Simply supported	-	-	No	No	Varies	No	BD	-		-	SS		-	-	-
CS Alternate Continuous	CS	CS	CS	CS	-	CS	OD	CS	CS	CS	-	CS	CS	CS	CS
iv) For ballast deck trestles, in sizing stringers, do you consider the jack stringer to share 100% of the load 50% of the load or no load at all?	N/A	50%	0%	100%	100%	50%	0%	0%	N/A	0%	OL only	0%	N/A	-	-
v) Do you size the ends of stringers by notching in order to properly bear them on caps? If yes, what size of notch is used? (in)	N	N	N	Y	N	N	(D)	Y 1/2 in	N	N	N	Y(A)		N	N

Notes
A) Sized to 16 3/4 in over caps
B) Stringers are packed tight if all stringers in bridge replaced Originally stringers were spaced
with a 1 1/2 in packer washer
C) Do not build BD timber trestles
D) Generally no, otherwise only to ensure a proper fit
E) 1/2" gap between stringers # 4 per rail
F) 0 - 8" Lap chord design
G) 2 separators

RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

4) Bents

i) Caps

a) Do you use: Wood?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Conc ?	Y	N	-	N	Y	Y	N		Y	N	N	-	-	N	Y
Both?	Y	N	-	-	Y	Y	-		Y				-		Y
b) Width (in)?	(A)	14	14	14	14	(B)	14	14	(C)	14(K)	14	14	14	12-14	14
Depth (in)?	(A)	14	15 5	14	13.5-15	(B)	14	12	(C)	14(K)	14	12	14(K)	12 14	(L)
Length (ft)?	(A)	13	OD 14 BD 16	14	14-16	(B)	16	14	(C)	OD 12 BD 16	14	12	13	14	(L)
ii) Piles - # per bent	5 & 6	5&6(E)	6	5	6	6	6	6	5 & 6	OD5,BD6	5&6(I)	5	5	6	6

Spacing of piles/posts from centerline of bent at bottom of cap for

a) Int piles/posts c/c?	(D)	3'0"	(F)	2'6"	Varies	1-3&3-6	2'6"	1'3"	(J)	(G)	1'3	2 3"	2 6"	1 3"	(M)
b) Outer piles/posts	(D)	5'0"	(F)	2'0"	Varies	5'6"	2'0"	3'3"	(J)	(G)	3'0"	2'4	4 6"	2'3"	2'0

iii) Up to what height (cap to ground) do you not provide any batter in piles/posts?

		2'4"	(H)	All	-	7	All	All	(N)		B'0"	All		N/A	-

Notes: A) Wood: 2 - 8" X 16" X 14'; Concrete 15" X 15" X 14'
B) Wood 14" X 14" X 14'; Concrete 15" X 15" X 14'
C) Wood 14" X 14" X 14'; Concrete 14" X 14" X 13' (Open deck trestle only)
D) 5. 2'6", 5'4"; 6: 3'3", 5'6"
E) 5 end, 6 interior
F) BD: 1'4", 4'0", 6'4"; OD: 1'4", 4'0", 6'0"
G) OD 2'2", 4'5"; BD 1'5 1/2", 3'9 1/2"
H) All bents have 4 batter piles
I) Older design for BD shows 6 pile bents
J) 2'0" for 6 > 37' Height; 2'6" for 5 <= 37' Height
K) Sized S1S to 13-3/4"
L) Wood 14 x 14 x 14'; conc. 14 x15 x 12' (open deck only)
M) 1'-3" or 1'-0"
N) 4' B/P - ground

RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

What is the amount of batter generally provided in

a) Int piles (in 12)?	1	1	1	0	Varies	1 5	1	1	1	(C)	1	1	1	1	1
b) Outer piles (in 12)?	2	2	2	2 5	Varies	3	2	2 5	2	(C)	2	2	2 5	2 5	2
c) Middle piles (in 12)?	-	-	-	-	-	-	-		-	(C)	-	-	-	-	0

iv) Nominal minimum diameter of piles specified for:

Top (in)?	6-9	12	(A)	14	14	12	14	-	14(D)	14	14	14		-	
Bottom (in)?	14(D)	9(F)	(A)	8	8	8(G)	9	8	9	8	8	9	-		-

a) Piles are driven to provide what min carrying capacity each (tons)?

	25	20	BD 23 OD 21	30	30	25	(B)	20	40	(E)	15	25			(H)
b) Nominal size of posts (in x in)?	12x12	12x12	12x12	12x12	12x12	12x12	12x12	12x12	14x14	12x14	12x12	12x12	-		12x12

Notes. A) Top <50' 13", 50' 14"; Bot <50' : 9", >50' : 8"
B) No longer driven
C) a) OD - 7/8"; BD - 1 3/8"
b) OD - 1 3/4"; BD - 2 1/2"
c) OD - 0", BD - 1/2"
D) 3 ft from bent
E) At least capacity req'd per design
F) Piles under 40' length
G) For piles 50' - 60'
H) Design 18 tons - Drive 25 tons

v) What is avg storey height of your bents (ft)

	-	25	11	10	15	24 7	16	12	-	12	19	12		16+	

RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

5) Any comments or pertinent information?

	-	-	-	-	-	-	-		Use conc backwalls for OD Don't build BD trestles						

C) OTHERS

I) What materials are applied to wood for the following:

i) Treatment?	(F)	(A)	Ties(C) Oth (A)	Conc	(G)	(A)	(B)	(B)	(B)	(H)	(I	(A)		(J)	(G)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ii) Fire retardent coating	(D)	Nil	None	None	-	Nonflam	Nil	Nil	Nil	Nil	Nil	(E)		Nil	

Notes
A) 50% Creosote 50% Petroleum mixture
B) Creosote
C) 30% Creosote, 70% Petroleum mix
D) None for general use For specific case, Non-flam on top of deck
E) Arban on ties and tie spacers
F) 100% Creosote
G) No 1 Creosote or creosote - coal tar solution
H) 60/40 Creosote/coal tar or 100% Creosote - 10 lbs/cuft retention
I) No 1 Creosote, 8 lbs
J) 80/20 CCTS or Marine treatment

iii) Protective materials between components such as between stringers and cap, cap and pile cut-off etc ?

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Stringer - cap	-	-	None	None	None	(F)	-	-	-	-	-		-	-	-
Cap - Pile cut-off	(A)	(B)	(C)	None	(E)	(J)	None	(M)	Epoxy	(G)	(H)	(I)	(D)	(L)	(E)
RESPONDENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Notes.
A) Top of piles to be protected, cut, tapered, swabbed with creosote sealing compound, fabric (5 oz with 25 - 36 threads and then again sealing compound
B) Hot creosote plastic cement and cotton fabric on pile cut-offs only
C) Coal tar pitch saturated cotton fabric and plastic cement between cap and pile cut-off
D) 20 ga galv iron
E) Pile pads on top padding
F) Roofing felt or 1/4 in. treated plywood or neoprene
G) 10 lb min roofing between cap & pile
H) 0 0024 zinc sheet between cap and pile No other used
I) Apply roofing paper to pile caps
J) Heavy roofing felt or neoprene
K) All piles have been sawn off, tops of piles to receive 3 coats of hot creosote & 1 coat of list grade A ashphalt & 22 ga galv iron on pile cover applied
L) Rubber &/or roofing mastic to protect field cut ends.
M) 65 lb min footing between cap and pile

2) What are the main maintenance propositions you commonly encounter on your trestles?

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)		[illegible]	

Notes
A) Decay in some areas, mechanical wear in others Replacement of timber caps with prestressed concrete has all but eliminated cap maintenance problems
B) Splitting of caps & decay in contact area of caps and stringers
C) Cap failure on heavy tonnage lines Precast prestressed conc caps are used to replace timber caps
D) Bad piles and caps
E) In the past, the crushing & splitting of timber caps However, conc caps alleviate this provlem
F) Tighten fasteners, repair headwalls, replace caps & add curb blocks
G) Decayed timber.
H) Broken caps, pumping piles on non-standard 4 pile bents
I) Chord shifting on caps, especially on lines with heavy unit coal train tonnage About one or two bridges destroyed by fire each year
J) Replacement of stringers, caps & piles Lining of track
K) Line & surface, bulkhead shifting, debris
L) Timber decay adjacent to bolts, drift pins and ground line Keep line & surface bolts tight
M) Bolt hole decay, crushed caps

RESPONDENT 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

3) Would you like to suggest any improvements in the current design practice of timber trestles?

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	-	-	No	No	-	(A)					[illegible]				

A) Use CMP around base of piles for ice/fire protection
Use timber piles only where high & dry, use steel or conc piles above ground or water level conc caps & timber stringers
Minimize timber/steel contact

4) Any comments or other pertinent information?

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	-	(A)		None	-				(B)	-	None			-	

A) New timber trestles are currently employed only in temp tracks & on branch lines
B) For over 60 yrs , a program of replacing timber trestles with RC trestles

5) Name and telephone number of a person who, if necessary, may be contacted for seeking further clarification of the answers provided above

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Compiled 30 September 1987 Reviewed 31 October 1987 Revised 16 June 1988

A Shakoor Uppal
Chairman - Subcommittee #3
A R E A Committee #7

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