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J. E. Stallmeyer

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JANUARY 1991

ROOM 7702
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U.S.A.

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BULLETIN

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JANUARY 1991

Proceedings Volume 92 (1991)

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Front Cover: AREA inspection train with CSX locomotives, inspection car and lounge plus Union Pacific coaches at Amtrak station in Miami, Florida, Oct. 26, 1990.

Rear Cover: CSX crew renews turnout at Knoxville, Maryland. Appalachian Trail runs on top of ridge in background.

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Photo 1: CSX track inspection car at rear of AREA inspection train, in siding at Hollywood, Florida, awaiting northbound Tri-Met commuter train.

JACKSONVILLE-MIAMI
A.R.E.A. INSPECTION TRAIN
OCTOBER 26, 1990

Following its fall conference near Jacksonville, Florida, which was a joint meeting with the Rail Transportation Division of the American Society of Mechanical Engineers, an inspection train was operated for AREA on a 417-mile trip over CSX from Jacksonville to Miami, on Friday, October 26. The train was furnished by CSX, including their track inspection car No. 318 and lounge car Greenbriar, and three coaches were provided by the Union Pacific.

The trip originated at the Amtrak Jacksonville Station in the northwest part of that city, and began by traversing the terminal trackage in Jacksonville before heading south on the well-maintained single track line through central Florida with its forests, citrus groves, and long straight sections across everglades pasture land. Speed allowed on most of the line is 70 mph. The rural nature of the state was broken by many towns and cities, and especially by the large urban area of Winter Park-Orlando, with many curves and grade crossings.

Approaching West Palm Beach, ownership of the track changes from CSX to the state of Florida, the stretch from here to Miami having been recently sold to them by CSX. This line has a new commuter service, known as Tri-Met, from West Palm Beach through the heavily urbanized corridor to Miami, and additional station and parking construction was under way. This right-of-way is also planned to be used by the Florida High-Speed Rail line from Miami to Orlando and Tampa.

The AREA train took the siding at Hollywood Florida for a northbound commuter train (see photos 1 and 2) and shortly thereafter arrived on schedule into the Amtrak station at Miami (see front cover and photo 3).

Photo 2: Tri-Met locomotive pushes northbound commuter train past AREA inspection special at Hollywood, Florida.

The AREA wishes to extend its thanks to CSX for running this train and the Union Pacific for providing the coaches. The superb condition of the train as evidenced by these photos and its on-time performance shows the pride taken by CSX in their equipment and operations.

Photo 3: AREA inspection train after arrival at Amtrak station in Miami.

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

W. S. Stokely, Chairman

Brief status of each Subcommittee Assignment:

Subcommittee 1. Roadbed

Subcommittee 1 - Roadbed has three assignments. Assignment D1-1-86, a report on the criteria justifying the use of under-cutters, was presented in its final draft at the Spring 88 meeting. Discussion at the Whole Committee level during the Fall, 1989 suggested the work was of a lesser value and was not approved for publication. Paper for dropping of the assignment is to be presented.

Assignment D1-2-86 is to update the Manual text on construction of roadbeds. This assignment is now in progress. Individual assignments were made during the Fall 1990 Meeting. A 1992 completion date is expected.

Assignment D1-3-88 has been completed, and will be published for information shortly. This topic will now become the charge of Committee 8, Concrete Structures and Foundations.

Subcommittee 2. Ballast

Subcommittee 2—Ballast has five assignments. Assignment C2-1-86 deals with reporting on results of AAR and other ballast research programs. The effort continues in the monitoring of the operation of the FAST/HAL Ballast Tests. This assignment is, of course, on-going to the extent that ballast tests are in progress.

Assignment D2-1-88 deals with tamping procedures and their relation to the ballast. Planning continues with field work expected in the spring of 1991. Gathering and reduction of data is expected to take 2 years, thus a reporting date of 1993 is planned.

Assignment D2-2-89 deals with Hot Plant Mixed Asphalt courses in the track substructure Subcommittee leadership is addressing this construction as a high strength sub-ballast course. It appears to be a special application, and focus is currently on economics. A reporting date is yet two years away.

Assignment D2-3-89 deals with comparing in-track performance of ballast with laboratory results obtained by the Mill Abrasion Test. Currently, emphasis is on the development of a Standard Mill Abrasion Test. Laboratory testing is being arranged in which 10 laboratories will run 10 tests each on 3 different materials. It is expected this repeatability testing and reduction of the data will take 18 months.

Assignment D2-4-89 addresses the effect of in-track degradation of ballast particles by weather, and chemicals of the atmosphere and lading. A paper on the matter is now being offered for publication as information, and the assignment is recommended as being dropped.

Subcommittee 3. Natural Waterways

Subcommittee 3—Natural Waterways has two assignments. Assignment D3-2-88 has been presented. The second assignment, D3-3-89, a glossary, is ready for letter ballot as Manual material.

Subcommittee 4. Culverts

Subcommittee 4—Culverts has two assignments, D4-1-88 on the matter of updating the Manual text on installation of pipe culverts, to include jacked installations. Progress is noted with completion expected in 1991. Assignment D4-2-89 on installation of culverts inside existing culverts is in progress. A 30 month time frame to Manual Revision is expected.

Subcommittee 5. Pipelines

Subcommittee 5—Pipelines has two assignments. Assignment D5-1-74 deals with casing pipes larger than 42" in diameter. Assignment D5-2-81 deals with plastic carrier pipes.

The first Assignment, 15 years old, recently received an affirmative Letter Ballot vote, and will be published for review leading to Manual material in the January 1991 Bulletin.

We expect the remaining assignment to get more attention.

Subcommittee 6. Fences

Subcommittee 6—Fences has two assignments. Assignment D6-1-87, dealing with security fences, has been reported out of Subcommittee. The Committee Chairman has returned the work with technical and graphics quality comments. This assignment is stalled, and in need of interested participants.

Assignment D6-2-87 deals with snow fences. A successful Letter Ballot recommends the current material be withdrawn, pending rewrite.

Management of the Subcommittee will provide the incoming Committee Chairman with a challenge.

Subcommittee 8. Tunnels

Subcommittee 8—Tunnels has two assignments. Assignment D8-1-87 addresses updating of the Manual materials, and D8-2-87 is to report on the Rogers Pass Project.

Again, work is stalled. Unfortunately, one person is the primary source of the out-put, and the individual is, in his day-to-day activities, stretched. We can offer no data at this time.

Subcommittee 9. Vegetation Control

Subcommittee 9—Vegetation Control has two assignments, D9-1-88, development of a commentary, on which a Letter Ballot has been passed, and D9-2-89, updating its Manual Chapter which is presently in progress.

Subcommittee 10. Geosynthetics

Subcommittee 10—Geosynthetics has completed two assignments. The Subcommittee is now undergoing a change in leadership. Work on the Assignments, D10-3-88, geotextile stabilized walls and slopes and D10-1-89, geosynthetics for stabilization of track roadbed, is expected to progress.

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

R. F. Silbaugh, Chairman

Status of Subcommittee Assignments

Subcommittee A—Recommendations for further study and research.

A list of recommended future topics for study by AREA Committee 2 was identified at the August 15, 1990 meeting. This list will be discussed to select the most beneficial topics at our October 23, 1990 committee meeting.

Subcommittee B—Revision of Manual

An article "Recommendations for Establishing and Maintaining a Track Geometry Data Base" has been approved by Committee 2 at its meeting on August 15, 1990 and has been forwarded to AREA for publication in the bulletin.

Subcommittee 1—Rail Planimetry

D1-1-85. Investigate characteristics of corrugation

Assigned: March 1, 1985
Estimated Completion: June 1991

Work has progressed using Jackson Jordan data collected on the CP and correlating it with CP Track Geometry Car and their corrugation reference device. Additional data must be studied before any conclusions can be made about the effects of the track on corrugation characteristics.

Several railroads are currently collecting data on corrugation and profile on their own. The committee will start working with railroads to see if data can be used by committee in pursuit of its task. Specific focus will be placed on corrugation data, sensitivity of corrugation measuring systems accuracy requirement and correlation of corrugation development with track and traffic parameters.

Subcommittee 2—Track surveying

Assigned: March 1, 1985
Completed: August 15, 1990

D2-1-85. Establish through an internal survey, the need for track survey data of different types and the requirement of each data element to be updated.

The track survey data recommendations were completed and approved by the committee, and submitted to AREA headquarters for review and publication.

This subcommittee was dissolved on August 15, 1990 so that the members can assist in completing assignments of the remaining subcommittees.

Subcommittee 3—New Technologies

C3-1-85. Evaluate the need and potential use by railways of information on track modules, subgrade moisture and lateral tie strength.

Assigned: March 1, 1985
Estimated Completion: October 1990

The remaining project, "Rail Wear Measurement" survey is near completion and will be finalized by October 1990. We will then look into new assignments to investigate based on the areas of Railway needs arising out of the questionnaires.

Subcommittee 4—Track geometry car development

C4-1-87. Proposed recommended practice for geometry cars

Assigned: March 1, 1985
Estimated completion: June 1991

Updating of the previous list of geometry measurement vehicles in use by the industry is underway.

The effort to define track geometry measurement terms is also an active project which we plan to complete and publish in 1991.

Subcommittee 5—Track Geometry Analysis

Assigned: May 1, 1985
Estimated Completion: March 1991

C5-1-85. Survey data processing techniques and equipment used on different railway's track geometry vehicles.

The recommended definition of Track Quality Index has been published in the AREA Manual.

A survey questionnaire on Track Geometry Analysis has been prepared, approved by the committee and sent to AREA headquarters for their review and distribution to railroads and suppliers. The results of this survey will be used to prepare a report to the committee.

Subcommittee 6—Rail Flaw Detection

Assigned: June 1, 1986
Estimated completion: October 1990

D6-1-86. Develop a recommended practice describing minimum acceptable flaw detection system capabilities.

D6-2-86. Develop a recommended practice describing test rail specimens which include simulated defects of known size and orientation to demonstrate rail flaw detection system capabilities.

C6-1-86. Interface with organizations dealing with development of rail flaw detection techniques.

C6-2-86. Inform the membership of the state-of-the-art in rail flaw detection.

The document titled "Recommended Minimum Performance Guideline for Rail Testing" has been completed and distributed to the committee membership for approval prior to submission to the Board.

Some of the benefits from these guidelines would be to provide a standard for contractors and for quality control on railway owned detection equipment and operators. Also, it may provide a reliability curve which in combination with the ratio of service to total failures, allow calculation of optimal testing intervals.

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

J. L. Watt, Chairman

Status of Subcommittee Assignments:

Subcommittee B—Revision of Manual.

Manual revisions are forthcoming since the AWPA has changed their manual slightly.

C1-2-63. Keep up to date specifications for cross and switch ties.

The specifications were just updated within the past two years to combine with RTA. A new industrial grade specification for cross and switch ties will be added this coming year.

C1-1-62. Investigate possible revision of crosstie design and/or spacing.

There has been no need for change demonstrated in this area.

D1-1-89. Wood tie disposal alternatives

New ideas continue to come to the forefront. We are gathering information on the various alternatives. The Cedrite plant in Kansas City is in volume production now.

Subcommittee No. 2—Wood Preservatives and Preservative Treatment of Forest Products.

C2-1-63. Keep up to date specifications for preservatives and update research for new preservatives.

AWPA is currently updating all of chapter C-6. Our committee is cooperating in this with AWPA Committee T-6. The AREA Manual will be revised accordingly as these revisions are completed in 1991.

C2-2-63. Keep up to date specifications for seasoning, conditioning, and treatment.

We are studying the environmental impact of technique changes by the rail industry.

C2-3-63. Advisability of preparing specifications to cover care and handling of forest products before and after treatment.

This section is similar to other parts of the subcommittee assignments in that there hasn't been much need for change in the past, but environmental considerations may necessitate a need in the near future.

Subcommittee No. 3—Service Records of Forest Products.

C3-1-63. Inform AREA about annual tie renewal statistics as furnished by the Economics and Finance Department, AAR

Information concerning annual tie renewal is furnished each year.

C3-2-63. Keep up to date with service test records of forest products used in railroad construction and maintenance.

The AAR has a list of tests in place on their computers. These tests are updated and visited periodically on field trips.

Subcommittee No. 4—Collaborate with AAR Research Department and Other Organizations in Research and Other Matters of Mutual Interest.

C4-1-76. Substitute for solid-sawn wood ties.

The Cedrite ties as well as the glue-lam and dowel laminated ties are currently doing well in service tests and at FAST. More railroads are testing the Cedrite tie now that they are in volume production. Some good results should be forthcoming.

C4-3-63. Splitting of ties and anti-splitting devices.

We should be able to make some definite recommendations upon the effectiveness of rail-plates, etc. this coming year.

C4-3-66. Wood deterioration in the presence of metal.

We are studying the results of research into this problem. No precise conclusions have yet been formed.

C4-4-82. Monitor progress of work of each subcommittee and assist with an appropriate exchange of technology between AREA and AAR.

A good exchange of data exists between AAR and AREA now as evidenced by the service test data gathered from various roads and put in AAR data bank.

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

A. W. Worth, Chairman

Brief status of each Subcommittee Assignment:

Subcommittee A

A continuing committee. All recommendations have been referred to the appropriate committees.

Subcommittee B. Revision of Manual.

A continuing committee. All recommendations have been referred to the appropriate subcommittees; the most recent being a recommendation for drawings for standardized mill gauges.

Subcommittee 1

C1-1-74. Collaborate with technical representatives of rail suppliers, welding contractors, suppliers of field welding, rail grinding and rail testing contractors on matters of mutual interest.

A continuing committee, necessary to maintain liaison between railroad members and suppliers and keep all concerned informed of ongoing developments and improvements in technology.

D1-1-81. High Strength Rail Welding

Assigned approximately 1981 (or earlier). When started, this committee was mostly involved with thermite welding, but after 1985 has concentrated on flash butt welding. The chairman started writing his report early in 1989, but additional information and requests for additions for changes keep coming in as the drafts are presented to the full committee. For example, it has been decided to include material on low alloy head hardened rail, not included in the original. Because of these rewrites a completion date of 1991 now is expected. A very worthwhile topic.

D1-2-81. Weld Qualification Testing

Assigned approximately 1981. The chairman of this subcommittee was expected to submit his final report in 1990, but to date he has not done so. Problem seems to be an overload of work at the AAR Technical Centre, where the work is being done. We are continuing to push for completion in 1991, as we want to get on with studies of welds on high strength rail, which have not been done yet.

Subcommittee 2

C2-1-55. Collaborate with technical representatives of rail and joint bar manufacturers in research and other matters of mutual interest.

A continuing committee, necessary to maintain liaison between railroad members and rail and joint bar manufacturers and keep all concerned informed of ongoing developments and changes in technology. Research work is ongoing on ultrasonic testing, stamping, bar coding, straightness, acceptance gauges and tolerances.

D2-1-88. Web Cracking of Rail from Roller Straightening

This is the AREA designation of a joint AAR/AREA/steel industry/railroad committee initially set up in January 1988, on which Mr. R. K. Steele of AAR made an initial presentation at the March 1989 technical conference in Chicago.

Initial optimistic estimates of a report in 1990 were based on hopes that a cheap and dependable device would be found for measuring residual stresses in rail webs on a production basis. Results so far have been inconclusive but the AAR is continuing to work on the problem. If such a device is found earliest possible date of a report now would be 1992, or later, depending on the size of the information matrix it is necessary to study.

D2-2-88. Tolerance and Method of Measuring Rail Head Radius

Assigned 1988. It has by now become evident that no progress will be possible on this assignment until subcommittee D5-2-88 completes its assignment and we have recommended that further work by this subcommittee be postponed till that time.

Subcommittee 3

C3-1-76. Rail Statistics

This committee reports in a standardized format each year the rail shipped to North American railroads from North American and non-North American producing mills, by weight and section. To ensure confidentiality, all data is sent to an independent accounting firm to be consolidated and information as to origin and destination is deleted. Report for 1988 was sent to AREA headquarters in May 1990. A continuing committee; a worthwhile subject that should be continued.

Subcommittee 4

C4-1-73. Update data on methods and equipment for making welding repairs to rail and turnouts including thermite welding.

A continuing committee. This committee maintains liaison with the AWS, which is active in the field of trackwork welding, and with AAR in connection with research at the FAST loop.

The AWS met on the Subject April 23 at Anaheim, CA, and good progress was made on draft recommendations. Final draft is expected to be sent to AWS and (we hope) Committee 4 before issue is made. Next meeting is at York, PA, in November 1990.

Results from AAR at the HAL FAST test so far are inconclusive but it appears fatigue strength of standard carbon weld kits may be insufficient and something with a higher yield strength may be needed for fatigue. A useful and necessary committee that should be continued.

Subcommittee 5

C5-1-78. Rail Specifications, Research and Development

This is a very important continuing committee. It has just completed an overhaul of pages 4-1-1 through 4-1-6.1 of the manual, deleting the 90 ARA-A and 100 RE sections and correcting the physical properties for the rest. It also has recommended deletion of specifications for the drop test machine (4-2-7, 4-2-8); all these changes have been approved by ballot and should appear in the bulletins shortly. It also is currently working on standard drawings for mill tolerance gauges; and is discussing implications of raising specified minimum BHN of rail from 289 to 300. A vital subcommittee and one that should be continued.

D5-1-84. Recomputation of Physical Properties of Rail Sections

With approval by the main committee by ballot in the summer of 1990 of all the recommendations of this subcommittee, in connection with overhaul of pages 4-1-1 through 4-1-6.1 of the Manual, the work of D5-1-84 has been completed and it is recommended the subject be discontinued.

D5-2-88. Wheel/Rail Profiles

This subcommittee was originally called "Wheel Rail Contact Stresses," and was set up early in 1988. The change to the present title was approved by the Board of Direction in the winter of 1989-90.

Purpose of the committee is to establish the optimal head profiles both for new rail and for grinding rail in track, now that the AAR Mechanical Division has settled on a new standard profile for wheels.

At their June 14 meeting, the Board of Direction moved that Committee 4 set up a subcommittee to cover the subject; as it happened, such was not necessary, as the subcommittee was already in existence, but it is evident there is widespread urgent interest in the subject and the committee should be continued.

This is a complex technical subject being pursued primarily through the AAR, and it is not likely a recommendation will be available before 1992 at the earliest.

Subcommittee 6

C6-1-62. Joint bars, design specifications, service tests, including insulated joints and compromise joints.

A continuing committee. Letter ballot has just been approved covering a complete overhaul of Sheets 4-1-6.2 through 4-1-15 of the manual, eliminating 90 ARA-A and 100 RE sections and all head contact bars and standardizing the AREA bars with those currently being purchased by the railroads. Draft specification for bonded insulated joint bars is also very near completion and should be ready to go out for ballot this coming winter.

The chairman of this subcommittee resigned effective July 9, 1990 and it will be necessary to pick a new chairman at the next meeting.

Subcommittee 7

C7-1-68. Effect of Heavy Wheel Loads on Rail

A continuing committee. This committee is charged with all ongoing research into the effects of heavier cars on fatigue and wear of rail steel, and such allied phenomena as corrugation, rail batter and problems at joints. It handles the liaison with AAR on rail life prediction computer models, and on results from the present HAL test at the AAR Transportation Test Facility. An important subcommittee that should be continued.

Subcommittee 8

C8-1-88. Management of Rail Test Resources

A continuing committee. The chairman of this committee, who resigned in June 1989 (apparently out of frustration) later agreed to return on the understanding that he could get some help and agreement on what the subcommittee is intended to accomplish.

The issue is a very touchy one because of possible legal implications of future legislation on the subject. A first draft of a report, presented to the subcommittee June 7, was sent back for rewriting on the grounds that it did not cover all the variables, and because it made quantitative recommendations it could be misleading. A new "guideline," to be simultaneously more comprehensive and less quantitative, is now in preparation and should be ready to go to the main committee for discussion by the spring of 1991. An important subject that deserves to be continued.

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

J. D. Baker, Chairman

Report on Special (D) and Continuing (C) Assignments

Assigned Number	Description of Assignments	Assigned Date	Estimated Comp. Percent (%)	Est. Compl. Date	Remarks
B-1-89	Switch point changeout	12/89	0%	10/92	
C2-1-79	Track tools	2/79	90%	5/91	
D4-1-84	Elastic rail fasteners - wood ties	4/86	95%	5/91	
D4-2-84	Hold down fastening - wood ties	4/88	20%	5/91	Request assignment to be dropped
D4-3-85	Tie plates - wood ties	4/85	95%	10/90	
D5-2-79	Gage plates - turnouts	10/79	75%	10/91	
D5-4-81	Explosion hardening of castings	1/81	95%	10/91	
D5-5-81	Maintenance parameters - switches	1/81	50%	5/92	Request assignment to be dropped
D5-6-88	Direct fixation fasteners - turnouts	12/88	40%	12/91	
D5-7-87	Frog castings	5/88	45%	10/91	
D5-8-89	TTC turnout design	5/89	0%	10/92	
D7-1-84	Rail lubrication	10/86	45%	5/92	
D8-2-84	Superelevation and spiral length	10/84	0%	5/92	
D8-3-85	Turnout geometry	10/85	0%	10/92	
D8-4-89	Vertical curves	10/89	0%	5/93	

Excerpts From Annual Report of A.R.E.A. Committee 6 - Buildings and Support Facilities

B. R. Schwab, Chairman

Subcommittee Assignments:

Subcommittee A: Recommendations for further study and research

Interior Paint Systems and Application Methods has been taken under study for Bulletin Information.

Subcommittee D-1-80. Design Criteria for C.T.C. Dispatch Facilities

Report finalized and sent to membership for ballot approval for publication in 1991 Manual.

Subcommittee C-1-73. Design Criteria for Car Shops

Report under review to include new sections on foundation and roof systems. Estimated completion date 1991.

Subcommittee C-3-84. Design Criteria for Railway Office Buildings

Report finalized and sent to membership for ballot approval for publication in 1991 Manual.

Subcommittee D-3-87. Design Criteria for Wheel and Bearing Shops

Report is actively under review by subcommittee. Estimated completion date 1991.

Subcommittee D-5-89. Design Criteria for Maintenance of Way Facilities

Report is actively progressing with assistance from Committee 27. Estimated completion date 1991-2

Subcommittee D-4-89. Design Criteria for Railway Material Management Facilities

Report is actively being progressed by the subcommittee chairman. Estimated completion date 1991-2.

Excerpts From Annual Report of Committee 7 - Timber Structures

W. Benton III, Chairman

Subcommittee Status:

Subcommittee A—Recommendations for further study and research

Attempting to develop a history of subjects investigated in the past, to have previous work to draw on and avoid duplication of effort.

Subcommittee B—Revision of Manual

Proposed Manual revisions were published in the January bulletin. Propose to have the question of "Metrication" handled by this subcommittee.

Subcommittee C-1-53—Specifications for design of wood bridges and trestles

We are still receiving replies to request for parameter to be followed in developing the load distributions to be studied.

Subcommittee D-4-82—Effect of unit trains on timber trestle components

It was suggested by the previous chairman that this topic be dropped but the Committee voted to keep the topic and assign a new subcomittee vice-chairman to try and spark this work. The Committee feels that this is an important topic that should be progressed. The status of this subcommittee will be watched and every effort made to help them complete the task in a timely fashion.

Subcommittee D-5-89—Methods to upgrade existing timber bridges

The subcommittee has developed a questionnaire to be distributed to Committee members to help obtain methods currently in use on member roads.

Subcommittee D-6-89—Specification for timber bridge ties

A first draft of the proposed specification has been forwarded to Committee members for review and comment.

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

D. J. Lewis, Chairman

Subcommittee Activities:

Subcommittee A. Recommendations for Further Study and Research

In cooperation with the other two structural committees, AAR, NSF and the University of Illinois, we are participating in the steering committee which is progressing with railroad bridge research. The future direction of this research is to determine the static, dynamic and impact loads that bridges must carry under current loading situations.

Subcommittee 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. In addition, this subcommittee is working on a format for "COMMENTARY" sections of this Chapter.

Subcommittee 1. Design of Concrete Structures

D1-1-84. Develop specifications for precast and cast-in-place concrete segmental bridges.

This assignment is now drafted and ready for subcommittee letter ballot. Upon favorable vote by the subcommittee the complete committee will have the opportunity to review and vote on this material. The Commentary is being drafted at the same time as main material but will be submitted as a separate letter ballot. Anticipated completion for the main manual material will be September 1991.

D1-5-87. Investigate applicable impact factors.

Letter ballot #4-90 dealt with impact but there were not enough responses for passage. Of those voting there were a sufficient number indicating to postpone this assignment until the results of the AAR-NSF bridge testing is completed. Testing for impact responses shall be tentatively performed in 1991. It is, therefore, felt that this assignment should be held until 1992.

D1-8-88. Review and rewrite Part 2, Reinforced Concrete Design.

This part is in the process of being reviewed and rewritten. Several changes were made and published in 1990. Additional changes are being considered and should be ready for 1991. The exception to this is changing the impact formula due to reasons stated above.

D1-9-88. Review and rewrite Part 17, Prestressed Concrete Design.

This part is on hold waiting for completion of assignments D1-1-84 and D1-8-88.

Subcommittee 2. Foundations and Earth Pressures

D2-1-89. Rewrite Part 20, Flexible Sheet Pile Bulkheads.

This assignment will be ready for committee letter ballot in near future (probably September).

D2-2-89. Commentary for Part 20, Flexible Sheet Pile Bulkheads.

This was a new assignment and is being written in conjunction with assignment D2-1-89. It also has to wait until accepted guidelines for Commentaries has been established (probably 1991).

Subcommittee 3. Durability of Concrete and Waterproofing

C3-1-88. Monitor Current Waterproofing Practices.

This is a continuous assignment and just had a few changes incorporated in the 1988 Manual. No other changes are presently anticipated.

C3-2-89. Review and Rewrite Part 1, Materials, Tests and Construction Requirements.

This is a continuous assignment and has some changes which were voted by letter ballot #3-90 and approved. The editorial comments are in the process of being changed and should be ready for publication in the bulletin soon.

D3-1-88. Investigate and Report on Current Methods of Protecting Concrete.

This assignment is being progressed by the subcommittee and should be ready for subcommittee soon (probably 1991).

D3-1-89. Guidelines for Field Bending of Partially Embedded Reinforcing Bars.

This assignment had very minor progress this year due to work on the other assignments.

Subcommittee 4. Repair, Restoration and Strengthening of Concrete Structures

D4-2-87. Study AAR Bridge Program and Make Recommendations for Implementation at FAST.

The subcommittee recommends dropping the assignment due to lack of concern and activity.

D4-3-88. Inspection and Repair of Prestressed Concrete.

This assignment is being worked on and may be incorporated into Review of Part 14 - Repair and Rehabilitation of Concrete Structures. There is no assignment number for review of Part 14 as of yet.

D4-4-88. Develop Criteria for Prevention of Scour Damage to Piers.

This assignment is being progressed and considered for a new part (Piers) in the Chapter.

Subcommittee 5. Design of Concrete Components for Bridges in Seismic Zones

D5-1-89. Develop Design Criteria or Retrofit Specifications or Guidelines.

The subcommittee submitted an informal report on the structural performance during the recent Loma Prieta Earthquake. It indicated that the damage to the Railroad bridges was relatively light by comparison to the damage sustained by the corresponding highway structures. In addition, ATC-6 "Seismic Design of Guidelines for Highway Bridges" is now published and in the process of being reviewed for developing a Railroad Guideline.

Subcommittee 6. Design of Foundations

D6-2-89. Review and Rewrite Part 22, Specifications for Subsurface Investigation.

This assignment is ready for letter ballot by committee at our next meeting (probably January 1991).

D6-3-89. Commentary for Part 4, Pile Foundations.

This was a new assignment and is being written presently. It will have to wait until accepted guidelines for Commentaries has been established (probably 1991).

Excerpts From Annual Report of A.R.E.A. Committee 9 - Highway-Rail Crossings

K. J. Anderson, Chairman

Status of Subcommittee Assignments:

Subcommittee A—Recommendations for Further Study and Research

This subcommittee is responsible for the development of topics which should be addressed in the manual. One of the new topics which has been submitted for approval as a new subcommittee is entitled **"Clearances for Highway Structures over Railroads".** Mr. Shoemaker, along with Mr. Autenreith, are also attempting to develop topics to research which can be published in the bulletin as information.

Subcommittee B—Revision of Manual

This subcommittee is responsible for the processing of manual revisions through the committee. Although no manual revisions were proposed this year, it is hopeful that manual revisions will be recommended by Subcommittee D-1-87 next year. There is also a possibility that manual revisions covering clearances for highway structures over railroads will be submitted for approval next year, if the subcommittee assignment is approved by the board.

Subcommittee D-1-87—Foundations for highway-railway grade crossings, collaborating with Committee 1.

Mr. Stanfill replaced Mr. Walker as Subcommittee Chairman in March. He is working with his subcommittee to refine the draft recommendations for Chapter 1, part 1 previously submitted to the subcommittee for review. Once the draft is refined, Committee 1 will be consulted prior to the final manual revision recommendations being developed. Our goal is to develop recommended manual revisions on this topic by July, 1991.

Subcommittee C-1-87—Grade crossing surfaces.

This subcommittee has been delegated the responsibility to work together with ASTM in the development of standard material specifications and product performance specifications for crossing surface material. Mr. Kuhn attended ASTM's meeting in May of this year to establish a joint task force with AREA Committee 9 to address these issues. This project is only beginning the data collection phase.

This subcommittee is also studying the proper location of joints in the vicinity of the crossing. The subcommittee has received some technical assistance from the AAR and is in the process of developing guidelines to be included as a manual revision in 1991.

Last year, it was suggested that Committee 9 survey all the major railroads to determine the type of surfaces most commonly used for various applications. This information could then be published in the bulletin. This subcommittee is in the process of developing the survey to be sent out in 1991.

Subcommittee D-2-87—Approaches to highway-railway grade crossings.

Mr. Bob Swanson resigned as Chairman of this subcommittee in March. Mr. Lundgren accepted the assignment in June. This subcommittee is awaiting the results of Dr. Ronald Eck's study on the issue of "hump-back" or high profile crossings. Dr. Eck is a professor at the University of West Virginia. The University of Calgary is working on a study of highway signs for possible use at high profile grade crossings. This subcommittee is maintaining contact with these researchers and will keep the Committee advised of their findings.

Subcommittee D-3-87—Grade crossing and separation elimination.

As reported last year, there are several reports available which adequately address these topics. Mr. Shoemaker is in the process of preparing a summary of the information currently available. Upon completion, the summary will be submitted for printing in the manual as information. Once this is accomplished, this subcommittee will be discontinued.

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

A. N. Hanna, Chairman

Status of Assignments:

Subcommittee A—Recommendations for Future Study and Research

The committee recommends that a research study be initiated to evaluate the durability of concrete ties currently in use by different railroads. This study should include both laboratory and field testing to examine the materials used in tie manufacture and relate material properties and manufacturing aspects to performance and durability. This information will help Subcommittee 4, Durability, identify the requirements that will insure durability and long service life.

Subcommittee B—Revision of Manual

Subcommittee has recommended changes to Articles 1.1.2.2., 1.3.2.1, 1.4.1.1, 1.4.1.2, and 1.2.2.6 of the Manual. The proposed changes were sent to all committee members in a letter ballot. All responding members accepted the changes. The recommended changes will be submitted for Board approval.

Subcommittee 1. Flexural Strength.

C1-1-87. Monitor developments in prestressed and reinforced concrete technology which may effect concrete tie requirements.

D1-2-89. Investigate impact resistance and design requirements for concrete ties.

D1-3-87. Evaluate acceptance criteria for repeated load test.

The subcommittee recommended that axle load should be considered a factor in developing concrete tie strength requirements, and therefore it will be included in Task C1-1-87. In Task D1-3-87, the subcommittee is considering the need for establishing a no-cracking criteria for the repeated load test. Work on these tasks is in progress. Because of the importance of these activities to the development of acceptable concrete ties, it is recommended that these activities be continued during the next year and that subcommittee assignments be revised in the future as needed.

Subcommittee 2. Switch, Bridge and Crossing Ties.

D2-1-89. Investigate requirements for concrete switch ties, bridge ties, and grade crossing ties.

The subcommittee has defined a work scope that will initially address recommended practice for the design and manufacture of concrete turnouts and use of concrete ties in grade crossings. The subcommittee has prepared a preliminary draft for review and comment by the members, but substantial work is needed before it can be submitted for ballot. Because of the increased interest in the use of concrete turnouts, we recommend that these assignments be continued until the subcommittee develops appropriate recommendations for incorporation in the Manual.

Subcommittee 3. Fastenings.

D3-1-83. Revise current test requirements.

D3-2-83. Investigate the effect of axle loads and tie spacing on fastening requirements.

D3-3-86. Review and recommend revisions of the load magnitude specified for the fastening repeated-load test.

Tasks D3-1-83 and D3-2-83 involve consideration of many variables and alternatives, and will require a considerable effort to complete these tasks. Task D3-3-86 is currently under study with limited progress. Mr. Jerman has been appointed chairman of this subcommittee to succeed Mr. W.R. Hamilton who recently resigned from the committee. In view of the need to develop better guidelines for rail fasteners, we recommend that this subcommittee assignments be continued until appropriate simplified recommendations are developed to replace the current Manual recommendations.

Subcommittee 4. Durability

D4-1-89. Resistance of concrete ties to alkali aggregate reaction.

D4-2-89. Resistance of concrete ties to freezing and thawing.

D4-3-89. Resistance of concrete ties to rail seat abrasion.

The subcommittee has prepared a draft addressing Tasks D4-1-89 and D4-2-89 for review. However, as this subject is highly specialized it seems desirable to seek review by other than committee members. Subcommittee chairman and vice chairman will review this need, develop a reviewer's list and seek AREA approval. Subcommittee chairman is providing information related to Task D4-3-89 through his involvement in an ad hoc committee on the subject. In view of the importance of addressing durability of concrete ties in the AREA Manual, we recommend that this subcommittee assignments be continued until appropriate Manual recommendations are developed.

Subcommittee 5. Maintenance Requirements.

C5-1-87. Maintenance requirements of concrete ties, including pads and insulation.

The subcommittee has prepared a questionnaire that was forwarded to AREA headquarters to those railroads that have concrete tie tracks. Results of the questionnaires will be used in developing Manual recommendations for maintenance requirements of concrete tie track. In view of the increased usage of concrete ties, we recommend that this assignment be continued as an ongoing activity.

Subcommittee 6. Ballast Requirements.

C6-1-87. Collaborate with Committee 1 on concrete tie ballast requirements.

The subcommittee has continued collaboration with Subcommittee 1 and will continue to furnish data and recommendations concerning tie ballast requirements. Committee 10 will retain the ballast requirements for concrete tie track in Chapter 10 until it is adequately covered in Chapter 1. We recommend that the subcommittee continues this liaison activity to insure appropriate coverage of ballast requirements for concrete tie track in Chapter 1 of the Manual.

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

A. R. Ranuio, Chairman

Subcommittee Assignments:

Subcommittee "A": Recommendations for Further Research and Study

Chairperson continued to consider the following:

- Elimination of outdated and cumbersome ICC regulatory rules
- Use of fixed asset software packages
- Development of a separate subcommittee for depreciation studies

Subcommittee "B": Revision of Manual

Have completed rewrite of manual for accounting for rolling stock and highway equipment as well as Canadian rules for property accounting. We will continue to support this subcommittee in order to process any further changes to the manual.

Subcommittee "1": Accounting

This subcommittee has concentrated on two specific areas, depreciation of assets and elimination of outdated and cumbersome regulatory accounting rules.

Beginning only in the last few years, railroads have been required to provide depreciation studies for roadway accounts every six years and for rolling stock accounts every three years. These studies must be presented to the ICC and supported through the approval process. Elaborate programs using assumptions for estimated future salvage, asset lives, retirement timing, and future obsolescence are used. This subcommittee was successful in obtaining useful industry data to support these studies. This aspect of the subcommittee has become so important that we propose to form a new subcommittee on depreciation.

This subcommittee has identified old outdated and cumbersome rules mandated by the ICC that need revision. These changes have been discussed by committee 11 members with results orally presented to the Chief Accounting Officer of the ICC. Change requests are:

1. Eliminate Account 76, Interest During Contruction by allocating to an appropriate group of accounts.
2. Reclassify Account 59 from an equipment account to a roadway account (Account 46)
3. Eliminate requirement of collecting costs by Valuation Sections and substitute collection by line segments and/or state boundaries.
4. Eliminate requirement of preparing signed Completion Reports & substitute equivalent data in an audited fixed asset data base.
5. Eliminate requirement of preparing the manually updated Record of Property Changes and substitute an audited fixed asset data base.
6. Eliminate requirement for using prescribed micro-detailed reporting units (i.e. lbs. of iron on a trestle and substitute a macro-detailed reporting unit (i.e. one each 50 ft. trestle).

Formal written requests for changes will be forwarded through the appropriate channels in the near future.

Subcommittee "2": Office and Drafting Practices

Propose to investigate use of personal computers and CADD systems for accounting purposes only in class 1 railroads. Propose to coordinate with Committee 22 to prevent overlap in interests.

We are reviewing mission statement and subcommittee title to determine beneficial changes needed.

Subcommittee "3": Taxes

This subcommittee continues to analyze federal tax legislation including treatment of the following:

1. Deferred taxes, corporate
2. Corporate alternative minimum tax
3. 50 year life for grading and tunnel bores

Subcommittee "4": Planning, Budgeting and Controls

Since this subcomittee is newly formed a canvassing of members was made to determine interests and needs for this group. Results have not yet been tabulated.

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

D. D. Dali, Chairman

Report on Continuing (C) Assignments

Assigned Number	**C-1-87**	**C-2-87**	**C-3-87**	**C-4-88**	**C-5-89**
Description of Assignment	Transit Corridors	Transit Track & Roadway Cons.	Stations & Structures	Electrification For Transit	Gen. Info - Rail Transit
Date Assigned/ (Undertaken)	6/86	6/86	6/86	3/88	3/89
Estimated % Completion	90%	80%	75%	20%	50%
Estimated Completion Date	3/91	3/91	3/91	3/92	3/91

All SC assignments are ongoing until final chapter manual is published.

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

R. C. Brownlee, Chairman

Status of Subcommittee Assignments:

Subcommittee 1—Water Pollution Control

Assignment C1-1-85—Leaking underground Storage Tanks Summary of Rules, has been completed and submitted for publication in the Bulletin as information. Assignment C1-2-86—Report on Storm Water Regulations, has been an ongoing task due to the inability of EPA to finalize the rules. It is anticipated that the rule will be promulgated this year and the assignment will be completed early in 1991. Assignment D1-3-88—Investigation and Control of Groundwater Contamination is being conducted jointly with Subcommittee 3. A new subcommittee chairman has been appointed and work assignments revised within the subcommittees. The report is expected to be ready for review at the October committee meeting with completion early in 1991.

Subcommittee 2—Air Pollution Control

Assignment D2-1-84—Revision of Manual, has progressed on schedule. All sections are expected to be complete by the October meeting with completion of the assignment early in 1991.

Subcommittee—Land Pollution and Solid Waste Management

This committee remains inactive. Members have been reassigned to work with Committee 2.

Subcommittee 4—Noise Pollution Control

Subcommittee 4 is currently inactive with members assigned to work on other assignments.

Subcommittee 5—Plant Utilities

Assignment D5-1-82—Revision of Part 5 of the Manual. This assignment has progressed quite well but will not be completed this year as planned. Part 5.6—Fuel and Lubricating Oil Systems, and Part 5.7—Fire Protection Systems, are complete and have been published as Manual material. Part 5.8—Cathodic Protection of Pipelines and Steel Storage Tanks, has been completed and submitted for publication in the Manual. Other sections are near completion with Manual publication expected in 1991.

Excerpts From Annual Report of A.R.E.A. Committee 14 - Yards and Terminals

J. S. Acs, Chairman

Status of Subcommittee Assignments:

Subcommittee A

Presently there are a number of subjects under evaluation to determine the validity of future considerations:

1. Automatic Car Identification System.
2. Security at Auto Terminals.
3. Coach Yard support facilities for Commuter/Passenger Operation.
4. Regional/Short Line Railroads effect on Yard/Terminal concept.
5. Environmental consideration relative to Yards & Terminals.

Subcommittee B

There are no proposals under study for Revision of Manual at this particular time.

Subcommittee C-1-90—Design of Double Stack Facilities

The original material—"Intermodal Terminals"—study has been concluded, new topic assignment received July 11, 1990. This is a new commission, subcommittee organized and the subject is under study.

Subcommittee D-8-88—Bulk Fluid Transfer Facilities

The subcommittee has been riffled with problems. Since there are too many probabilities of material transfer, the subcommittee is reorganizing. Initial report should be available in the spring of "91."

Subcommittee D-3-84—Run Through Trains Effect on Yards

This study began in 1983 under the direction of four (4) different chairmen. Present chairman progressing the work with subcommittee study. This subject will be systematized and the projected preliminary report will be available end of this year.

Subcommittee D-4-86—Control of Cars with Contaminated Wheels

The subcommittee made some progress with changes initated by the second chairman at the helm. We anticipate to report this information in the spring of 1991.

Subcommittee C-2-88—Working with TRB on Intermodal Terminals.

This is an on-going effort to coordinate AREA/TRB activities within the set guidelines of both organizations. This is a one-man subcommittee basically in an advisory capacity to report and monitor TRB activities and coordinate periodical conference attendance with our committee members.

Subcommittee D-1-90—Fueling and Sanding Facilities in Yards.

The subject was approved for subcommittee study on July 11, 1990. Chairman was appointed, members are currently solicited and the entire subcommittee is being formulated.

Subcommittee D-7-87—Yard Control System

The first half of the report is completed and being circulated for comments by the committee members. The final portion of the report is under preparation.

Subcommittee D-2-89—Rail/Water Transfer Facilities.

Study progressing, data is presently being circulated within the subcommittee. Report should be available for Bulletin distribution by December, 1991 and technical Manual format by March, 1992.

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

M. Noyszewski, Chairman

Brief status of subcommittee assignments:

A. Recommendations for further study and research

The committee is continuing the work closely with the AAR/NSF Bridge Research Program through John Choros of the AAR Technical Center. The Bridge Research Steering Committee for this program includes 5 members of Committee 15.

B. Revision of Manual

The Committee has been working to prepare this year's submittal for changes to Chapter 15 of the AREA Manual and is working closely with other subcommittees on proposed future changes.

D1-1-87. Obtain data from which the frequency of occurrence of maximum stress in steel railway bridges may be determined under service loading.

This assignment is being progressed by Subcommittee 1—Design Loading and Stresses. It continues to a very difficult assignment because of shortage of reliable data on complete loading histories from different railroads. This subcommittee is working with the rating subcommittee and expects that the results of the current AAR/NSF Bridge Research Program will be crucial to conclude this assignment.

C2-1-82. Develop fracture control plan.

This assignment has been essentially completed by Subcommittee 2—Materials. The appropriate elements are now in the AREA Manual. However, there is a need to continue this assignment as the fracture control plan will require updating as additional data becomes available.

C3-1-86. For steel fabrication develop materials, methods, quality control procedures and qualifications of fabricators.

This assignment now is under Subcommittee 3—Fabrication and Erection. The committee continues to work on the development of specification for the loading details for fabricated members and other recommended changes in the fabrication area.

D6-1-88. Develop methods for repairing damaged steel bridge members.

This assignment is being progressed by Subcommittee 6—Repairs and Maintenance. Presentations have been made during the past year, and additional presentations are scheduled. It is estimated that at least two more years will be necessary to complete this assignment.

D7-1-87. Develop specifications for the design of confined elastomeric bearings in collaboration with Committee 8.

This assignment is being progressed by Subcommittee 7—Special Types of Construction. The subcommittee continues work on developing specifications for Manual inclusion. All work for development of pot bearing specifications is being done by this subcommittee per agreement with Committee 8.

C8-1-60. Develop bibliography and technical explanation of various requirements in A.R.E.A. specifications relating to iron and steel structures.

This assignment is being progressed by Subcommittee 8—Commentary and Bibliography. There is a continuing need for this committee to update and add items in its area of responsibility.

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

M. W. Franke, Chairman

Brief status of subcommittee assignments:

Subcommittee B—Revision of Manual

Work continued on revision of the Davis Formula and a final version is being prepared for approval by A.R.E.A. headquarters and submission to the Committee 16 membership for letter ballot in accordance with the "Information and Rules for Guidance of Technical Committees."

Subcommittee 3 - Application of Industrial Engineering to the Railway Industry (D3-2-87) Railway Application of Artificial Intelligence)

A survey form has been finalized by the Committee on this subject and will be submitted to A.R.E.A. headquarters for approval and dissemination to Committee 16 members. The survey information thus gathered will be compiled and published in 1991, together with appropriate narrative.

Subcommittee 4 - Economics of Railway Operations Without Institutional Restraints (D4-1-87)

Progress on this project has been hindered by an inability of the subcommittee chairman to devote sufficient time to lead the work. The project has been reassigned and significant progress is expected to be made over the next few months.

Subcommittee 5 - Economics Factors in Centralizing or Decentralizing Dispatching Functions (D5-1-89)

A survey form has been finalized which will be submitted to A.R.E.A. headquarters for approval and dissemination to Committee 16 members. The results will be compiled and published in 1991, together with appropriate narrative.

Excerpts From Annual Report of A.R.E.A. Committee 17 - High Speed Rail

R. D. Johnson, Chairman

Status of Subcommittee Assignments:

Subcommittee D-1-89. Corridor Evaluation

A. Assigned January 26, 1989.

B. Ten areas of investigation identified within subcommittee. Report submitted for consideration for publishment as information to AREA membership entitled "Review of High Speed Rail Systems Around the World and in the United States."

C. Completion is too early to determine.

D. The benefits will be a standard of evaluation criteria which does not now exist.

E. No problem areas.

F. Continue activity.

Subcommittee C-1-89. Track, Structures, and Track Train Interactions

A. Assigned January 26, 1989.

B. Seventeen pages of a preliminary text for manual consideration is under review.

C. Completion date is too early to determine.

D. The benefit will be a standard of evaluation criteria which does not now exist.

E. No problem areas.

F. Continue activity.

Subcommittee C-2-89. Vehicles, Control, and Propulsion System Considerations for High Speed Rail, Collaborating on Electrification with Committee 33 - Electrical Energy Utilization, and the AAR Communications and Signal Division.

A. Assigned January 26, 1989.

B. Report has been submitted for consideration for publishing as information to AREA membership entitled "A Survey of Wheel-On-Rail Traction Vehicles Capable of Running at 200 Km/Hr or More." Three areas of investigation identified with chairmen assigned.

C. Completion is too early to determine.

D. The benefit will be a standard of evaluation criteria which does not now exist.

E. No problem areas.

F. Continue activity.

Subcommittee D-2-89. Evaluation of Systems for Operation Over 250 M.P.H.

Not assigned for study yet.

Report on Committee 18 - Light Density & Short Line Railways

J. W. Heavin, Chairman

Committee 18 had its organizational meeting on Sunday, September 16, 1990 in the Palmer House Hotel, Chicago in connection with the REMSA, Roadmasters and Maintenance of Way and Bridge and Building Association Technical Conference September 17 to September 19, 1990.

Approximately thirty people attended the session and collaborated in finalizing the major subcommittee assignments, selecting subcommittee leadership, establishing basis for committee and subcommittee meetings and for completing the work of the committee.

Subcommittee B will review the current manual for its application to shortlines and, more critically, examine deleted portions of the manual that may be valuable to these lines. This task will be chaired by Mr. Michael G. Arter, Vice President Chief Engineer of the Dakota Minnesota & Eastern Railroad.

Subcommittee C-1-90 will investigate two recurring topics. First, the recommended practices concerning use of used track material will be reviewed. The subcommittee is planning to develop an inventory listing of rail less than 100#. The second charge concerns recommended practices for obtaining, maintaining, organizing and operating maintenance of way work equipment on shortlines. This subcommittee will be chaired by Mr. Carl T. Broussard, Asst. Gen. Mgr.-Maintenance, Louisiana and Delta Railroad, Inc.

Subcommittee D-1-90 has been charged with investigating the special considerations for obtaining contracted engineering, repair, and maintenance services for short lines. They are also investigating inspection criteria.

Excerpts From Annual Report of A.R.E.A. Committee 22 - Economics of Railway Construction & Maintenance

S. H. Morrell, Chairman

Status of Subcommittee assignments:

Subcommittee B, Revision of Manual

(a) Assigned: Unknown

(b) Progress: Rewrite of entire Manual underway with progress of each part shown below.

(c) Completion date: 6/92 per Committee's five-year goals.

(d) Benefits: Greatly improved quality of information in Chapter 22 of Manual.

(e) Problems: None. Awaiting completion of Part 3 before submitting entire revision to the Board.

(f) Recommendations: Continue.

Subcommittee B1, Part 1

Revision of Manual - Personnel

(a) Assigned: 1/14/88.

(b) Progress: 100% - Committee approved by ballot.

(c) Completion date: 1/90.

(d) Benefits: Improved information.

(e) Problems: None.

(f) Recommendations: Continue.

Subcommittee B-1, Part 2

Revision of Manual - Programming Work and Budgeting

(a) Assigned: 1/14/88.

(b) Progress: 100% - Committee approved by ballot.

(c) Completion date: 1/90.

(d) Benefits: Provide high quality information.

(d) Problems: None.

(f) Recommendations: Continue.

Subcommittee B-1, Part 3

Revisions of Manual - Construction and Maintenance Operations

(a) Assigned: 1/14/88.

(b) Progress: 60% - Reviewing proposed changes.

(c) Completion date: 6/91.

(d) Benefits: Improved information.

(e) Problems: None

(f) Recommendations: Continue.

Subcommittee B-1, Part 4

Revisions of Manual - Equated Mileage Parameters

(a) Assigned: 1/14/88.

(b) Progress: 100% - Committee approved by ballot.

(c) Completion date: 1/90.

(d) Benefits: Improved usefulness and understanding of equated mileage parameters.

(e) Problems: None

(f) Recommendations: Continue.

Subcommittee D-1-90. Renewal of Concrete Ties complete or in part.

(a) Assigned: 1/29/90.

(b) Progress: 0% - Reviewing Committee 10's work.

(c) Completion date:

(d) Benefits: Addresses an important and extensive topic.

(e) Problems: None.

(f) Recommendations: Continue.

Subcommittee D-2-86. Economics of Various Surface Gang Consists used by Railroads in North America.

(a) Assigned: 1/14/86.

(b) Progress: 40%

(c) Completion date: 3/91

(d) Benefits: Information

(e) Problems: None

(f) Recommendations: Continue to completion.

Subcommittee D-3-88. Economics of Vegetation Control Methods Working with Committees 1 and 13.

(a) Assigned: 1/14/88

(b) Progress: 30%

(c) Completion date: 1/91

(d) Benefits: Develop costs of Vegetation Control Methods.

(e) Problems: None

(f) Recommendations: Continue

Subcommittee D-4-90. Track Time Usage.

(a) Assigned: 1/29/90.

(b) Progress: 10%—Further clarification of the subcommittee's goals is needed.

(c) Completion date:

(d) Benefits: Addresses economics of gang size and track time relationships.

(e) Problems: None.

(f) Recommendations: Continue.

Subcommittee D-5-87. Economics of Standardization of Turnout Materials.

(a) Assigned: 1/87.

(b) Progress: 100%—Submitted for publication.

(c) Completion date: 6/90

(d) Benefits: Can have significant impact on industry.

(e) Problems: None.

(f) Recommendations: None.

Subcommittee D-6-90. Centralized vs. Decentralized Renewal Planning.

(a) Assigned: 1/29/90.

(b) Progress: 10%

(c) Completion date:

(d) Benefits: Provide planning alternatives based on size, budget or other economic considerations.

(e) Problems: None.

(f) Recommendations: Continue.

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

J. W. Orrison, Chairman

Subcommittee Assignments

Subcommittee A. Recommendations for further study and research

Assigned: Prior to 1983

Progress: Subcommittee will be involved in assisting with review of establishing subcommittee goals for the future years and will be responsible for identifying topics that should be handled as recommendations for further study and research.

Completion: Should be continuous.

Benefits: Develop meaningful new assignments for the committee membership.

Problems: None.

Recommendations: Continue.

Subcommittee 1. Recruiting and Speakers (C1-1-82)

Assigned: Prior to 1983

Progress: Published an annual survey of college graduate hiring by railroad engineering and maintenance departments. Efforts to make the report more current allow publication of the report in the spring. Advise schools of availability of railroad speakers for student groups. Plan to develop speakers presentation library.

Completion: Should be continuous.

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

Problems: None.

Recommendations: Continue.

Subcommittee 2. Recruiting and Speakers (C2-2-88)

Assigned: 1988.

Progress: The purpose of this subcommittee has been redirected to administrate AREA Student Interest Award Program (SIAP). The subcommittee is involved in administrating Award announcement, judging and selection of up to 10 papers for recognition to receive awards.

Completion: Should be continuous.

Benefits: Opportunity to increase student interest in AREA.

Problems: None.

Subcommittee 3. Faculty Relations (C3-3-85)

Assigned: 1985.

Progress: The purpose of the subcommittee is to provide opportunity for the railway industry to stimulate faculty involvement in railroad-related engineering problems.

Completion: Should be continuous.

Benefits: Opportunity to develop increased interest in railway engineering on the part of engineering faculty.

Problems: None.

Recommendations: Continue.

Subcommittee 4. Student Relations (C4-4-86)

Assigned: Prior to 1983.

Progress: Will progress all initiatives concerning student relations including the AREA Student Affiliates Program.

Completion: Should be continuous.

Benefits: Increased student awareness of AREA and provide for their involvement with AREA as student affiliates.

Problems: None.

Recommendations: Continue.

Subcommittee 5. Continuing Education (C5-5-71)

Assigned: Prior to 1983.

Progress: Exploring new alternatives to stimulate the participation of AREA's membership in continuing education activities.

Completion: Should be continuous.

Benefits: Provides opportunity for AREA members to improve their knowledge of subject matter which is relevant to the railroad industry.

Problems: Low activity.

Recommendations: Continue.

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

J. J. Hannaford, Chairman

Subcommittee assignments:

Subcommittee A—Recommendation for further study and research.

The task of this subcommittee is directing the committee toward new tasks, set goals and interface with the REMSA group.

Subcommittee B—Revision of Manual

Ballot on revisions to sections in Chapter 27 have been approved.

Subcommittee C-1-74—Reliability Engineering, as applicable to work equipment.

The survey on design and testing of new equipment, performance and consistent and reliable service was completed, approved and distributed.

Subcommittee C-2-83—Preventative maintenance of maintenance of way equipment.

The preventative maintenance program for equipment has been drafted. This program will be addressed and critiqued at our September meeting.

Subcommittee D-2-86—Computer applications as applicable to work equipment.

Computer application survey has been completed. The results will be discussed at the September meeting and this committee will continue to gather information on computer assist packages.

Subcommittee C-3-84—Maintenance of Way Equipment Safety.

A survey of safety problems on work equipment has been developed and sent to the supply industry.

Subcommittee D-1-77—Training Programs for Machine Operators and Maintainers

Currently this committee is drafting a letter to the chief engineers addressing a training program which may be available to, or exchanged from railroad to railroad.

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

J. T. Ormsby, Chairman

Subcommittee Progress

A. Recommendations for Further Study

Special Subcommittee to prepare a series of standard, AAR approved "Plates" to depict the clearance outline of the latest generation of Multi Level and Auto Rack cars, beyond the Plate "F". Many carriers currently refer to this general category as Plate "G", a broad, all encompassing and nondimensional subriquet.

B. Revision of Manual

The graphics portion of Chapter 28 has been undergoing a continuing refinement. As much as we of committee would like to take credit for this visual facelift, Tom Smithberger has been the chief surgeon responsible for much of it. Many thanks to Tom.

In addition, the committee is totally revamping its index in order to clarify its rather nebulous list of miscellaneous topics.

Subcommittee C-1-62. Compilation of the Railroad Clearance Requirements of the Various States.

No changes noted in past year. Committee is looking into adding Mexico to current listing.

Subcommittee C-2-85. Compilation of a Comprehensive Glossary and Bibliography Pertaining to the Technical Literature on Railroad High and Wide Clearances.

Five new definitions have been approved by committee ballot over the past year.

Subcommittee C-3-85. Review of Railway Line Clearances to develop improved user accessibility.

The definition of the Standard car for the determination of published clearance has been Board approved. It will now be necessary to incorporate this change into Chapter 28, Section 3-2-4 with Board approval.

Subcommittee D-3-85. Conversion of "Heavy Car & Special Type Flat Car" Section of the Official Railway Equipment Register to UMLER Compatible Format.

This Subcommittee is looking into the possibility of including Private cars in the Heavy Capacity and Special Type Flat Car section of the equipment register. Babcock & Wilcox has already taken this step.

Subcommittee D-4-85. Research and Develop book covering heavy-duty car diagrams and ratings.

This Subcommittee has progressed to the point where a final product should be ready for committee review before our Spring meeting, culminating a long and detailed study.

Subcommittee D-5-86. Recommended procedure for safe movement of oversize and overweight shipments on foreign (jointly operated) track.

This study has been completed, and ballot approved and is awaiting Board review for inclusion in the Manual.

Subcommittee D-6-89. Recommendations for a Uniform Electronic Clearance Message.

This is a highly important area of study in an age of high speed communication. The committee has acted quickly and efficiently in resolving the myriad aspects of a structured, complete format. The final product should be ready for comittee ballot before the spring meeting. A call for ballot was motioned, seconded, voted and passed at the April meeting.

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

R. B. Sliepka, Chairman

Subcommittee Progress:

Assignment Number	**C2-1-86**	**C2-2-86**	**C3-1-78**	**C3-2-78**	**D4-1-86**	**D4-2-86**
Description of Assignment	Computer Applications	Data Gathering	Engineer Design	Computer Graphics	Industry Standard	Manual on Graphics
Date Assigned	1-86	1-86	1-86	1-86	1-86	1-86
Estimated % Completion					70%	50%
Estimated Completion Date	Continuing	Continuing	Continuing	Continuing	1993	1994
Problems	None	None	None	None	None	None
Recommend Assignment Being Dropped/ (Discontinued)	NO	NO	NO	NO	NO	NO
Recommend Assignment Being Postponed	NO	NO	NO	NO	NO	NO

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

J. Popoff, Chairman

Status of Subcommittee Assignments:

Subcommittee 1—Electrification Economics

C1-1-73. Monitor Economics of Electrification

This assignment was made in 1973 and is an ongoing review of the economic factors influencing the installation and maintenance of railroad electrification. An update bulletin was published as information in 1985. The subcommittee is actively preparing an update for publication in 1991 and for possible presentation at the 1991 Fall Technical Conference.

Subcommittee 4—Railroad Electrification Systems

C4-1-76, Railroad Electrification Systems

This assignment was made initially in 1976 and consists of a review of the specifications and guidelines for the major components and systems for railroad electrification, contained in Part 4 of Chapter 33 of the manual. Substantial efforts have been placed on the development of specifications for the footings and foundations for the catenary structures. A number of new techniques and designs have been used in recent years and have been incorporated. The Subcommittee's submittal was tendered to the Committee at large for balloting in April and was passed.

The Subcommittee suggested that a new assignment regarding electrical and physical clearances of electrification would be appropriate.

D4-1-87. Electrification Safety

This assignment was made in 1987 for the review of safety requirements associated with the construction and operational maintenance of electrified systems. This assignment has been placed on hold pending a determination of the potential legal issues by the AREA Headquarters staff. As a result no progress has been made to date on this assignment.

Subcommittee 6—Power Supply and Distribution

C6-1-87. Review and update Part 6 of the Manual

This assignment was made in 1976 and consists of an ongoing review of the specifications for the power supply and distribution system for railroad electrification. The subcommittee has submitted their penultimate draft of the power utility portion to the subcommittee for review. It is expected to be circulated to the Committee at large for balloting in the 1991. The subcommittee is preparing the first draft of electromagnetic interference section.

Subcommittee 8—Electrical Noise

D8-1-86. Review Part 8 of the Manual

This assignment was initiated in 1981 to look at the impact of electrical noise generated by railroad electrification equipment and other railroad equipment and to determine whether a new section was required in Chapter 33. The Committee at large has agreed to place a low priority on this assignment pending the completion of Subcommittee 4 and Subcommittee 6 current assignments. Subcommittee 8 is working closely with Subcommittee 6 on the matter of Electromagnetic Interference as it relates to the Power Supply and Distribution.

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

F. J. Loyd, Jr., Chairman

Subcommittee Activities:

Subcommittee A—Recommendations For Further Study and Research

This is an ongoing subcommittee.

This Committee investigates and reviews products and technological changes in the Industry and makes recommendations to the Committee Chairman concerning need for further study and research.

The Kaman Science Corporation System and Kilo-Wate Weighing Systems, both being marketed throughout the U.S. were referred to Subcommittee C-2-82 for study.

The Kaman system was abandoned by Kaman. There were exensive data collected on the system that was installed in Burlington Northern's Yard in Kansas City in line with the Streeter Richardson coupled-in-motion scale also installed at that location.

Both the Kilo-Wate and the Kaman system produced information concerning individual car weights that would be helpful for load-control. Total unit train accuracy was also of interest for some applications; however, neither have been recognized to comply to standards in the applications studied.

Two items identified by the Committee to be addressed pertain to: (1) Railroad Master Scale Program and (2) Recommended Track Scale Testing Criteria. The Board approved the formation of a subcommittee to study Item 2, which began in 1990. Also, concerns about overloads, unbalanced loads and impacts from flat wheels may be another area that the Committee may need to get involved with in the future.

A subcommittee to study the "Railroad Master Scale Program" will be requested of the Board for Creation in 1991.

Subcommittee B—Revision of the A.A.R. Scale Handbook

This is an ongoing subcommittee.

There have been no changes to the AAR Scale Handbook submitted the past year; however, the changes voted on at the National Conference on Weights and Measures, effective January 1, 1991, will have to be included in the Handbook in 1991.

This Subcommittee is one of the most important within Committee 34 because of the critical need to keep the AAR Scale Handbook up to date with technological advances, State and Federal Laws, etc.

Changes to the Handbook are made available to Committee Members and holders of the publication.

Subcommittee C-1-85—Preparation of Subjects For Publication

This is an ongoing subcommittee.

Changes to the AAR Scale Handbook to bring it into conformance with NIST H44 (State and Federal Regulations) will be upcoming. There are currently no outstanding assignments pending. The paper entitled "Criteria for Location of Coupled-In-Motion Weighing Systems," prepared by Subcommittee D-1-83, was finalized June, 1990 and forwarded for publication in an AREA Bulletin. Also AAR Circular OT-17-F, "Recommended Practices for Inspecting, Testing and Repairing Industry Track, Vehicle, Hopper Type and Belt Conveyor and Scales" was updated with input from Committee 34 and republished June 1, 990. It was also forwarded for publication in an AREA Bulletin.

Subcommittee C-2-82 - Innovations in Scales Used in Connection With Operations of Railroads

This is an ongoing subcommittee that investigates new technology and changes in the weighing industry that affect Railroads.

The Subcommittee discontinued investigation of a Kaman Weigh-In-Motion System located on the Burlington Northern in Kansas City, Kansas when Kaman decided to close development of the system. Item being studied presently deals with high speed Coupled-in-Motion weighing as relates to accuracy and to the benefits to the Railroad industry.

Subcommittee D-1-83—Criteria For The Location of Coupled-In-Motion Track Scales

A number of this subcommittee's members were associated with the National Conference on Weights and Measures S&T Railroad Advisory Committee, which developed considerable data and information concerning topographical situations for Coupled-in-Motion Systems.

The final draft of this study has been submitted for publication in an AREA Bulletin this fall, after which it will be determined in the fall meeting of Committee 34 if this Subcommittee will be discontinued or will remain to conduct further studies correlated with the NCWM S&T Committee Study of coupled-in-motion individual car weights used for custody transfer.

A meeting of this Subcommittee will be held prior to the October, 1990 Committee 34 meeting.

Subcommittee D-2-87—Investigate Stenciling of Cars Using Coupled-In-Motion Weights

This Subcommittee, under the direction of the new Chairman has made substantial progress. Questions concerning how C.I.M. light weights could be applied/usage guidelines have sparked further considerations for the subcommittee's study. Historical data concerning empty car weights and the economic implications, of the present tare weighing program vs. a modified program using coupled-in-motion weights are factors with relevant effect on the subcommittee's study.

A subcommittee meeting to further discuss and study existing data and the direction of the subcommittee's focus is planned prior to the full Committee 34 meeting in October.

Subcommittee D-3-90—Track Scale Testing Guidelines, Test and Inspection Forms

This newly formed Subcommittee has begun researching various test reports and will plan to meet to study the various forms and guidelines in place on the different Railroads. This meeting is planned prior to the Committee 34 meeting in October.

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, 1991. These comments will be considered by 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 if approved go into effect August 1, 1991.

Proposed 1991 Manual Revisions To Chapter 1 - Roadway and Ballast

Parts 2, 5, 6 and 9 of Chapter 1 are proposed to be revised as follows:

PART 2—BALLAST

Present Section 2.1 on the design of the track ballast section now refers to Chapter 22, Part 3, Section 3.3 or individual railway company standards exclusively. The proposed new Section 2.1 contains some references to Chapter 22, but also recommends other parameters as well to be followed in the design of the ballast section. The new Section 2.1 is as follows:

2.1 DESIGN

2.1.1 Track Substructure Design

2.1.1.1 Description

This section of these specifications will discuss the proportioning of the track substructure components, the ballast and sub-ballast sections. Single and multiple track construction will be addressed, as will track with superelevation. The following figures are shown:

Figure 2.01.01 Typical Section Track Substructure
Figure 2.01.02 Single Track, Superelevated
Figure 2.01.03 Multiple Track, Tangent
Figure 2.01.04 Multiple Track, Superelevated

2.1.1.2 Variables of Design

The variables to be considered in establishing the dimensions of a track substructure are noted below and shown on Figure 2.01.01. The variables of the track superstructure which effect the design of the substructure are first noted.

2.1.1.2.1 For the Track Superstructure

TRG = The Track Gage.
TSE = The Superelevation of the Track.
TTH = The Thickness of the Cross Tie.
TLE = The Length of the Cross Tie.
TWD = The Width of the Cross Tie.
TSP = The Spacing of Cross Ties, center to center.

The variables TRG, TTH, TLE, TWD and TSP are not shown on the figures.

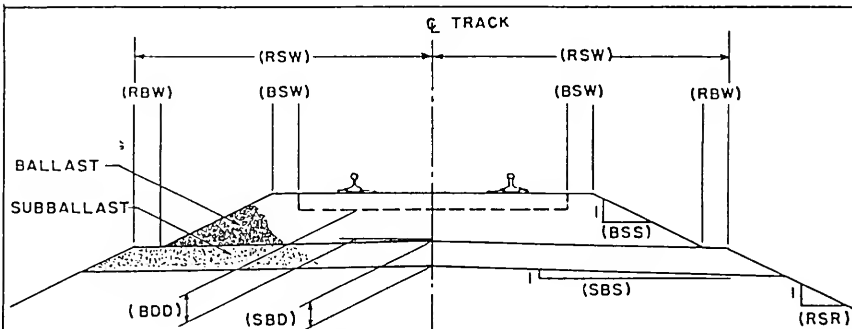
2.1.1.2.2 For the Track Substructure

2.1.1.2.2.1 Ballast Section

BDD = The Ballast Section Depth.
BSW = The Ballast Section Shoulder Width.
BSS = The Side Slope Run component of the Ballast Section in a unity rise to run ratio.

2.1.1.2.2.2 Sub-ballast Section

SBD = The Sub-ballast Depth
SBS = The Side Slope Run component of the Sub-ballast Section in a unity rise to run ratio.



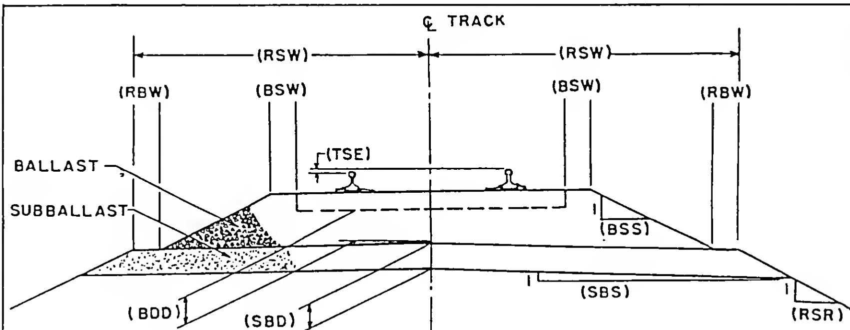
TYPICAL SECTION
TRACK SUBSTRUCTURE

Ballast:
BDD = Depth of Ballast
BSW = Ballast Shoulder Width
BSS = Ballast Side Slope Run

Subballast:
SBD = Subballast Depth
SBS = Subballast Side Slope Run

Roadbed:
RSW = Roadbed Shoulder Width
RSR = Roadbed Side Slope Run
RBW = Roadbed Berm Width

Figure 2.01.01



SINGLE TRACK
SUPERELEVATED

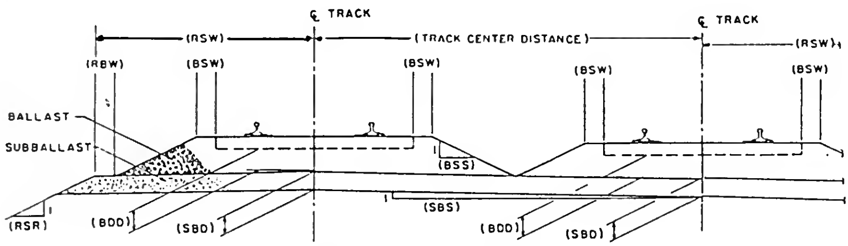
Ballast:
BDD = Depth of Ballast
BSW = Ballast Shoulder Width
BSS = Ballast Side Slope Run

Subballast:
SBD = Subballast Depth
SBS = Subballast Side Slope Run

Roadbed:
RSW = Roadbed Shoulder Width
RSR = Roadbed Side Slope Run
RBW = Roadbed Berm Width

Track Superstructure
TSE = Track Superelevation

Figure 2.01.02



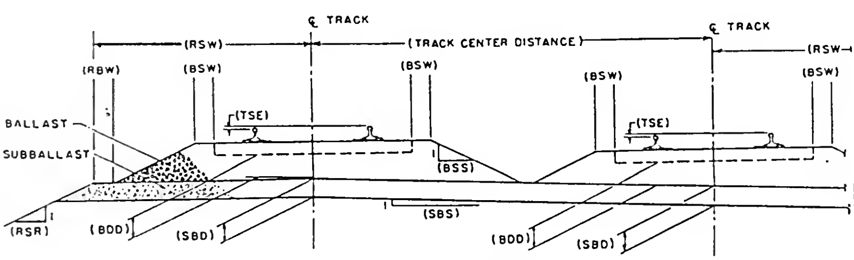
MULTIPLE TRACK
TANGENT

Ballast:
BDD = Depth of Ballast
BSW = Ballast Shoulder Width
BSS = Ballast Side Slope Run

Subballast:
SBD = Subballast Depth
SBS = Subballast Side Slope Run

Roadbed:
RSW = Roadbed Shoulder Width
RSR = Roadbed Side Slope Run
RBW = Roadbed Berm Width

Figure 2.01.03



MULTIPLE TRACK
SUPERELEVATED

Ballast:
BDD = Depth of Ballast
BSW = Ballast Shoulder Width
BSS = Ballast Side Slope Run

Subballast:
SBD = Subballast Depth
SBS = Subballast Side Slope Run

Roadbed:
RSW = Roadbed Shoulder Width
RSR = Roadbed Side Slope Run
RBW = Roadbed Berm Width

Track Superstructure
TSE = Track Superelevation

Figure 2.01.04

2.1.1.2.2.3 Roadbed

RSW = The Roadbed Shoulder Width.
RBR = The Side Slope Run component of the Roadbed Section in a unity rise to run ratio.
RBW = The Roadbed Berm Width.

2.1.1.3 Standards, Design Criteria and Regulation

Unless otherwise established by the Standards of Track Construction and/or Maintenance of Way of the railway company, the Project Design Criteria, or a like document, the below paragraphs of this Part of this Manual shall govern the proportioning of the track substructure components.

Regulation, promulgated by lawful authority, shall supersede the content of this Section 2.1.1 of the Manual.

2.1.1.4 Track Superstructure

The Track Gage (TRG) shall be 56.50 inches, Standard Gage. The Superelevation of Track (TSE) shall be determined in accordance with Chapter 5, Part 3 of this Manual.

The Cross Tie Thickness (TTH), Length (TLE), Width (TWD) and the Spacing (TSP) shall be proportioned in accordance with relationships show in Chapter 22, Part 3 of this Manual.

2.1.1.5 Track Substructure

2.1.1.5.1 Total Depth of Section (BDD + SBD)

The total depth of the track substructure section shall be determined in accordance with the relationships shown in Chapter 22, Part 3 of this Manual. The sum of Ballast Section Depth (BDD) and Sub-ballast Depth (SBD) shall equal the calculated total depth of track substructure section.

2.1.1.5.2 Ballast Section

2.1.1.5.2.1 Ballast Section Depth (BDD)

The ballast section is the upper portion of the track substructure section and is constructed of material conforming to Section 2.1.3 of this Part of the Manual.

For single track construction, the measurement BDD is made under the Line Rail in tangent track, or under inside rail in curved track, and is made with respect to the top of the sub-ballast at the center line of track. On tangent multiple track construction, the measurement is made under that rail which is toward the crown of the Sub-ballast Section. On curved multiple track construction, the measurement is made under the rail to the inside of the curve.

A value for BDD of 12 inches is recommended for Standard Gage construction in main track service. A lesser value, but not less than 8 inches, may be appropriate for tracks of lesser construction or in lesser service.

2.1.1.5.2.2 Ballast Section Shoulder Width (BSW)

The Ballast Section Shoulder Width is proportioned in accordance with Chapter 22, Part 3 of this Manual and is to provide additional lateral strength to the track.

The measure is made from the end of the cross tie to the point of beginning of the Ballast Side Slope (BSS), and is made in the plane of the top of the cross tie.

A value for BSW of not less than 12 inches is recommended for Standard Gage construction of continuous welded rail in main track service. A value of 8 inches is recommended for like service but constructed of bolt joined rail. A lesser value, but not less than 6 inches, may be appropriate for lesser construction or service.

2.1.1.5.2.3 Side Slope (BSS)

The Side Slope run component of the Ballast Section is proportioned to provide confining pressure to that part of the Ballast Section expected to transmit the vertical load from the bottom of the cross tie to the top of the sub-ballast.

The BSS run component is measured in the plane of the top of the cross tie, and the rise component is measured perpendicular to the run component.

A BSS value of 2 is commonly used.

2.1.1.5.3 Sub-ballast

2.1.1.5.3.1 Sub-ballast Depth (SBD)

The Sub-ballast is the lower section of the track substructure and is constructed in accordance with the specifications contained in Section 2.11 of this Part of the Manual.

The depth measured is made with respect to the top of the Roadbed.

A value for SBD of 12 inches is commonly used for Standard Gage construction in main track service. A minimum value of 6 inches is considered necessary to perform the separation of layers and shielding of the roadbed from weather functions.

2.1.1.5.3.2 Side Slope (SBS)

The Side Slope run component of the Sub-ballast Section is proportioned to provide drainage to the top of the roadbed construction.

A value for SBS of not less than 24 or more than 40 is recommended. Sub-ballast materials having relatively lower permeability rates may use relatively higher SBS values.

2.1.1.6 Roadbed

The Roadbed Shoulder Width (RSW), Side Slope Run component of the Roadbed (RBR), and Roadbed Berm Width (RBW) shall be established in accordance with principals and recommendations contained in Part 1 of this Chapter of the Manual.

PART 5—PIPELINES

Part 5 revisions include replacement of Table 5.1.4.1. and 5.2.4.1, "Minimum Wall Thickness for Steel Casing Pipe for E72 Loading" with new tables titled, "Minimum Wall Thickness for Steel Casing Pipe for E80 Loading." The new tables also show values for diameters in excess of 42" but not to exceed 72". In addition paragraph 5.1.4.2 and 5.2.4.2 on cast iron pipe specifications are to be eliminated with appropriate renumbering of subsequent paragraphs. The new Table 5.1.4.1 and duplicate Table 5.2.4.1 is as follows:

Table 5.1.4.1
Minimum Wall Thickness for Steel Casing Pipe for E80 Loading

Nominal Diameter (Inches)	Nominal Thickness (Inches)
14 and Under	0.188
16	0.219
18	0.250
20 and 22	0.281
24	0.312
26	0.344
28	0.375
30	0.406
32	0.438
34 and 36	0.469
38	0.500
40	0.531
42	0.563
44 and 46	0.594
48	0.625
50	0.656
52	0.688
54	0.719
56 and 58	0.750
60	0.781
62	0.813
64	0.844
66 and 68	0.875
70	0.906
72	0.938

PART 6—FENCES

Various revisions are proposed to Part 6 including revisions to specifications for material for wood and concrete fence posts, wire galvanizing and fence post hole requirements. Specifications for snow fencing are proposed to be removed since they are contrary to available technology and successful practice. Revisions to the various sections and articles are as follows:

Proposed Revision to 6.2.1

6.2.1.1 Kinds of Wood

The manufacturer may furnish posts made from any of the following woods listed unless otherwise specified by the purchaser.

With the exception of Redwood, all kinds of wood should receive preservative treatment.

Black Locust	Black Walnut	Ash	Hackberry
Cypress	Heart Yellow Pine	Beech	Maple
Catalpa	Larch	Birch	Red Oak
Cedar	Red Mulberry	Black Gum	Sap Yellow Pine
Chestnut	Redwood	Cherry	Sap Fir
Douglas Fir	White Oak	Elm	Sycamore
Hickory			

Proposed Revision to 6.3.1

6.3.1 Materials

Cement, aggregate, water and metal reinforcement shall conform in quality to the AREA specifications for concrete and reinforced concrete, Part 1, Chapter 8, with the following exceptions:

The maximum size of aggregate shall be not more than three-quarters the clear imbedment distance.

Reinforcement shall be in the form of round or square bars or cold drawn steel wire.

Crimped, stranded or flat reinforcement shall not be used.

Where choices can be made between sizes of reinforcement, it is preferable to use the larger number of smaller bars.

Proposed Revision to 6.5.2

6.5.2.7 Galvanizing

(a) The galvanizing of wire shall consist of a uniform coating of zinc, the weight of which shall be not less than 1.20 oz. per sq. ft. of surface treated. For woven wire, ASTM A116, and for barbed wire, ASTM A121 is to be complied with.

Proposed Revision to 6.5.3

6.5.3.3 Post Holes

Holes of full depth shall be provided for all end, corner, anchor and gate posts, even if blasting must be resorted to. Posts may be installed in drilled holes of the same dimension as the post and the post made firm in place, or they may be installed in larger drilled or dug holes and backfilled and compacted. For intermediate or line post, where rock is encountered, not more than two adjacent wood posts shall be set on sills 6 in. by 6 in. by 4 ft. long, braced on both sides by 2 in. by 6 in. braces, 3 ft. long. Holes shall be provided for all other posts. Posts shall be set with large end down and in perfect line on the side on which the wire is to be strung. After the fence is erected, the tops of the wood posts shall be sawed off with a 1/4 pitch, the high side being next to the wire and 2 in. above it.

Backfill of post holes shall be compacted by mechanical means to at least 90% of the ASTM D1557 maximum density at moisture content of within 4% of optimum. An acceptable alternate method of backfill would be the use of a sand-cement slurry consisting of 2 sacks of cement per cubic yard of clean, washed concrete sand and sufficient water to produce a thick slurry. This slurry would be placed in the post holes.

Proposed Revision to 6.7 and 6.8

All material is to be withdrawn with the words "Withdrawn for Further Study" inserted on Sections 6.7 and 6.8.

PART 9—RAILROAD VEGETATION CONTROL

It is proposed to remove Table 3—Susceptibility of Wood Species to Herbicide Treatments from Part 9 due to it being of no current value. A commentary for Part 9 is proposed to be added as Article 9.4.4 that follows:

9.4.4 Commentary

Like other areas of engineering maintenance, that of vegetation control has become more complex. Since the days when section gangs grubbed weeds, and simple one-system cars applied diesel fuel, the field has become mechanized and the herbicides regulated by federal and state laws. It has been suggested that the term "control" is too imprecise and that "management" be substituted. Such a change implies a concept greater than that of prevention or removal. As yet, the possibility of farming rights-of-way remains untried and falls outside our current concerns.

To what extent can railroad employees still apply herbicides? Federal and state certification requirements differentiate between "commercial" and "private" (not for hire) applicators. In most areas the latter may still use general-use pesticides on their own or their employer's property without passing state examination. Since only a few are restricted-use products, most railroads make use of their own personnel for at least some of their granular or pelletized application. Other railroads have crews who are Certified Private Applicators in several states, and who can purchase and apply restricted-use products if necessary. It is probable that both the list of states requiring all users to be certified and the list of restricted-use herbicides will grow.

It will be increasingly important for railroad personnel to gain proficiency through contact with a number of sources. For example, the Weed Science Society (address given 9.4.3) is an excellent source of information on products other than just those mentioned in Table One. The Federal Environmental Protection Agency and its various state branches are the ultimate sources of the most up-to-date regulations. State and county departments of agriculture and county and university extension agents can be good sources, especially for species identification. The National Railroad Contractors Association can provide a list of companies with specialized equipment and certified applicators. State and County Health Boards may have special ordinances affecting local usage and, of course, the manufacturers themselves can provide technical data regarding their own products.

A list of the state agencies responsible for application certification is to be included with this proposed revision, but is not printed here and is available from A.R.E.A. Headquarters for $2.00.

Proposed 1991 Manual Revisions To Chapter 3—Ties and Wood Preservation

The following revisions to Chapter 3 in the A.R.E.A. Manual of Recommended Practices are necessary to bring it up to date because of changes made in the American Wood Preservers Association Standards in 1989.

PART 6—WOOD PRESERVING

Section 6.3 Conditioning prior to treatment

Change the eleventh word in the fifth sentence to read "M2-89"

Section 6.10 Specified requirements

Insert Table 7. Specified Requirements, that follows on page 43.

7. SPECIFIED REQUIREMENTS

C6—Crossties and Switch Ties—Preservative Treatment by Pressure Processes - 1989

	Oak and Hickory	Mixed Hardwoods	Southern and Ponderosa Pine	Cypress, Pacific Coast Douglas Fir, W. Hemlock, W. Larch	Intermountain Douglas Fir	Jack, Red and Lodgepole Pine
2.2 **Incising**	Optional	Optional	Optional	Required	Required	Required
3.0 **Conditioning**						
Steaming	Not Permitted	Not Permitted	Permitted	Not Permitted	Not Permitted	Permitted
Temp.-Deg. F. Max	—	—	245	—	—	240
Duration-Hrs. Max.	—	—	18	—	—	3
Vac.-Inches Min.	—	—	22	—	—	22
3.2 Boulton Drying	Permitted	Permitted	Permitted	Permitted	Permitted	Permitted
3.3 Kiln Drying	Permitted	Permitted	Permitted	Permitted	Permitted	Permitted
3.4 Vapor Drying	Permitted	Permitted	Permitted	—	—	—
3.5 Controlled Air Drying	Permitted	Permitted	Permitted	—	—	—
4.0 **Treatment**						
4.12 Pressure-Lbs. Max.	250	200	200	150	150	175
Lbs. Min.	150	150	50	50	50	50
4.13 Temp.-Deg. F. Max.	210	210	210	210	200	220
Deg. F. Min.	180	180	180	180	180	180
5.0 **Results of Treatment**						
5.1 Retention-pcf, Min.						
5.11 Creosote	7 or Refusal	7	8	8 or Refusal	Refusal	6
Creosote-Coal Tar Solution	7 or Refusal	7	8	8	Refusal	7
Creosote-Petroleum Solution	7 or Refusal	7	8	8	Refusal	7
5.12 Pentachlorophenol (4.5% Solution Min.)	0.35 or Refusal	0.35	0.40	0.40	Refusal	—
5.2 Penetration in inches or % of Sapwood-Min.	White Oak-95% Sapwood Red Oak-65% Annual Rings	1.5 or 75%	2.5 or 85%	0.5 and 90%	90%	0.5 or 90%
5.21 Penetration Determination	A borer core shall be taken from the center of 20 ties in each charge. If 80% of the borings meet above requirements the charge shall be accepted. Except for oak, if the average penetration of the 20, 3.0″ borings meet the penetration requirements, the charge shall be accepted.					

PART 7—SPECIFICATIONS FOR PRESERVATIVES

Section 7.1 Creosote

This section is to be deleted.

Section 7.2 Creosote Coal Tar Solutions

This section is to be renumbered 7.1 and replaced with the following:

7.1 CREOSOTE SOLUTIONS[1]

1. The material shall be a pure coal tar product derived entirely from tar produced by the carbonization of bituminous coal. It may either be a coal tar distillate or a solution of coal tar in coal tar distillate.

2. The new material and the material in use in treating operations shall conform to the following detailed requirements.

	New Material		Material In Use	
	Not Less Than	Not More Than	Not Less Than	Not More Than
2.1 Water, % by Volume	—	1.5	—	3.0
2.2 Matter Insoluble in Xylene, % by wt.	—	3.5	—	4.5
2.3 Coke Residue, % by wt.	—	9.0	—	10.0
2.4 Specific Gravity at 38°C Compared to water at 15.5°C:				
2.41 Whole Creosote	1.08	1.13	1.08	1.13
2.42 Fraction 235-315°C	1.025	—	1.025	—
2.43 Fraction 315-355°	1.085	—	1.085	—
2.5 Distillation: The distillate, % by wt. on a water free basis, shall be within the following limits:				
2.51 Up to 210°C	—	5	—	5
2.52 Up to 235°C	—	25	—	25
2.53 Up to 315°C	32	—	32	—
2.54 Up to 355°C	52	—	52	—

3.0 Tests to establish conformance with the foregoing requirements shall be made in accordance with the standard methods of the American Wood Preservers Association. (See Standard A1)

[1]American Wood-Preservers' Association Standard P2-89 (This Standard is under the jurisdiction of AWPA Committee P-2)

Section 7.3 Creosote-Coal Tar Solution to be Used in the Treatment of Marine Piles and Timbers

This Section is to be deleted.

Section 7.4 Coal Tar Creosote to be Used in the Treatment of Marine Piles and Timbers

This Section is to be renumbered to 7.2 and replaced with the following:

7.2 COAL TAR CREOSOTE FOR LAND AND FRESH WATER AND MARINE (COASTAL WATER USE)[1]

1. The creosote shall be a distillate derived entirely from tar produced by the carbonization of bituminous coal.

2. The new material and the material in use in treating solutions shall conform to the following detailed requirements.

	New Material		Material In Use	
	Not Less Than	**Not More Than**	**Not Less Than**	**Not More Than**
2.1 Water, % by Volume	—	1.5	—	3.0
2.2 Matter Insoluble in Xylene, % by wt.	—	0.5	—	1.5
2.2 Specific Gravity at 38°C Compared to water at 15.5°C:				
2.31 Whole Creosote	1.070	—	1.070	—
2.32 Fraction 235-315 C	1.028	—	1.028	—
2.33 Fraction 315-355 C	1.100	—	1.100	—
2.4 Distillation: The distillate, % by wt. on a water free basis, shall be within the following limits:				
Up to 210 C	—	2.0	—	2.0
Up to 235 C	—	12.0	—	12.0
Up to 270 C	10	40	10	40
Up to 315 C	40	65	40	65
Up to 355 C	65	77	65	77

3.0 Tests to establish conformance with the foregoing requirements shall be made in accordance with the standard methods of the American Wood Preservers Association. (See Standard A1)

[1]American Wood-Preservers' Association Standard P1/P13-89 (This Standard is under the jurisdiction of AWPA Subcommittee P-2)

Section 7.5 Creosote-Petroleum Solution

This Section is to be renumbered 7.3 and replaced with the following:

7.3 CREOSOTE-PETROLEUM OIL SOLUTION[1]

Creosote-petroleum oil solution shall consist solely of specified proportions of coal tar creosote which meets A.W.P.A. Standard P1 and of petroleum oil which meets A.W.P.A. Standard P4. No creosote-petroleum oil solution shall contain less than 50 percent by volume of such creosote or more than 50 percent by volume of such petroleum oil*

[1]American Wood-Preservers' Association Standard P3-67

*Owing to the lack of suitable methods of analysis, it is not possible to determine the relative amounts of either component once these materials have been blended. The purchaser may, therefore, wish to consider obtaining the materials separately and having them blended under his supervision.

Section 7.6 Petroleum for Blending with Creosote

This Section will be renumbered to 7.4.

Section 7.7 Pentachlorophenol and Section 7.8 Copper Naphthenate

These Sections will be renumbered to 7.5 and 7.6 respectively. The closing words in the last sentence of new articles 7.5.4 and 7.6.5 will be revised to read ". . . the standards of the AWPA (See Standard P-9)."

Section 7.9 Solubilized Copper-8-Quinolinolate

This Section will be renumbered to 7.7.

Section 7.10 Hydrocarbon Solvent, Type A

This section will be renumbered 7.8. As follows Note 2 is to be revised and Note 4 is to be added.

Change Paragraph C in Note 2 to read "The co-solvent shall not induce leaching of pentachlorophenol from the total preservative blend as determined by the AWPA method in Standard A5, Paragraph 2. The amount of pentachlorophenol found in the test sample shall not be less than that found in the control."

Add Note 4 to read "When copper naphthenate is used, the penta solvency requirement in sub-section 7.8.4 may be deleted."

Sections 7.11 to 7.19

These Sections will be renumbered 7.9 to 7.16 respectively with Section 7.19 being deleted.

Section 7.20 pH of Treating Solutions

This section will be renumbered to 7.17 and the reference to FCAP in the listing of preservative solutions will be deleted.

PART 8 - METHODS OF TESTING PROPERTIES, VOLUME, PENETRATION, AND QUANTITY OF PRESERVATIVES, AND/OR MEASURING AND SAMPLING CREOSOTE

Section 8.1 Standard Volume Correction Table for Creosote-Petroleum Solutions

Table II on page 47 is to be added to Section 8.1.

8.2 Volume Correction for Temperature in the Measurement of Creosote.

This Section is to be replaced with the Table I on page 48.

PART 9—SPECIFICATIONS FOR TREATMENT

Section 9.4 Preservatives

Paragraph 9.4.2.4 is to be deleted.

Section 9.6 Methods of Determining Penetration in Wood Treated with Preservatives

Article 9.6.6 is to be deleted and 9.6.7 is to be renumbered to 9.6.6.

Section 9.8 Specific Requirements for Preservative Treatment by Pressure Processes

That portion of Table 1 concerning specified requirements for lumber, timbers, bridge ties, mine ties, piles, poles and posts will be replaced with new Table 1 requirements. Current requirements for treatment of cross and switch ties and glue laminated timbers will remain as now specified in Table 1.

A copy of the new Table 1 material is available from AREA headquarters by sending $2.00, and requesting a copy of Section 9.8, Table 1.

Table II - Factors to be Used for Determining The Specific Gravity at 100°F When Observed at Temperatures Ranging from 60° to 220°F.

Factors only apply to oil entirely free from crystals.

Observed Temp.		Add to Observed Specific Gravity		Observed Temp.		Add to Observed Specific Gravity		Observed Temp.		Add to Observed Specific Gravity		Observed Temp.		Subtract from Observed Specific Gravity	
°F	°C	Creosote	Solution	°F	°C	Creosote	Solution	°F	°C	Creosote	Solution	°F	°C	Creosote	Solution
220	104.4	.0491	.0481	180	82.2	.0326	.0319	140	60.0	.0161	.0158	99	37.2	.0004	.0004
219	103.9	.0487	.0477	179	81.7	.0322	.0315	139	59.4	.0157	.0154	98	36.7	.0008	.0008
218	103.3	.0483	.0473	178	81.1	.0318	.0311	138	58.9	.0153	.0150	97	36.1	.0012	.0012
217	102.8	.0479	.0469	177	80.6	.0314	.0307	137	58.3	.0149	.0146	96	35.6	.0016	.0016
216	102.2	.0475	.0465	176	80.0	.0309	.0303	136	57.8	.0145	.0142	95	35.0	.0020	.0020
215	101.7	.0471	.0460	175	79.4	.0305	.0298	135	57.2	.0141	.0138	94	34.4	.0024	.0023
214	101.1	.0467	.0456	174	78.9	.0301	.0294	134	56.7	.0137	.0134	93	33.9	.0028	.0027
213	100.6	.0462	.0452	173	78.3	.0297	.0290	133	56.1	.0133	.0130	92	33.3	.0032	.0031
212	100.0	.0458	.0448	172	77.8	.0293	.0286	132	55.6	.0129	.0126	91	32.8	.0036	.0035
211	99.4	.0454	.0444	171	77.2	.0289	.0282	131	55.0	.0125	.0122	90	32.2	.0040	.0039
210	98.9	.0450	.0440	170	76.7	.0284	.0278	130	54.4	.0121	.0118	89	31.7	.0043	.0043
209	98.3	.0446	.0436	169	76.1	.0280	.0274	129	53.9	.0117	.0114	88	31.1	.0047	.0047
208	97.8	.0442	.0432	168	75.6	.0276	.0270	128	53.3	.0113	.0110	87	30.6	.0051	.0051
207	97.2	.0438	.0428	167	75.0	.0272	.0266	127	52.8	.0109	.0106	86	30.0	.0055	.0055
206	96.7	.0434	.0424	166	74.4	.0268	.0262	126	52.2	.0105	.0102	85	29.4	.0059	.0058
205	96.1	.0430	.0420	165	73.9	.0264	.0258	125	51.7	.0101	.0098	84	28.1	.0063	.0062
204	95.5	.0426	.0416	164	73.3	.0260	.0254	124	51.1	.0097	.0094	83	28.3	.0067	.0066
203	95.0	.0422	.0412	163	72.8	.0256	.0250	123	50.6	.0093	.0090	82	27.8	.0071	.0070
202	94.4	.0418	.0408	162	72.2	.0252	.0246	122	50.0	.0089	.0087	81	27.2	.0075	.0074
201	93.9	.0413	.0404	161	71.7	.0248	.0242	121	49.4	.0084	.0083	80	26.7	.0079	.0078
200	93.3	.0409	.0400	160	71.1	.0244	.0238	120	48.9	.0080	.0079	79	26.1	.0083	.0082
199	92.8	.0405	.0396	159	70.6	.0239	.0234	119	48.3	.0076	.0075	78	25.6	.0087	.0086
198	92.2	.0401	.0392	158	70.0	.0234	.0230	118	47.8	.0072	.0071	77	25.0	.0091	.0090
197	91.7	.0397	.0388	157	69.4	.0230	.0226	117	47.2	.0068	.0067	76	24.4	.0095	.0094
196	91.1	.0392	.0384	156	68.9	.0226	.0222	116	46.7	.0064	.0063	75	23.7	.0099	.0097
195	90.6	.0388	.0379	155	68.3	.0222	.0218	115	46.1	.0060	.0059	74	23.3	.0103	.0101
194	90.0	.0384	.0375	154	67.8	.0218	.0214	114	45.6	.0056	.0055	73	22.8	.0107	.0105
193	89.4	.0380	.0371	153	67.2	.0214	.0210	113	45.0	.0052	.0051	72	22.2	.0111	.0109
192	88.9	.0375	.0367	152	66.7	.0210	.0206	112	44.4	.0048	.0047	71	21.7	.0115	.0113
191	88.3	.0371	.0363	151	66.1	.0206	.0202	111	43.9	.0044	.0043	70	21.1	.0118	.0117
190	87.8	.0367	.0359	150	65.6	.0202	.0198	110	43.3	.0040	.0039	69	20.6	.0122	.0121
189	87.2	.0363	.0355	149	65.0	.0198	.0194	109	42.8	.0036	.0035	68	20.0	.0126	.0124
188	86.7	.0359	.0351	148	64.4	.0194	.0190	108	42.2	.0032	.0031	67	19.4	.0130	.0128
187	86.1	.0355	.0347	147	63.9	.0189	.0186	107	41.7	.0028	.0027	66	18.9	.0134	.0132
186	85.6	.0351	.0343	146	63.3	.0186	.0182	106	41.1	.0024	.0023	65	18.3	.0138	.0136
185	85.0	.0347	.0339	145	62.8	.0182	.0178	105	40.6	.0020	.0020	64	17.8	.0142	.0140
184	84.4	.0343	.0335	144	62.2	.0177	.0174	104	40.0	.0016	.0016	63	17.2	.0146	.0144
183	83.9	.0339	.0331	143	61.7	.0173	.0170	103	39.4	.0012	.0012	62	16.7	.0150	.0148
182	83.3	.0334	.0327	142	61.1	.0169	.0166	102	38.9	.0008	.0008	61	16.1	.0154	.0152
181	82.8	.0330	.0323	141	60.6	.0165	.0162	101	38.3	.0004	.0004	60	15.5	.0158	.0155
								100	37.8	.0000	.0000				

*These factors ordinarily used for specific gravity correction are merely approximations, but these approximations are usually well within the limit of experimental error of the specific gravity limitations.

8.2 VOLUME AND SPECIFIC GRAVITY CORRECTION TABLES FOR CREOSOTE, CREOSOTE-COAL TAR SOLUTION (UP TO 50% TAR)[1]

Table 1 - Factors to Be Used for Determining the Volume at 100°F. Occupied by Unit Volume at Temperatures Ranging From 60° to 220°F.

Volume Correction Table

The observed volume is to be multiplied by the factor corresponding to the observed temperature. (Factors only apply to oil entirely free from crystals.)

Observed °F	Temp. °C	Correction Factor Creosote-Solution	Observed °F	Temp. °C	Correction Factor Creosote-Solution	Observed °F	Temp. °C	Correction Factor Creosote-Solution	Observed °F	Temp. °C	Correction Factor Creosote-Solution
220	104.4	.9554	179	81.7	.9702	139	59.4	.9851	99	37.2	1.0004
219	103.9	.9557	178	81.1	.9705	138	58.9	.9854	98	36.7	1.0008
218	103.3	.9561	177	80.6	.9709	137	58.3	.9858	97	36.1	1.0012
217	102.8	.9564	176	80.0	.9713	136	57.8	.9862	96	35.6	1.0016
216	102.2	.9568	175	79.4	.9716	135	57.2	.9866	95	35.0	1.0020
215	101.7	.9571	174	78.9	.9720	134	56.7	.9869	94	34.4	1.0024
214	101.1	.9575	173	78.3	.9724	133	56.1	.9873	93	33.9	1.0027
213	100.6	.9578	172	77.8	.9727	132	55.6	.9877	92	33.3	1.0031
212	100.0	.9582	171	77.2	.9731	131	55.0	.9881	91	32.8	1.0035
211	99.4	.9586	170	76.7	.9734	130	54.4	.9885	90	32.2	1.0039
210	98.9	.9589	169	76.1	.9738	129	53.9	.9888	89	31.7	1.0043
209	98.3	.9593	168	75.6	.9742	128	53.3	.9892	88	31.1	1.0047
208	97.8	.9596	167	75.0	.9746	127	52.8	.9896	87	30.6	1.0051
207	97.2	.9600	166	74.4	.9750	126	52.2	.9900	86	30.0	1.0055
206	96.7	.9604	165	73.9	.9753	125	51.7	.9904	85	29.4	1.0059
205	96.1	.9607	164	73.3	.9757	124	51.1	.9908	84	28.9	1.0063
204	95.5	.9611	163	72.8	.9761	123	50.6	.9911	83	28.3	1.0068
203	95.0	.9614	162	72.2	.9764	122	50.0	.9915	82	27.8	1.0071
202	94.4	.9618	161	71.7	.9768	121	49.4	.9919	81	27.2	1.0075
201	93.9	.9622	160	71.1	.9772	120	48.9	.9923	80	26.7	1.0078
200	93.3	.9625	159	70.6	.9775	119	48.3	.9927	79	26.1	1.0083
199	92.8	.9629	158	70.0	.9779	118	47.8	.9930	78	25.6	1.0086
198	92.2	.9633	157	69.4	.9783	117	47.2	.9934	77	25.0	1.0090
197	91.7	.9636	156	68.9	.9787	116	46.7	.9938	76	24.4	1.0095
196	91.1	.9640	155	68.3	.9791	115	46.1	.9942	75	23.9	1.0098
195	90.6	.9643	154	67.8	.9794	114	45.6	.9946	74	23.3	1.0102
194	90.0	.9647	153	67.2	.9798	113	45.0	.9950	73	22.8	1.0106
193	89.4	.9651	152	66.7	.9801	112	44.4	.9954	72	22.2	1.0110
192	88.9	.9654	151	66.1	.9805	111	43.9	.9957	71	21.7	1.0114
191	88.3	.9658	150	65.6	.9809	110	43.3	.9961	70	21.1	1.0118
190	87.8	.9661	149	65.0	.9813	109	42.8	.9965	69	20.6	1.0122
189	87.2	.9665	148	64.4	.9817	108	42.2	.9969	68	20.0	1.0126
188	86.7	.9669	147	63.9	.9820	107	41.7	.9973	67	19.4	1.0130
187	86.1	.9672	146	63.3	.9824	106	41.1	.9977	66	18.9	1.0134
186	85.6	.9676	145	62.8	.9828	105	40.6	.9980	65	18.3	1.0138
185	85.0	.9680	144	62.2	.9832	104	40.0	.9984	64	17.8	1.0142
184	84.4	.9683	143	61.7	.9835	103	39.4	.9989	63	17.2	1.0146
183	83.9	.9687	142	61.1	.9839	102	38.9	.9992	62	16.7	1.0150
182	83.3	.9691	141	60.6	.9843	101	38.3	.9996	61	16.1	1.0154
181	82.8	.9694	140	60.0	.9847	100	37.8	1.000	60	15.5	1.0159
180	82.2	.9698									

[1]American Wood Preservers Association Standard F1-89.

Proposed 1991 Manual Revisions To Chapter 4 - Rail

For the reasons provided it is proposed to make the following changes to Parts 1 and 2 of Chapter 4. The changes proposed for Parts 1 and 2 are described, and if applicable, detailed after the summary.

Part 1—Design

i) Delete 90 ARA-A and 100 RE rail sections and corresponding splice bars. Statistics show demand for new rail in those sections is vanishing and members feel that they are too light for present day speeds and axle loads in primary lines where new rail is used. Demand for lighter rail is being filled by second hand rail.

ii) Show recomputed physical properties and exact unit weights of current 115, 119, 132, 133, 136 and 140 RE rail sections using modern computer techniques. Now that CAD techniques are available it had become evident that old hand computed values were in error by various amounts. Also, lateral moment of inertia, lateral section modulus, height of shear center and torsional rigidity dimensional properties were added, to meet demand for these numbers for modern analytical techniques.

iii) Delete old designs for head contact bars as demand for these is minimal for modern rail sections with generous head-web fillet radii. Also, change bar designs to those for which rolls are currently available in North America so when customers specify bars to AREA drawings they will be able to get them.

iv) Change splice bar punching and specified bolt size for 132, 136 and 140 RE from 1″ to 1-1/8″ to correspond with what the railroad industry in fact is using and intends to continue to use for those sections.

v) Add splice bar drawings and bar punching drawings and specifications for 133 RE. Unlike other heavy section bars, these bars have been standardized at 38 inches long with one inch bolts to correspond with what the industry is using in that section.

New Rail Dimensional Properties Calculated

115RE:

1.	Rail Area (sq. in.)	Head	4.03
		Web	2.80
		Base	4.42
		Whole Rail	11.25
2.	Rail Weight (lbs/yd)		114.7
3.	Moment of Inertia about the neutral axis		65.9
4.	Section modulus of the head		18.1
	Section modulus of the base		22.0
5.	Height of neutral axis above base		3.00
6.	Lateral moment of inertia		10.7
7.	Lateral section modulus of the head		7.90
	Lateral section modulus of the base		3.90
8.	Height of shear center above base		1.45
9.	Torsional rigidity is 'KG' where G is the modulus is rigidity & K = (error for K greater than 10%)		4.69

119 RE:

1.	Rail Area (sq. in.)	Head	4.42
		Web	2.80
		Base	4.42
		Whole Rail	11.64
2.	Rail Weight (lbs/yd)		118.7
3.	Moment of Inertia about the neutral axis		71.4
4.	Section modulus of the head		19.4
	Section modulus of the base		22.8
5.	Height of neutral axis above base		3.13
6.	Lateral moment of inertia		10.8
7.	Lateral section modulus of the head		8.16
	Lateral section modulus of the base		3.94
8.	Height of shear center above base		1.51
9.	Torsional rigidity is 'KG' where G is the modulus is rigidity & K = (error for K greater than 10%)		5.11

132 RE:

1.	Rail Area (sq. in.)	Head	4.53
		Web	3.35
		Base	5.03
		Whole Rail	12.91
2.	Rail Weight (lbs/yd)		131.7
3.	Moment of Inertia about the neutral axis		87.9
4.	Section modulus of the head		22.4
	Section modulus of the base		27.4
5.	Height of neutral axis above base		3.20
6.	Lateral moment of inertia		14.4
7.	Lateral section modulus of the head		9.57
	Lateral section modulus of the base		4.79
8.	Height of shear center above base		1.57
9.	Torsional rigidity is 'KG' where G is the modulus is rigidity & K = (error for K greater than 10%)		5.31

133 RE:

1.	Rail Area (sq. in.)	Head	4.85
		Web	3.20
		Base	5.02
		Whole Rail	13.07
2.	Rail Weight (lbs/yd)		133.4
3.	Moment of Inertia about the neutral axis		86.2
4.	Section modulus of the head		22.3
	Section modulus of the base		26.9
5.	Height of neutral axis above base		3.20
6.	Lateral moment of inertia		14.4
7.	Lateral section modulus of the head		9.62
	Lateral section modulus of the base		4.81

8.	Height of shear center above base		1.57
9.	Torsional rigidity is 'KG' where G is the modulus is rigidity & K = (error for K greater than 10%)		5.69

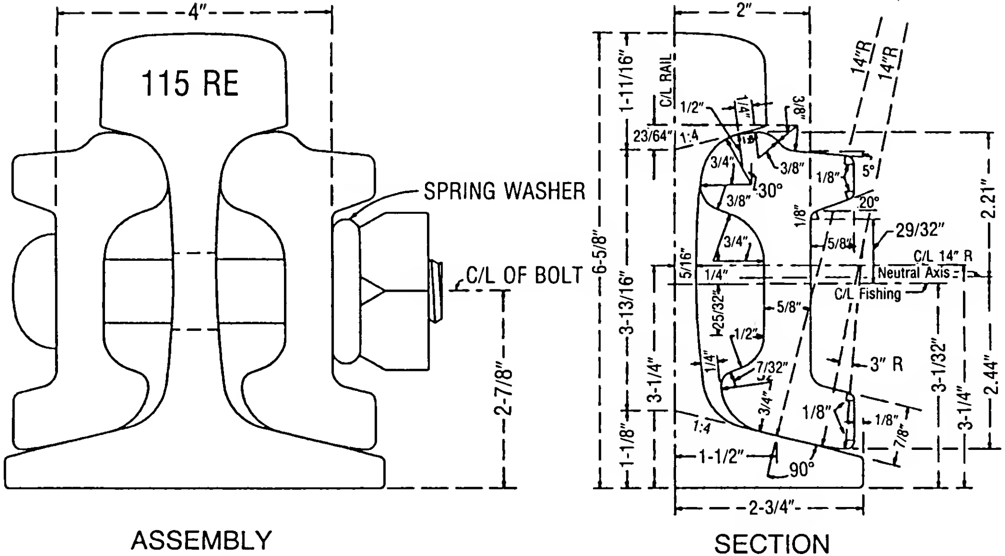
136 RE:

1.	Rail Area (sq. in.)	Head	4.98
		Web	3.39
		Base	5.01
		Whole Rail	13.38
2.	Rail Weight (lbs/yd)		136.4
3.	Moment of Inertia about the neutral axis		95.0
4.	Section modulus of the head		24.0
	Section modulus of the base		28.3
5.	Height of neutral axis above base		3.36
6.	Lateral moment of inertia		14.5
7.	Lateral section modulus of the head		9.88
	Lateral section modulus of the base		4.84
8.	Height of shear center above base		1.65
9.	Torsional rigidity is 'KG' where G is the modulus is rigidity & K = (error for K greater than 10%)		6.24

140 RE:

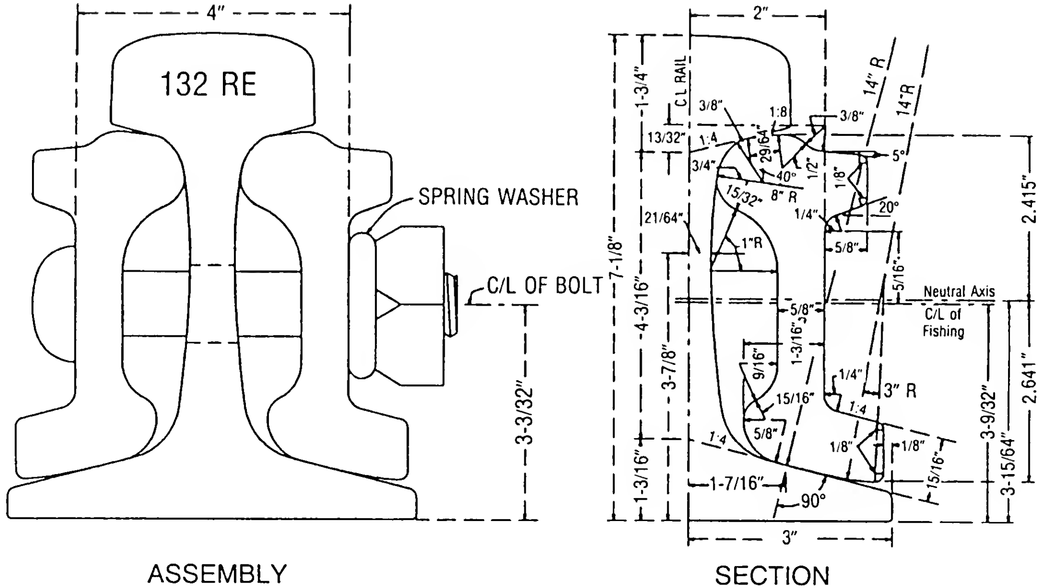
1.	Rail Area (sq. in.)	Head	5.21
		Web	3.44
		Base	5.04
		Whole Rail	13.69
2.	Rail Weight (lbs/yd)		139.6
3.	Moment of Inertia about the neutral axis		95.9
4.	Section modulus of the head		24.3
	Section modulus of the base		28.6
5.	Height of neutral axis above base		3.36
6.	Lateral moment of inertia		14.9
7.	Lateral section modulus of the head		9.95
	Lateral section modulus of the base		4.98
8.	Height of shear center above base		1.67
9.	Torsional rigidity is 'KG' where G is the modulus is rigidity & K = (error for K greater than 10%)		6.85

PROPOSED JOINT BAR DESIGNS AND DETAILS FOR 115, 119, 132, 133 AND 140 RE RAILS. (on following pages)



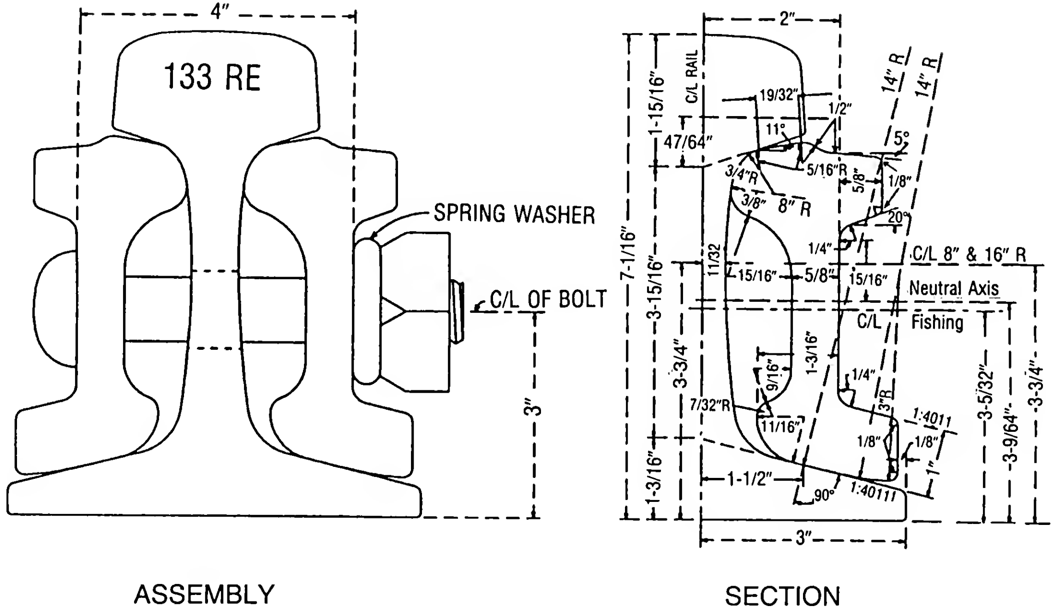
Physical Properties		One Bar	Two Bars
Moment of inertia in.^{4}		11.67	23.34
Section Modulus	Above n. a. in.^{3}	5.27	10.54
	Below n. a. in.^{3}	4.77	9.54
Area sq. in.		5.35	10.70
Net weight, 24-in. length, lb.		35.28	70.56
Net weight, 36-in. length, lb.		53.45	106.90

Fig. 1—Joint bar and assembly for 115 RE and 119 RE rail (115 RE shown)



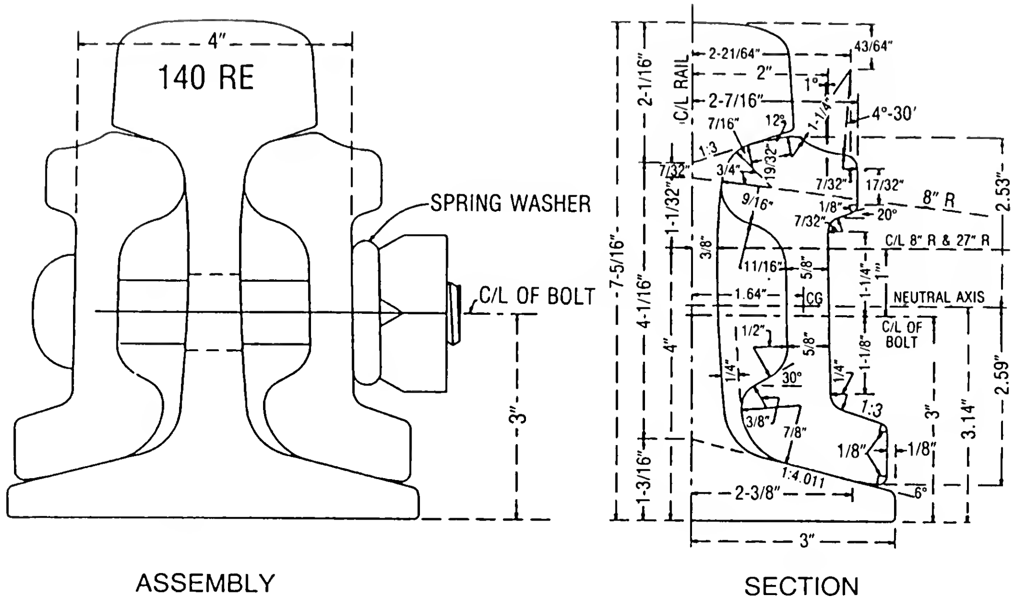
Physical Properties	One Bar	Two Bars
Moment of inertia in.^{4}	16.14	32.28
Section Modulus — Above n. a. in.^{3}	6.68	13.36
Section Modulus — Below n. a. in.^{3}	6.11	12.22
Area sq. in.	5.89	11.78
Net weight, 24-in. length, lb.	38.95	77.90
Net weight, 36-in. length, lb.	58.95	117.90

Fig. 2—Joint bar and assembly for 132 RE and 136 RE rail (132 RE shown)



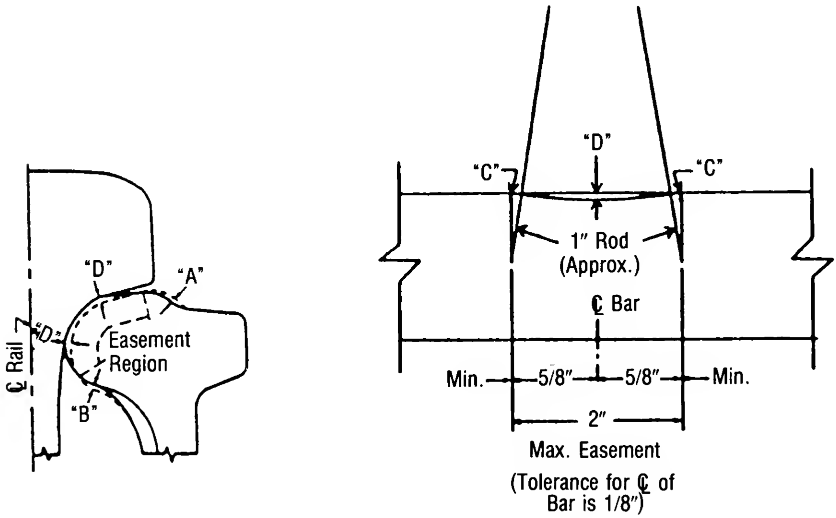
Physical Properties	One Bar	Two Bars
Moment of inertia in.^{4}	15.13	30.26
Section Modulus — Above n. a. in.^{3}	6.41	12.82
Section Modulus — Below n. a. in.^{3}	5.9	11.8
Area sq. in.	5.83	11.66
Net weight, 24-in. length, lb.	38.56	77.12
Net weight, 38-in. length, lb.	61.66	123.32

Fig. 3—Joint bar and assembly for 133 RE rail



Physical Properties		One Bar	Two Bars
Moment of inertia in.^{4}		15.94	31.9
Section Modulus	Above n. a. in.^{3}	6.30	12.6
	Below n. a. in.^{3}	6.15	12.3
Area sq. in.		5.98	11.96
Net weight, 24-in. length, lb.		39.9	79.8
Net weight, 36-in. length, lb.		59.9	119.7

Fig. 4—Joint bar and assembly for 140 RE rail



PART SECTION PART ELEVATION

NOTES

1. "D" 1/32″ min. for Rail Sections 119 lb. and less; and 3/64″ min. for Rail Sections over 119 lb.
2. Maximum displacement of "A" and "B" is 3/32″.
3. Deformation due to flow of material at points "C" may be in addition to easement width.

HEAD FREE JOINT BAR

Fig.5—Recommended head easement for joint bars.

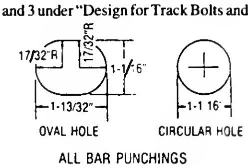
[1]RAIL DRILLINGS, BAR PUNCHINGS AND BOLTS

Table 1—Recommended Rail Drillings, Bar Punchings and Track Bolts for 115RE, 119RE, 132RE, 133RE, 136RE and 140RE Rails and Joint Bars

	Dimensions in inches			
	115 RE and 119 RE	133 RE	132 RE and 136 RE	140 RE
Rail Drillings				
a	2-7/8	3	3-3/32	3
b	3-1/2	3-1/2	3-1/2	3-1/2
c	6	6	6	6
d*	6	6	6	6
Bar Punchings				
24-in. 4-Hole Bar				
e	7-1/8	7-1/8	7-1/8	7-1/8
f	6	6	6	6
g	2-7/8	2-7/16	2-7/16	2-7/16
6-Hole Bar				
h	7-1/8	7-1/8	7-1/8	7-1/8
i	6	6	6	6
j	6	6	6	6
k	2-7/16	3-7/16	2-7/16	2-7/16
m	36	38	36	36
Track Bolt				
D	1	1	1-1/8	1-1/8
L	6	6	6	6
I	2-1/4	2-1/4	2-1/4	2-1/4

[1] See Figs. 1 and 2 for bar punching and rail drillings and Figs. 1, 2 and 3 under "Design for Track Bolts and Nuts," for dimensions of track bolts and nuts.

*This drilling to be omitted for 4-hole bars



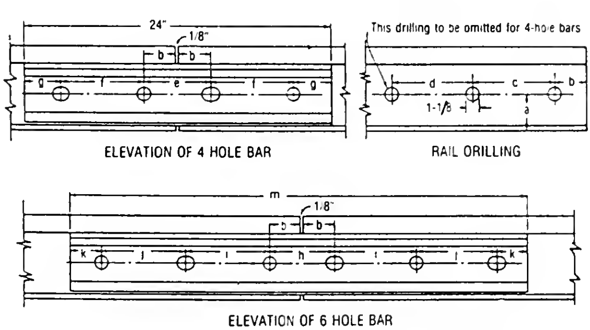


Fig. 1—Recommended rail drillings and bar punchings for 115RE, 119RE and 133RE, utilizing 1" track bolts.

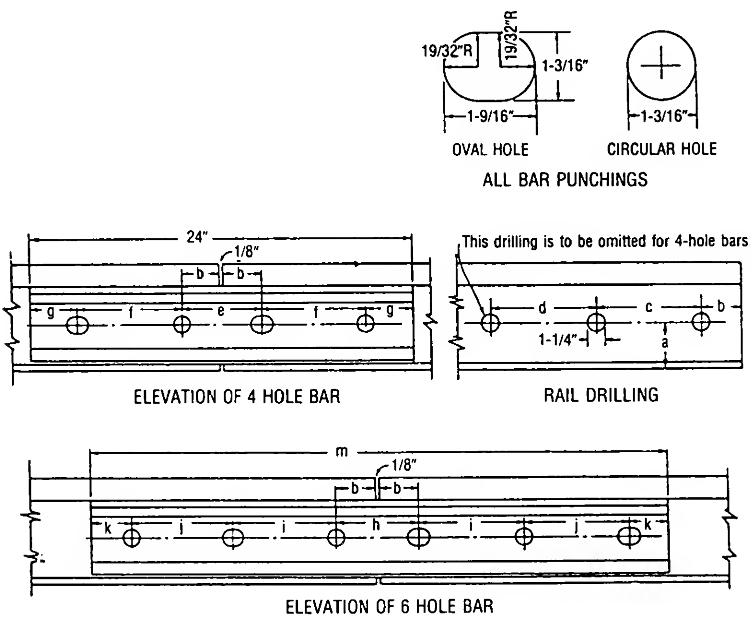


Fig. 2—Recommended rail drillings and bar punchings for 132RE, 136RE and 140RE rails and joint bars, utilizing 1-1/8" bolts.

Part 2—Specifications

i) Delete sheets 4-2-7 and 4-2-8, "Specifications for Drop Test Machine, 1961," in their entirety. The drop test was deleted from the AREA Specification for rails two years ago, being replaced by the present section 9, "Interior Condition/Macroetch Standards." Consensus is that with introduction of macroetch standards there is no further need for the drop test; and if the drop test is no longer being done there is no longer any need to specify a machine to do it with.

Proposed 1991 Manual Revisions To Chapter 6 — Buildings and Support Facilities

Proposed new Chapter 6 material includes a rewritten Part 2—Design Criteria for Railway Office Buildings, a new Part 5—Energy Conservation and Audits and a new Part 11—Design Criteria for CTC Centers. The new Part 11 appears on the following pages 59 to 61. Copies of the new Part 2 and Part 5 may be obtained by writing AREA Headquarters and enclosing $2.00 for each copy requested.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Part 11

Design Criteria for CTC Centers

11.1 FOREWORD

11.1.1 A centralized dispatching facility houses Centralized Traffic Control (CTC) equipment and the personnel to operate and maintain it. In its broadest sense, CTC is the control center of a transportation network. It monitors, directs, and controls all train operations, while keeping in almost constant communication with every activity in its territory. We will be mainly concerned with the building that houses this "Nerve Center."

11.1.2 Basic design preparation begins with ascertaining the proposed method of operation of the particular facility. A detailed design program must be prepared with major input from the Operations, Signal and Communications Departments. Since the communication network required is very extensive, it is often decided to include other functions at this location. These other functions may include crew management, locomotive dispatching and car distribution. These departments provide design criteria in the development of the design program.

11.2 SITE CONSIDERATIONS

11.2.1 The facility location is determined by the particular circumstances of the territory to be served and the signal communication systems to be used. A sophisticated data link may permit the facility to be far removed. A simpler arrangement using cable connections may require that the facility be within a prescribed distance. The concerns relative to location must include availability of an ultra reliable power supply, soil stability, highway accessibility, protectable area, adequate parking space, drainage, sanitary sewer and water systems.

11.3 EQUIPMENT

11.3.1 Control consoles may be hardwired pushbutton, stylus select device CRT, or keypad CRT or any combination of those types.

(a) Hardwired pushbutton: This rather conventional system is best described as one large console (or several smaller consoles) which present a schematic of the territory to be controlled, with pushbuttons located at strategic points on the schematic which define the entrance and exit locations used for route control. In addition there exists a separate matrix of unit lever type switches (either toggle or lever type) which can force switch position in the NX mode, and provide unit lever capability.

(b) Stylus select device CRT: This term applies to a color monitor with an SSD overlay on the face of the monitor which responds to either pressure or the intersection of infrared light beams which produce a signal to activate a device. Each CRT presents a schematic or a portion of the territory to be controlled. Sensitized areas called "Poke points" are located at strategic places on the schematic. These "Poke points" are poked with a stylus in order to effect NX control. Since only a portion of the controlled territory can be displayed on a CRT, a "Search and scroll" function is necessary to first "Call up" the location to be controlled. An alternative to the "Search and scroll" technique is to have a bank of CRT's in sufficient number to cover the entire controlled territory . . .

(c) Keypad/CRT: This term applies to a color monitor which is linked to a function type keypad device which is used to enter entrance/exit type commands for route control. The CRT presents a schematic of a portion of the territory to be controlled, and as commands are entered on the keypad the CRT dynamically indicates field conditions. A "Search and scroll" function is also necessary with this system.

11.3.2 Overview displays include the following types multiple CRT's, mneumonic wallboards and projected overviews.

(a) Multiple CRT's: These provide only a limited overview in that they cannot be read from a distance. They are usually clustered around each dispatcher, with each screen showing a particular territory.

(b) Hardwired mneumonic wallboards: These are either a mosaic or phenolic type schematic display of the controlled territory which employs lighted track segments, and defines switch and signal indications by use of colored light bulbs.

(c) Projected overview: This system uses a series of projection units to project the schematic of the controlled territory on a series of large screens. Dynamic indications of switch, signal and train status are conveyed through the use of colors, changes of color and also shapes and images of field apparatus. Projection can be from front or rear.

11.3.3 Auxiliary functions which may be performed at this same location are listed in the following.

(a) Crew calling/dispatching
(b) Passenger information systems
(c) Telecommunications control
(d) Motive power control and assignments
(e) Hot box monitoring
(f) Television train consist monitoring if the facility is in a yard location.
(g) Facility security

11.4 FUNCTIONAL REQUIREMENTS

11.4.1 Supervisory offices will include private offices for the chief and assistant chief dispatchers frequently overlooking the dispatchers and the display.

11.4.2 Relay racks and computer equipment should be housed in computer room environment space. Close control of temperature and humidity combined with a relatively dust free atmosphere ensures optimum operation and life for electronic gear.

11.4.3 Service spaces should include a technician's room for minor repairs and equipment monitoring. Wall display systems require sufficient space behind the display to permit service and adjustment of the equipment.

11.4.4 The location within the building of the dispatchers space ideally is in the central core since this space should be without windows and be well insulated thermally and sonically. The electronic equipment and associated power conditioning units are best located remote from the dispatchers for isolation of the noise and heat generated by this gear.

11.4.5 Locker facilities for each individual should be provided in a space easily accessible to the dispatching theater.

11.4.6 Lunch room with microwave ovens, refrigerator, kitchen sink, coffee maker, storage cabinets and vending machines is required.

11.4.7 Smoking lounge may be required if the theater area is made a non-smoking area as recommended.

11.5 SUPPORT SYSTEMS

11.5.1 Lighting is required to be of low intensity for general area with hidden light source to minimize reflections. Dimmer control of general lighting is essential. Task lighting must be tightly controlled beams with dimmer control of intensity. The use of indirect lighting with long life low maintenance sources is most practical in the dispatchers room. Lighting in the other spaces has no special requirement although use of long life low maintenance sources is very practical to minimize security risk of frequent required service.

11.5.2 Communications by the dispatchers creates certain acoustical problems which require a compromise. Radio contact with trains usually brings a noisy atmosphere into the space with a great deal of cross talk and some static. Headphones are a solution to the problem but that affects the viability of alarm sounds used in conjunction with the overview display.

11.5.3 HVAC systems in the computer and technician spaces should be the computer room type with a downflow air distribution using the access floor space as a supply air plenum. Conditions in this space should be designed to 72 FDB and 50% relative humidity. Systems in the dispatcher area should be designed to normal office standards with zone control to permit some individual temperature control. Draft conditions in these areas must be carefully controlled since these individuals must remain at fixed positions for extended time periods. Fresh air supply should be brought in through the HVAC equipment and filtered to limit dust. Adequate exhaust and some air purification through activated carbon filters should be given consideration in the design. Redundant HVAC equipment is essential for both reliable operation and for routine maintenance of equipment during system operation since downtime is not available.

11.5.4 Fire protection is an absolute requirement with the detection system being of paramount importance. Halon fire suppression is the current best system for electronic equipment areas. Individual ABC extinguishers should be provided at each console and in service spaces. Water sprinkler systems should be avoided if the code permits, since the equipment being protected will usually be destroyed by the water damage. Ionization type detectors should be installed using a cross zone plan to trigger halon discharge. An annunciator panel with mimic board should be installed to indicate actual location of any sensor in alarm. Abort switches to prevent an unnecessary halon discharge should be provided in a central location.

11.5.5 Wiring spaces and routes to consoles and displays from the computer should be through a raised access floor system. Signal and communication cable should enter the building through a splicing chamber. If the entrance is remote from the computer room, an access floor route is preferred for cable runs. Lacking an access floor system cable horizontal runs should be in oversized cable tray run overhead. Power wiring should be shielded cable or in metal conduit.

11.5.6 Uninterruptible power supply (UPS) is required for computers and communications as well as any other critical real time process being powered by the electrical system. Redundant power supplies are essential to reliable operation and may consist of standby generators, batteries and multiple primary power sources from the utility company. A typical UPS system should have 20 minutes of battery backup with an emergency generator sized to carry the battery charger, air conditioning and lighting systems. The fuel storage supply should be capable of sustaining full load generator operation for a three day minimum.

11.6 ROOM FINISHES

11.6.1 The console room or dispatchers space should have acoustical absorption on all surfaces; e.g. anti-static carpet tiles over raised access floor, carpet or sound soak type material on walls and acoustical ceiling tile. Non-reflective colors should be considered for all surfaces to reduce glare.

11.6.2 The computer room and technician's room should have hard smooth non-dusting surfaces; e.g. laminated plastic tiles for raised access floor, painted or vinyl covered dry wall and vapor barrier ceilings. Sub floor must be sealed against dusting and vapor dispersion.

11.6.3 The UPS and battery room should have light colored acid resistant finishes on the floor and walls.

11.6.4 The offices need no special finishes although the sound absorption wall and ceiling treatments in the dispatchers room are frequently carried over into the offices.

Proposed 1991 Manual Revisions To Chapter 8 - Concrete Structures and Foundations

Proposed revisions to Part 1—Materials, Tests and Construction Requirements include definitions to be added to Article 1.1.3, revised wording for Article 1.1.6 and the addition of Article 1.5.4. Specifically the revisions are:

Article 1.1.3 Definitions

Add the following new definitions:

ACI. American Concrete Institute, 22400 West Seven Mile Road, Detroit, Michigan 48219, a nonprofit organization which is dedicated to serving the users interests in the areas of concrete design, construction, and maintenance through information provided in its publications and seminars that will extend and improve the use of concrete in construction.

ASTM. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, founded in 1898, is a scientific and technical organization formed for "the development of standards on characteristics and performance of materials, products, systems, and services; and the promotion of related knowledge."

Chemical Resistance. The ability of the material to resist attack by chemicals such as caustics, chlorides or acids (e.g. salt or diesel fuel).

Coefficient of Thermal Expansion. Change in linear dimension per unit length or change in volume per unit volume per degree of temperature change.

Compressive Strength. The compressive stress which a material is capable of sustaining as measured in psi.

Concrete Curing Compound. A chemical compound which is applied to a concrete surface to prevent the loss of moisture during early stages of cement hydration.

Cyclopean Concrete. Mass concrete in which large individual aggregate each of 100 pounds or more are placed and embedded as concrete is deposited.

Expansion Joint. A joint or dimensional gap between adjacent parts of a building, structure or concrete work which permits relative movement due to temperature changes (or other conditions) without rupture or damage.

Fineness Modulus. The sum of the total percentages coarser in the sieve analysis (using square mesh sieves in the Tyler or U.S. series, not including half sizes) divided by 100.

Honeycomb Concrete. Concrete with voids due to failure of mortar to fill effectively the spaces around coarse aggregate particles.

Laitance. A thin layer of weak nondurable material containing cement and fines which is brought to the surface of freshly placed concrete by bleeding of water.

Plans. The drawings and specifications prepared and approved by the Engineer.

Sieve. A screening device with uniform openings used to separate aggregate particles according to size.

Sieve Analysis. A determination of the proportions of particles lying within certain size ranges in a granular material by separation on sieves of different size openings.

Sieve Number. A number used to designate the size of a sieve, usually the approximate number of sieve openings per linear inch.

Slump. A measure of freshly mixed concrete or mortar; equal to the decrease in height, measured to the nearest 1/4", of the molded mass immediately after the removal from the slump cone.

Slump Cone. A mold in the form of the frustum of right circular cone with a base diameter of 8 inches, a top diameter of 4 inches and a height of 12 inches used to fabricate a specimen of freshly mixed concrete. A similar mold that is 6 inches high is used to fabricate a specimen of freshly mixed mortar.

Soundness. The freedom of a solid from cracks, flaws, fissures, or variations from an accepted standard; in the case of a cement, freedom from excessive volume change after setting; in the case of aggregate, the ability to withstand the aggressive action to which concrete containing it might be exposed, particularly that due to weather.

Temperature Sticks. Calibrated crayons that melt at a predetermined temperature.

Water Absorption. The amount of water absorbed by a material after immersion for a prescribed period of time. Expressed as a percentage of the original weight of the material.

Article 1.1.6 Selection of Materials

Revise the first sentence to read:

The concrete materials shall be selected for strength, durability and chemical resistance and combined in such a manner as to produce uniformity of color and texture in the surface of any structure or group of structures in which they are to be used.

Article 1.5.4 Bending and Straightening

Add this new article with the following text:

Reinforcement bars shall only be fabricated in accordance with Article 1.9.2 and Part 2, Article 2.4.2. Field bending and straightening of partially embedded bars shall be done only in accordance with the Plans or as permitted by the Engineer.

Proposed 1991 Manual Revisions To Chapter 10 - Concrete Ties

Substantive changes proposed for Chapter 10 include the addition of specifications for 7′9″ ties and deletion of material in the commentary concerning the ballast reaction with concrete ties. The proposed changes to the articles are:

Article 1.1.2.2

Change last paragraph to read as follows:

These specifications cover tie designs between 7 ft. 9 inches and 9 ft. 0 inches in length and between 8 inches and 13 inches in width at their bottom surface. Because of bond transfer, pretensioned concrete ties shall be at least 8 ft. 0 inches long unless additional provisions are made to ensure adequate bond transfer.

Article 1.3.2.1

Revise to read as follows:

The overall nominal length of prestressed concrete ties shall not exceed 9 ft. 0 inches exclusive of prestressing tendons. The nominal length shall not be less than 7 ft. 9 inches and 8 ft. 0 inches for post-tensioned and pretensioned concrete ties, respectively. A tolerance of plus or minus 1/4 inch from nominal length is permitted.

Article 1.4.1.1

Revise first paragraph to read as follows:

Figure 1.4.1.1 gives the unfactored positive bending moment at the centerline of the rail seat for tie length of 7′-9″, 8′-0″, 8′-6″, and 9′-0″ for various tie spacings.

Figure 1.4.1.1

Revise to include a line for Tie Length 7′-9″ as shown.

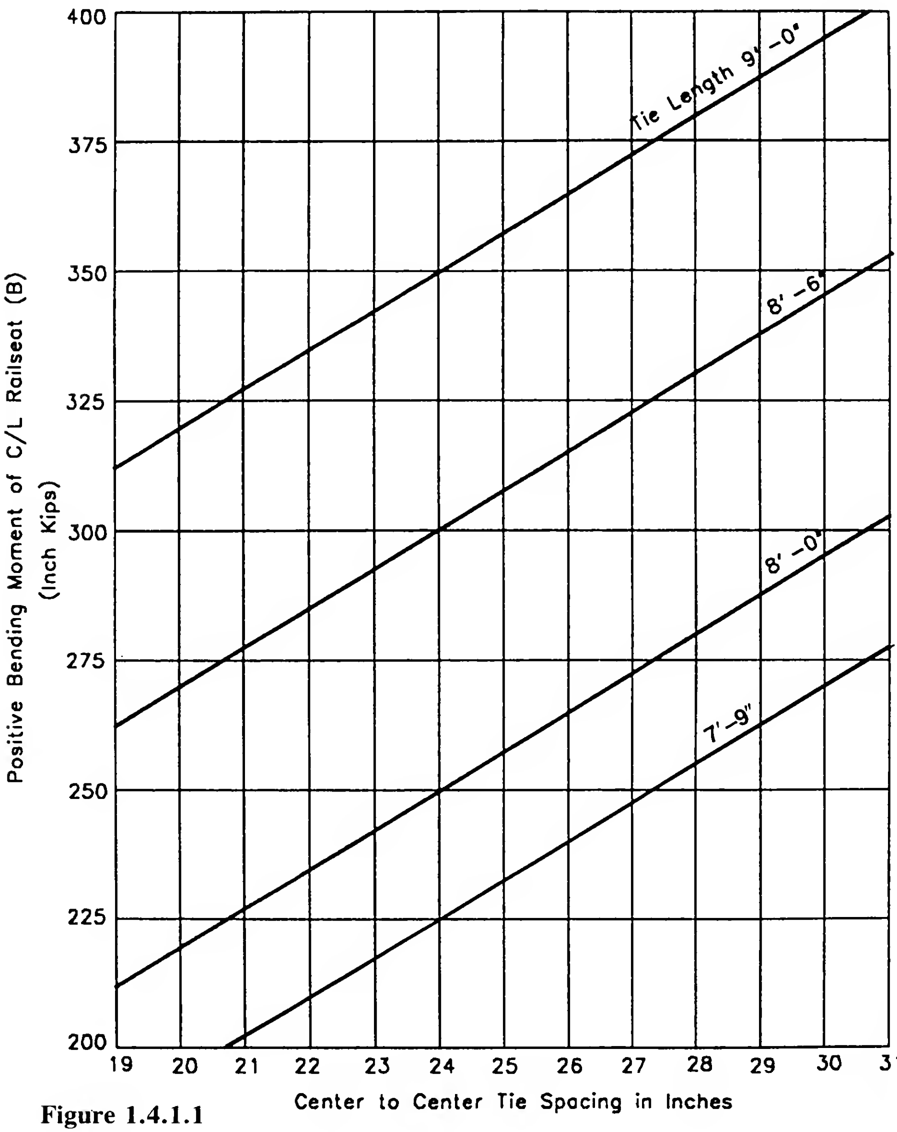


Figure 1.4.1.1

Article 1.4.1.2

In the table listing factors for rail seat negative, center negative, and center positive moments for different tie lengths, insert the following as the first line in the table:

7′-9″	0.72M	1.13M	0.61M

Article 1.13.1.3

Delete the last portion of the article starting with the last sentence of the second paragraph.

Article 1.13.2.1

Delete the entire article except for the first sentence.

Article 1.2.2.6 (to be added)

1.2.2.6 Durability

Consideration shall be given to concrete ingredients and properties that affect the durability of concrete ties. These include alkalai-aggregate reaction, freezing and thawing damage, air-entraining agents and other admixtures, sulfate and chemical reactions, as well as concrete tie manufacturing process.

Proposed 1991 Manual Revisions To Chapter 12 - Rail Transit

The diagram recommended for third rail clearances is referred to in Chapter 33 - Electrical Energy Utilization and was formerly published in Chapter 28 - Clearances. The third rail diagram is now the responsibility of Committee 12 - Rail Transit and is proposed to be added to Chapter 12 material as shown on page 66.

THIRD-RAIL TERRITORY

NOTE 1 – THE THIRD RAIL HAS TWO LOCATIONS, ONE LOCATION AS SHOWN WITH SOLID LINES FOR TANGENTS AND CURVES NOT EXCEEDING 7°–10'. THE SECOND LOCATION FOR SWITCHES AND CURVES EXCEEDING 7°–10', SHOWN IN DASH LINES.

NO PART OF THE THIRD-RAIL STRUCTURE OR TRAIN CONTROL IN THIRD-RAIL TERRITORY SHALL PROJECT BEYOND THE THIRD-RAIL CLEARANCE LINES HT-GT-FT-AT-BT-CT-DT-ET-JT-KT-LT, EXCEPT ON SWITCHES AND CURVES EXCEEDING 7°–10', USE THE DASH CLEARANCE LINES H'T'-G'T'-F'T'-A'T'-B'T'-C'T'.

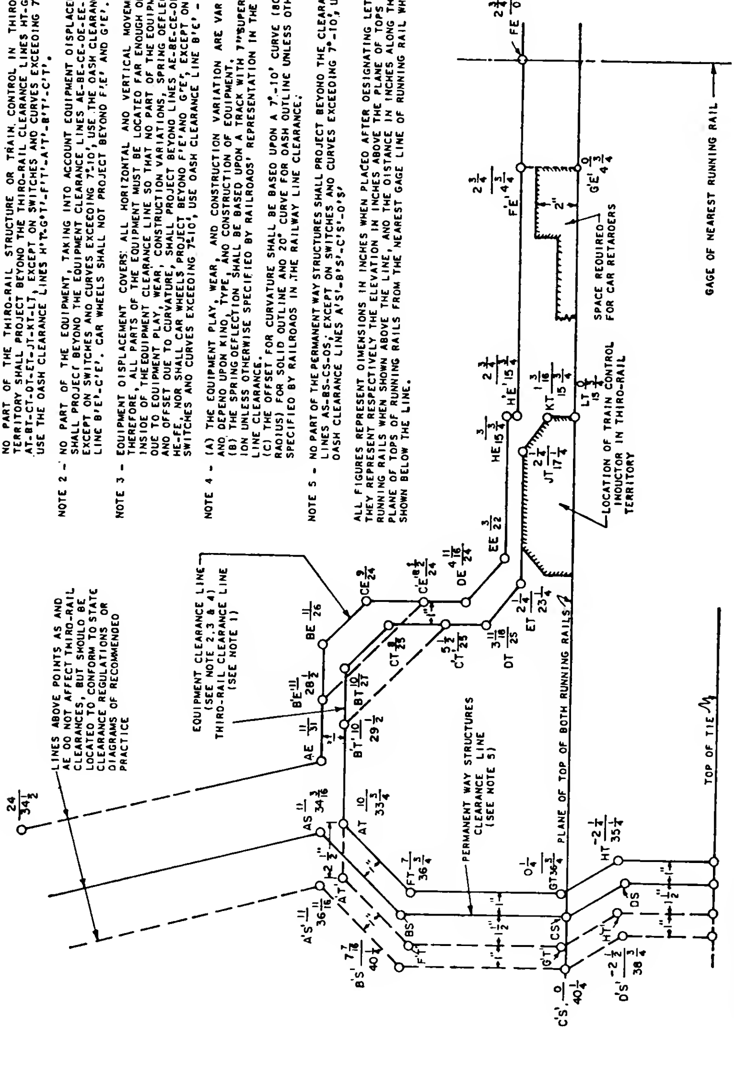
NOTE 2 – NO PART OF THE EQUIPMENT, TAKING INTO ACCOUNT EQUIPMENT DISPLACEMENT, SHALL PROJECT BEYOND THE EQUIPMENT CLEARANCE LINES AE-BE-CE-DE-EE-HE-FE, EXCEPT ON SWITCHES AND CURVES EXCEEDING 7°–10', USE THE DASH CLEARANCE LINE B'E'-C'E'. CAR WHEELS SHALL NOT PROJECT BEYOND F'E' AND G'E'.

NOTE 3 – EQUIPMENT DISPLACEMENT COVERS: ALL HORIZONTAL AND VERTICAL MOVEMENT. THEREFORE, ALL PARTS OF THE EQUIPMENT MUST BE LOCATED FAR ENOUGH ON THE INSIDE OF THE EQUIPMENT CLEARANCE LINE SO THAT NO PART OF THE EQUIPMENT, DUE TO EQUIPMENT PLAY, WEAR, CONSTRUCTION VARIATIONS, SPRING DEFLECTION, AND OFFSET DUE TO CURVATURE, SHALL PROJECT BEYOND LINES AE-BE-CE-DE-EE-HE-FE, NOR SHALL CAR WHEELS PROJECT BEYOND F'E' AND G'E', EXCEPT ON SWITCHES AND CURVES EXCEEDING 7°–10', USE DASH CLEARANCE LINE B'E' – C'E'.

NOTE 4 – (A) THE EQUIPMENT PLAY, WEAR, AND CONSTRUCTION VARIATION ARE VARIABLE AND DEPEND UPON KIND, TYPE, AND CONSTRUCTION OF EQUIPMENT.
(B) THE SPRING DEFLECTION SHALL BE BASED UPON A TRACK WITH 7" SUPERELEVATION UNLESS OTHERWISE SPECIFIED BY RAILROADS' REPRESENTATION IN THE RAILWAY LINE CLEARANCE.
(C) THE OFFSET FOR CURVATURE SHALL BE BASED UPON A 7°–10' CURVE (800' RADIUS) FOR SOLID OUTLINE AND 20° CURVE FOR DASH OUTLINE UNLESS OTHERWISE SPECIFIED BY RAILROADS IN THE RAILWAY LINE CLEARANCE.

NOTE 5 – NO PART OF THE PERMANENT WAY STRUCTURES SHALL PROJECT BEYOND THE CLEARANCE LINES AS-BS-CS-DS, EXCEPT ON SWITCHES AND CURVES EXCEEDING 7°–10', USE DASH CLEARANCE LINES A'S'-B'S'-C'S'-D'S'.

ALL FIGURES REPRESENT DIMENSIONS IN INCHES WHEN PLACED AFTER DESIGNATING LETTERS. THEY REPRESENT RESPECTIVELY THE ELEVATION IN INCHES ABOVE THE PLANE OF TOPS OF RUNNING RAILS WHEN SHOWN ABOVE THE LINE, AND THE DISTANCE IN INCHES ALONG THE PLANE OF TOPS OF RUNNING RAILS FROM THE NEAREST GAGE LINE OF RUNNING RAIL WHEN SHOWN BELOW THE LINE.



Proposed 1991 Manual Revisions To Chapter 15 - Steel Structures

Changes are proposed in Parts 1 through 4, 6, 7 and 9 of Chapter 15. Substantive revisions include adoption of the ANSI/AASHTO/AWS D1.5 Bridge Welding Code of 1988 to the specifications, revised and additional specifications concerning fatigue and fracture critical requirements, and redefining the current impact formula replacing the term 100/S with RE, a percentage of the axle load to reflect the equipment rocking effect (RE). The proposed changes are:

FOREWORD

Revise the second paragraph of the FOREWORD to Chapter 15 to read:

Grateful acknowledgement is hereby made to the American Association of State Highway and Transportation Officials and the American Welding Society for having made available their Bridge Welding Code (AWS D1.5) for use by reference in these specifications. In applying AWS D1.5, the term "allowable stresses" is to be construed as those allowed herein. Certain other modifications and exceptions to the Code are also specified.

PART 1—DESIGN ASTM A 36 STEEL

Article 1.2.1 Materials

Revise the last line of Paragraph 1.2.1 (a) to read:

Welding electrodes .... See AWS D1.5

Article 1.2.2 Welding

Delete existing Article 1.2.2 in its entirety and substitute the following:

(a) Welding shall conform to the applicable provisions of the Bridge Welding Code ANSI/AASHTO/AWS D1.5 of the American Association of State Highway and Transportation Officials and the American Welding Society, herein referred to as AWS D1.5, unless otherwise modified or supplemented by these specifications.

(b) In applying the AWS D1.5 the following substitutions shall be made:

1. Wherever the designation AASHTO is used it shall be construed to refer to AREA.
2. Wherever the term AASHTO Specification or AASHTO Standard Specification for Highway Bridges is used, it shall be construed to refer to AREA Chapter 15 specifications.
3. Wherever the word "highway" (as in highway bridge) appears, it shall be interpreted to mean railway or railroad.
4. Wherever the word "State" (as in State approval, State specification, State inspector, etc.) appears, it shall be construed to refer to the Company as defined in Article 1.1.1 herein.
5. The terms "Engineer," "Inspector" and "Contractor" shall have the definitions given in Article 1.1.1 herein.
6. Wherever AASHTO Material Specifications or AASHTO-M specifications are referenced, the corresponding ASTM specification shall be used.
7. The term "allowable stresses" is to be construed as those allowed herein.
8. In addition to the herein referenced specifications, the welding of Tubes and Pipes shall conform to the applicable provisions of the Structural Welding Code—Steel ANSI/AWS D1.1 of the American Welding Society.

Article 1.3.5 Impact Load

Replace Article 1.3.5 with the following:

(a) Impact load shall be determined by taking a percentage of the live load specified in Art. 1.3.3 and shall be applied vertically at top of each rail.

(b) For open deck bridges the percentage of live load to be used shall be determined by the applicable formula below. For ballasted deck bridges the impact load to be used shall be 90% of that specified for open deck bridges.

1. Percentage of live load for rolling equipment without hammer blow (diesels, electric locomotives, tenders alone, etc.):

For L less than 80 ft. .... $RE + 40 - \frac{3L^2}{1600}$

For L 80 ft. or more .... $RE + 16 - \frac{600}{L - 20}$

2. Percentage of live load for steam locomotives with hammer blow:

A. For beam spans, stringers, girders, floorbeams, posts of deck truss spans carrying load from floor beam only, and floorbeam hangers:

For L less than 100 ft. .... $RE + 60 - \frac{L^2}{500}$

For L 100 ft. or more .... $RE + 10 + \frac{1800}{L - 40}$

B. For truss spans .... $RE + 15 + \frac{4000}{L - 25}$

where RE = the rocking effect consisting of the percentage of downward on one rail and upward on the other rail, increasing and decreasing, respectively, the loads otherwise specified. The load on each rail shall be equal to 10 percent of the axle loads (20 percent of the wheel loads).

L = length, ft, center to center of supports for stringers, transverse floorbeams without stringers, longitudinal girders and trusses (main members), or

L = length, ft, of the longer adjacent supported stringers, longitudinal beam, girder or truss for impact in floorbeams, floorbeam hangers, subdiagonals of trusses, transverse girders, supports for longitudinal and transverse girders and viaduct columns.

(c) For members receiving load from more than one track, the impact load shall be applied on the number of tracks designated below:

Load received from:

Two tracks:

For L less than 175 ft. .... Full impact on two tracks

For L from 175 ft. to 225 ft. ...... Full impact on one track and a percentage of full impact on the other as given by the formula, $450 - 2L$

For L greater than 225 ft. .... Full impact on one track and none on the other

More than two tracks:

For all values of L .... Full impact on any two tracks

Article 1.3.13 Fatigue

Replace the existing article with the following:

(a) Members and connections subjected to repeated fluctuations of stress shall meet the fatigue requirements of this article as well as the strength requirements of Section 1.4 or 2.4.

(b) The major factors governing fatigue strength are the number of stress cycles, the magnitude of the stress range, and the type and location of constructional detail.

(c) The number of stress cycles, N, to be considered shall be selected from Table 1.3.13A, unless traffic surveys or other considerations indicate otherwise. N depends on the span length in the case of longitudinal members, and on the number of tracks in the case of floorbeams, hangers, and certain truss members.

(d) Mean Impact Load shall be taken as the following percentages of the impact load specified in Article 1.3.5:

Member span length L, ft.	Percentage
$L \leq 30$	100%
$L > 30$	65%

(e) The live load for fatigue design is specified in Art. 1.3.3.

(f) The stress range, S_R,is defined as the algebraic difference between the maximum and minimum calculated stress due to dead load, live load, mean impact load, and centrifugal load. Where live load, impact load and centrifugal load result in compressive stresses and the dead load stress is compression, fatigue need not be considered.

(g) The type and location of the various constructional details are illustrated in Figure 1.3.13 and categorized in Table 1.3.13C.

(h) The stress range for other than Fracture Critical Members shall not exceed the allowable fatigue stress range, S_{Rfat}, listed in Table 1.3.13B.

(i) The stress range for Fracture Critical Members shall not exceed the allowable fatigue stress range, S_{Rfat}, listed in Table 1.14.11.

(j) For span lengths exceeding 300 ft, a special analysis of the number of relevant cycles is required (see Commentary).

Tables 1.3.13A, 1.3.13C and Figure 1.3.13:

Tables and figure are to be replaced with the following revised ones:

Table 1.3.13A—Number of Stress Cycles, N

Member Description	*Span Length, L of Flexural Member or Truss or Load Condition*	*Constant Stress Cycles, N*
Classification I		
Longitudinal flexural members and their connections.	$L > 100$ ft	2,000,000
Truss chord members including end posts, and their connections.	$L \leq 100$ ft	> 2,000,000

Classification II		
Floorbeans and their connections		
Truss hangers and sub-diagonals that carry floorbeam reactions only, and their connections	Two Tracks Loaded	2,000,000
Truss web members and their connections	One Track Loaded	> 2,000,000

Note: Table 1.3.13A is based on bridges designed for the live loading specified in Art. 1.3.13(e). For bridges designed for other live loadings see Commentary, Article 9.1.3.13.

Table 1.3.13C—CONSTRUCTION DETAILS

General Condition	Situation	Kind of Stress	Stress Category (See Table 1.3.13B)	Illustrative Example (See Figure 1.3.13)
Plain member	Base metal with rolled or cleaned surface. Flame cut edges with smoothness of 1,000 or less	T or Rev[a]	A	1,2
Cope	Standard cope ground smooth with radius greater than or equal than 3/4 in.	T or Rev	C	23
Built-up members	Base metal and weld metal in member without attachments, built up of plates or shapes connected by continuous full penetration groove welds with backing bars removed or by continuous fillet welds parallel to direction of stress	T or Rev	B	3,4,5,7
	Base metal and weld metal in members without attachments, built up of plates or shapes connected by continuous full penetration groove welds with backing bars not removed or by continuous partial penetration groove welds parallel to direction of stress	T or Rev	B′	3,4,5,7
	Calculated flexural stress at toe of transverse stiffener welds on girder webs or flanges	T or Rev	C	6
	Base metal at ends of partial length welded coverplates narrower than the flange having square or tapered ends, with or without welds across ends, or wider than flange with welds across ends			

	(a) Flange thickness ≤ 0.8 in.	T or Rev	E	7
	(b) Flange thickness > 0.8 in.	T or Rev	E′	7
	Base metal at ends of partial length welded coverplates wider than the flange without welds across ends	T or Rev	E′	7
Groove welded connections	Base metal and weld metal in or adjacent to full penetration groove welded splices of rolled or welded sections having similar profiles, where welds are ground flush with grinding in direction of applied stress and weld soundness is established by nondestructive inspection	T or Rev	B	8,10
	Base metal and weld metal in or adjacent to full penetration groove welded splices with 2 ft radius transitions in width, where welds are ground flush with grinding in direction of stress and weld soundness is established by nondestructive inspection	T or Rev	B	13
	Base metal and weld metal in or adjacent to full penetration groove weld splice at transition in width or thickness, with welds ground to slope no steeper than 1 to 2-1/2 with grinding in direction of stress and weld soundness established by nondestructive inspection	T or Rev	B	11,12
	Base metal and weld metal in or adjacent to full penetration groove weld splice without transition, or with transition having slope no greater than 1 to 2-1/2, where reinforcement is not removed and weld soundness is established by nondestructive inspection	T or Rev	C	8,10,11,12
Groove welded attachment-longitudinally loaded[b]	Base metal adjacent to details attached by full or partial penetration groove weld where detail length L in direction of stress is less than 2 in.	T or Rev	C	6,15
	Base metal adjacent to detail attached by full or partial penetration groove weld where detail length L in direction of stress is between 2 in and 12 times plate thickness but less than 4 in	T or Rev	D	15

	Base metal adjacent to detail attached by full or partial penetration groove weld where detail length L in direction of stress is greater than 12 times plate thickness or greater than 4 in.:	T or Rev	E	15
	(a) Detail thickness < 1.0 in.	T or Rev	E	15
	(b) Detail thickness ≥ 1.0 in.	T or Rev	E′	15
	Base metal adjacent to detail attached by full or partial penetration groove weld with transition radius R, regardless of detail length:			
	—With end weld ground smooth:	T or Rev		16
	(a) Transition radius ≥ 24 in.		B	
	(b) 24 in. > Transition radius ≥ 6 in.		C	
	(c) 6 in. > Transition radius ≥ 2 in.		D	
	(d) 2 in. > Transition radius ≥ 0 in.		E	
	—For transition radii with end weld not ground smooth	T or Rev	E	16
Groove welded attachment-transversely loaded [b,c]	Detail attached to base metal by full penetration groove weld with a transition radius R, regardless of detail length and with weld soundness transverse to direction of stress established by nondestructive inspection:	T or Rev		16
	—With equal plate thickness and weld reinforcement removed:	T or Rev		16
	(a) Transition radius ≥ 24 in.		B	
	(b) 24 in. > Transition radius ≥ 6 in.		C	
	(c) 6 in. > Transition radius ≥ 2 in.		D	
	(d) 2 in. > Transition radius ≥ 0 in.		E	
	—With equal plate thickness and weld reinforcement removed:	T or Rev		16
	(a) Transition radius ≥ 6 in.		C	
	(b) 6 in. > Transition radius ≥ 2 in.		D	
	(c) 2 in. > Transition radius ≥ 0 in.		E	
	—With unequal plate thicknesses and weld reinforcement removed:	T or Rev		16
	(a) Transition radius ≥ 2 in.		D	
	(b) 2 in. > Transition radius ≥ 0 in.		E	
	—For transition radii with unequal plate thicknesses and weld reinforcement not removed	T or Rev	E	16
Fillet welded connection	Base metal at detail connected with transversely loaded weld perpendicular to direction of stress:			

	(a) Detail thickness ≤ 0.5 in.	T or Rev	C	14
	(b) Detail thickness > 0.5 in.	T or Rev	See Fig.	22
	Base metal at intermittent fillet welds	T or Rev	E	
	Shear stress on throat of fillet welds	Shear	F	9
Fillet welded attachment longitudinally loaded[b,c,d]	Base metal adjacent to detail attached by fillet weld with length L in direction of stress less than 2 in.; stud-type shear connectors	T or Rev	C	15,17,18,19, 20
	Base metal adjacent to details attached by fillet welds with length L in direction of stress between 2 in. and 12 times plate thickness but less than 4 in.	T or Rev	D	15,17
	Base metal adjacent to detail attached by fillet welds with length L in direction of stress greater than 12 times plate thickness or greater than 4 in.:			
	(a) Detail thickness < 1.0 in.	T or Rev	E	7,9,15,17
	(b) Detail thickness ≥ 1.0 in.	T or Rev	E′	7,9,15
	Base metal adjacent to details attached by fillet weld with transition radius R regardless of detail length:			
	—With end weld ground smooth	T or Rev		16
	(a) Transition radius ≥ 2 in.		D	
	(b) 2 in. > Transition ≥ 0 in.		E	
	—For transition radii with end welds not ground smooth	T or Rev	E	16
Fillet welded attachment-transversely loaded with weld in direction of principal stress[b,d]	Detail attached to base metal by fillet weld with transition radius R. regardless of detail length (shear stress on throat of fillet weld governed by Category F):			
	—With end weld ground smooth	T or Rev		16
	(a) Transition radius ≥ 2 in.		D	
	(b) 2 in. > Transition radius ≥ 0 in.		E	
	—For transition radii with end weld not ground smooth	T or Rev	E	16
Mechanically fastened connection	Base metal at gross section of high-strength-bolted slip resistant connections, having no out-of-plane bending in connecting material	T or Rev	B	21
	Base metal at net section of high-strength-bolted bearing type connection	T or Rev	B	21

Base metal at net section of riveted connection	T or Rev	D	21

[a]"T" signifies range in tensile stress only; "Rev" signifies range of stress involving both tension and compression during stress cycle.

[b]"Longitudinally loaded" signifies direction of applied stress parallel to longitudinal axis of weld; "Transversely loaded" signifies direction of applied stress perpendicular to longitudinal axis of weld.

[c]Transversely loaded partial penetration groove welds are prohibited.

[d]Gusset plates attached to girder flange surfaces with only transverse fillet welds are prohibited.

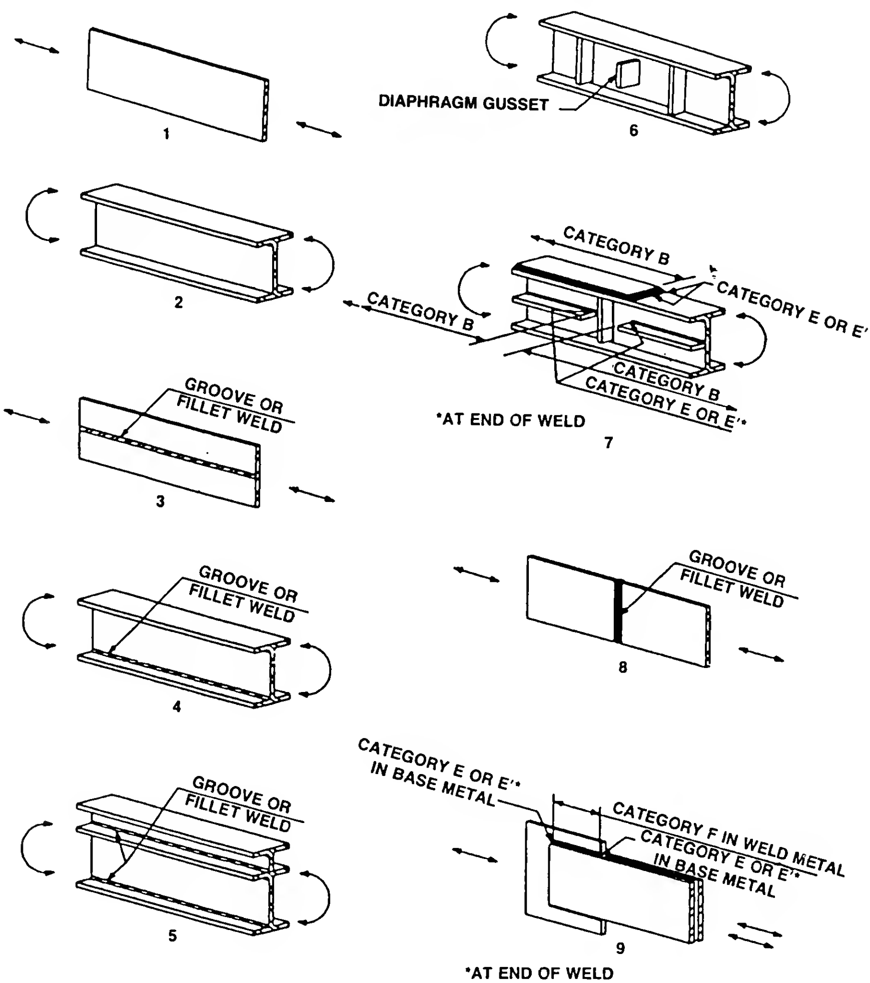
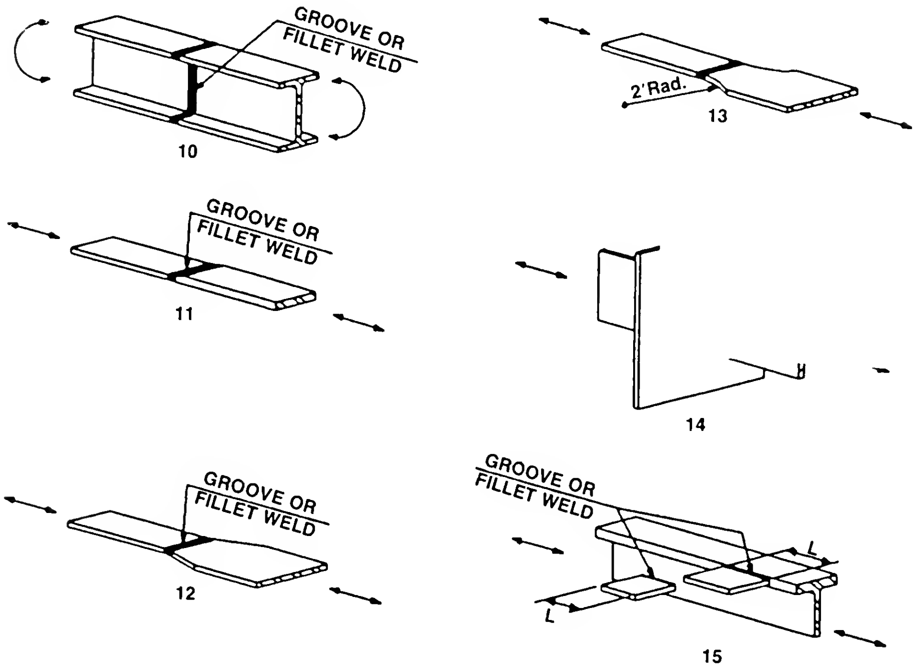
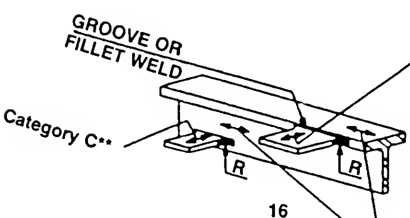


Figure 1.3.13
Examples of Fatigue Conditions
Refer to Table 1.3.13C





WELD CONDITIONS*		
THICKNESS	REINFORCEMENT	CATEGORY
UNEQUAL	IN PLACE	E
	REMOVED	D
EQUAL	IN PLACE	C
	REMOVED	B

*FOR TRANSVERSE LOADING-CHECK TRANSITION RADIUS FOR POSSIBLE LOWER CATEGORY

	CATEGORY	
R**	FILLET	GROOVE
$R \geq 24''$	D	B
$24'' > R > 6''$	D	C
$6'' > R > 2''$	D	D
$2'' > R$	E	E
NOT GROUND	E	E

**ALSO APPLIES TO TRANSVERSE LOADING

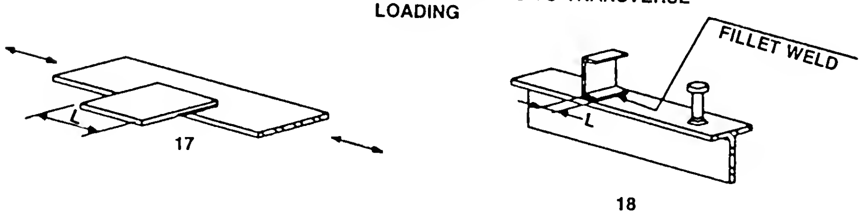


Figure 1.3.13 (Cont.)

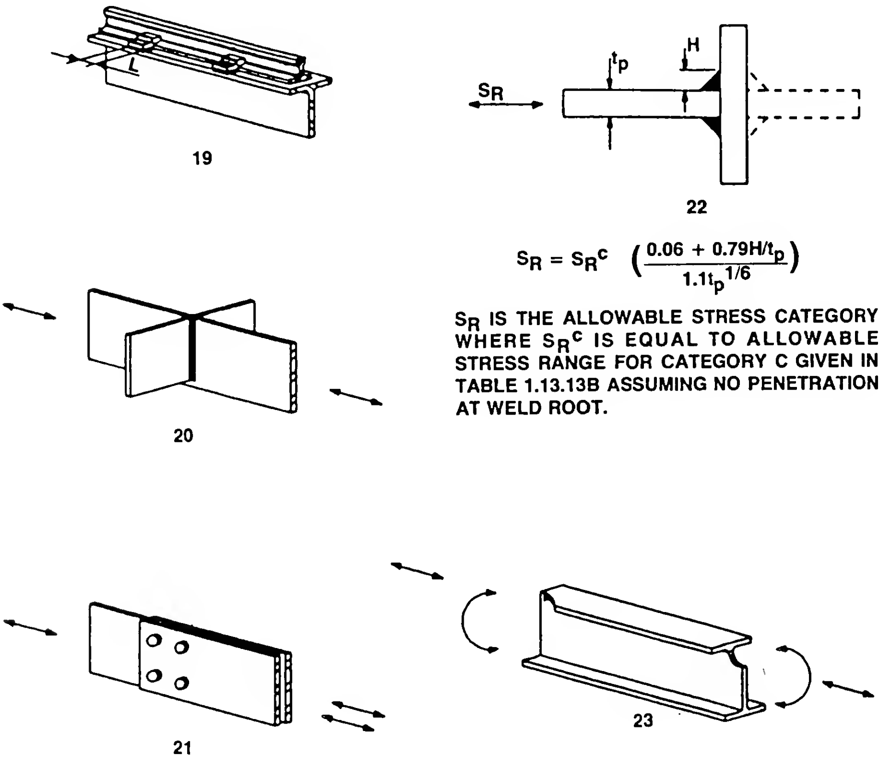


Figure 1.3.13 (Cont.)

Article 1.7.3 Thickness of Web Plates

Revise 1.7.3 (a) to read:

(a) The thickness of the webs of plate girders shall not be less than 1/6 the thickness of the flange nor less than 1/160 of the clear distance between the flanges, except that if the extreme fiber stress in the compression flange is less than that allowable, the denominator 160 may be multiplied by the factor $\sqrt{P_c/f}$ where

P_c = allowable stress in the compression flange, as determined by the applicable formula of Art. 1.4.1, psi

f = extreme fiber stress in the compression flange, psi

Article 1.7.7 Stiffeners at Points of Bearing

Add to paragraph 1.7.7 (d) the following:

Where bearing stiffeners are welded to the flange in compliance with Art. 3.1.10 (a), an area equal to the length of the full penetration groove weld multiplied by the stiffener thickness shall be considered effective in bearing.

Article 1.10.2 Prohibited Types of Joints and Welds

Revise paragraph (a) to read:

(a) Those listed as such in AWS D1.5.

Add new paragraphs 1.10.2 (e) and (f):

(e) Partial joint penetration groove welds.

(f) Transverse tack welds on tension flanges of flexural members.

Article 1.10.6 Material Weldability

Add to Section 1.10 this new Article 1.10.6 as follows:

(a) When an ASTM A709 grade of structural steel is to be supplied in accordance with these specifications and the grade meets the chemical and mechanical properties of ASTM A36, A572 Grade 50, or A588, the applicable prequalified procedures of AWS D1.5 shall apply.

(b) When a steel listed in AREA Section 1.2.1 or 2.2.1 is to be supplied, other than a steel listed in paragraph (a) above or in AWS D1.5 Article 9.2.1, weldability and weld procedure qualification shall be established by the contractor in accordance with AWS D1.5 Article 9.2.4. The contractor rather than the company, shall assume additional costs described in AWS D1.5 Article 9.2.4.2.

(c) The maximum 4 inch thickness limits of AWS D1.5 Article 9.2.1 do not apply. No additional weldability or weld procedure qualification testing will be required because of the increased thicknesses.

Article 1.14.1 Scope

Revise paragraph (f) to read:

(f) Supplement recommendations for welding contained elsewhere in Chapter 15 and in AWS D1.5.

Article 1.14.8 Welding Requirements

1. Replace "AWS D1.1" in Article 1.14.8 (a) with "AWS D1.5."

2. Revise existing Paragraph 1.14.8 (j) to read:

(j) Qualifications of welders, welding operators and tack welders shall be in accordance with Sections 5.8 and 5.9 of AWS D1.5 except that tests, as prescribed in Parts C and D of Section 5 of AWS D1.5, shall include radiographic examination of the test welds. The radiographs shall be made available to the Engineer. Tackers shall be qualified by tests, as prescribed in Part E, Section 5 of AWS D1.5.

Article 1.14.9 Welding Procedures

1. Revise the last sentence of the second Paragraph of Article 1.14.9.3 (a) to read:

In addition to the filler metal qualification test described in this paragraph, a macroetch test shall be performed as described in Article 5.13.3 of AWS D1.5 to represent the maximum single pass fillet weld and the minimum single and minimum multiple pass fillet welds to be used in construction.

2. Revise Notes For Figure 1.14.9, Note 5 to read:

   5. Testing of the specimens shall be performed in accordance with ASTM A370 and AWS D1.5, Sec. 5, Part B, as applicable. Dimensions of the specimens shall be in accordance with specifications as follows:

      a. Side-bend specimens—AWS D1.5, Sec. 5, Part B, Fig. 5.5C, except the specimen thickness shall be as shown in Fig. 1.14.9.

b. Reduced-section tension specimens—AWS D1.5, Sec. 5, Part B, Fig. 5.5B with "t" equal to test plate thickness.

c. Charpy V-notch impact specimens—ASTM A370, full-size Type A specimen.

d. All-weld-metal tension specimens—AWS D1.5, Sec. 5, Part B, Fig. 5.5A and ASTM A370.

3. Replace "AWS D1.1" in Notes For Figure 1.14.9, Note 7 with "AWS D1.5."

4. Replace "AWS D1.1" in Paragraphs 1.14.9.4 (h) and 14 with "AWS D1.5."

Table 1.14.11—Fracture Critical Members

Revise footnote[b] to:

[b]Partial length welded cover plates shall not be used on non-redundant members having flanges more than 0.8 inches thick.

PART 2—DESIGN HIGH STRENGTH STEELS

Article 2.2.1 Materials

Replace "AWS D1.1" in the last line of Article 2.2.1 (a) with "AWS D1.5."

Article 2.7.2 Thickness of Web Plates

Replace the value 32,500 referred to in the paragraph and used in the denominator of the formula $\sqrt{Fy/32{,}500}$ to 30,500.

PART 3—FABRICATION

Article 3.3.1 General

Revise the last sentence of existing Paragraph 3.3.1 (a) to read:

AWS D1.5 shall be used for all requirements not specifically covered in these specifications.

Article 3.3.6 Welder and Welding Operator Qualifications:

Revise the first sentence of existing Paragraph 3.3.6 (a) to read:

(a) Welds shall be made only by welders, welding operators and tack welders who have been previously qualified by tests as prescribed by AWS D1.5 to perform the type of work required.

Article 3.4.1 Shop Painting of Structural Steel

Revise paragraph 3.4.1(c) to read: "Shop and field contact surfaces shall not be painted unless required by the engineer."

Article 3.5.5 Inspection-Welded Work

Revise the first sentence of existing Paragraph 3.5.5 (b) to read:

(b) All groove welds carrying live-load stress in flanges of flexural members and in tension members shall be inspected by radiographic, ultrasonic or another nondestructive testing method which will satisfactorily present evidence to the Engineer that the welds meet the quality requirements of AWS D1.5.

PART 4—ERECTION

Article 4.4 Drawings to Govern

Revise Article 4.4 title and text to:

4.4 Drawings or Special Provisions to Govern

(a) Where the drawings, special provisions and/or these specifications differ, the drawings, special provisions and these specifications shall govern in that order."

Article 4.16 Field Assembly of Pieces

Revise Article 4.16 title and first sentence of paragraph (a) to:

4.16 Field Assembly of Members

(a) Members shall be accurately assembled as shown on the plans and carefully handled so that no parts will be bent, broken or otherwise damaged. Hammering which . . .

Article 4.21 Field Connections Using Pins

Revise paragraph 4.21(a) by deleting the second sentence. The revised paragraph shall then read:

Pins may be driven or jacked into place. Pin nuts shall be screwed tight and the threads burred.

Article 4.23 Misfits

Revise the last sentence of paragraph 4.23(b) to read:

Where material requiring correction is furnished by the company, the contractor shall render to the company within 30 days an itemized bill for such work of correction for the approval of the Engineer.

Article 4.24 Field Cleaning and Painting

Revise paragraph 4.24(c) to read:

The intermediate and finish coats of field paint shall be in accordance with the system selected and specified by the Engineer from Table 1—General Painting Guide for Steel Structures of the Steel Structures Painting Council Manual, Vol. 2.

Article 4.26 Removal of Old Structure and Falsework, and Cleanup

Revise paragraph 4.26(a) by inserting the following phrase after the word tracks - "with clearance specified in Art. 4.8(b), and". The first sentence shall then read in part "a site immediately adjacent to the tracks with clearance specified in Art. 4.8(b) and at an elevation convenient for future handling, as specified."

PART 6—MOVEABLE BRIDGES

Article 6.4.2 Machinery Parts

1. Add "or Bending" to the heading "Tension" of the table in Article 6.4.2(a). The heading will then read "Tension or Bending."
2. Revise paragraph (b) to:

(b) The following allowable bending stresses, psi, shall be used for trunnions:

	Rotation More Than 180 Deg.	*Rotation 90 Deg. or Less*	*Fixed Trunnions*
Forged carbon steel, ASTM A 668, Class D	10,000	15,000	17,000
Forged alloy steel, ASTM A 668, Class G	10,000	20,000	22,000

PART 7—EXISTING BRIDGES

Subarticle 7.3.3.3 Impact Load

In the third line, replace the term "100/S" with "RE".

PART 9—COMMENTARY

Section 9.1 and 9.2 Design

Add a new Article 9.1.2.2 as follows:

9.1.2.2 Welding

Prior to 1990, these specifications stipulated that welding of structural steel should conform to the American Welding Society Structural Welding Code—Steel ANSI/AWS D1.1. With the introduction of the Bridge Welding Code ANSI/AASHTO/AWS D1.5 in 1988, under a joint development effort of the American Association of State Highway and Transportation Officials (AASHTO) and the American Welding Society (AWS), the AREA had available a welding specification that specifically addresses bridge construction.

The development of the AWS D1.5 code represents a landmark of cooperative industry action to address the proliferation of costly and sometimes contradictory regulations. While some specifications of AWS D1.5 may appear unorthodox to members of the welding community, AWS has agreed that AASHTO should play a deciding role in determining the specifics of the code.

Since AWS D1.5 is directed toward the construction of highway bridges constructed in accordance with standard State Specifications, several terminology and definition substitutions must be made in order to render the bridge code applicable to the construction of railroad bridges.

Article 9.1.3.13 and 9.2.3.1 Fatigue

Replace existing material in this article up to the "List of Symbols" on page 15-9-13 with the following:

9.1.3.13 and 9.2.3.1 Fatigue

Members subjected to repeated applications of load under certain conditions will fail at a lower stress than they would under a single application of load. Such failures are commonly referred to as fatigue failures. All editions of these specifications between 1910 and 1969, inclusive, have required that members subject to reversal of stress (whether axial, bending or shearing) during the passage of the live load be proportioned as follows:

> Determine the maximum stress of one sign and the maximum stress of the opposite sign and increase each by 50% of the smaller; proportion the member to satisfy each stress so increased; and proportion the connection for the sum of the maximum stresses.

Tests on small and medium-size laboratory specimens and tests on full-size structures have shown that under some conditions, repeated loadings will reduce the life of members and their connections even if all stresses are tensile. Thus, reversal of stress is not necessary to cause failures from fatigue. AWS bridge and structural welding codes have recognized this fact and have included requirements for modifying the allowable design stresses for certain types of welded members and their connections. Tests (6, 7) have also shown that riveted or bolted members and connections are similarly affected where there is no reversal.

The fatigue formulas in Parts 1 and 2, 1969 edition of these specifications, were based on the formulas in AASHO (now known as AASHTO) Interim Specifications, Bridges, 1966 and 1967 (8) and on additional data published in 1968 and 1969 (29, 30). These formulas included consideration of:

(1) Frequency of applications of the critical loadings. Two cases: up to 500,000 constant stress cycles, and more than 500,000 constant stress cycles. Dead load plus wind load was not included as a case.

(2) R, the ratio of minimum to maximum stress.

(3) The methods used to fabricate and connect members.

After 1969 additional research (32, 33) demonstrated that:

(1) Stress range (S_R) is the significant factor for fatigue strength, rather than the stress ratio (R).

(2) Cracks that may form due to fatigue in regions of fluctuating compression stress are self-arresting, providing that they cannot run into tensile regions along paths created by residual tensile stresses. Hence, pure compression regions are not subject to fatigue failure.

(3) Allowable stress range (S_R) for the various details can be expressed in terms of the number constant stress cycles (N).

S_R-N curves, developed (33) by using 95% confidence limits for 95% survival applied to test data, were used for the original fatigue categories A through F, and had the same definitions as given in AASHTO Interim Specifications, Bridges, 1974.

The current revision of Chapter 15 reflects the continuing research done under the NCHRP program in the 1970's and 1980's. A discussion of the effect of various welded details on the fatigue life of a typical structural component is included in the latest edition of the AISC Bridge Fatigue Guide -Design and Details (38).

Fatigue damage prior to the introduction of 263,000 lb cars (100 ton capacity) in the 1960's, was primarily the result of the passage of heavier locomotives. With 20 trains a day for 60 years, the number of damaging cycles caused by locomotives would be less than 500,000.

Fatigue problems accelerated in the 1970's and 1980's, with the introduction of heavy and frequent unit train service where the effect of each car is equivalent to that of a locomotive. With the same 20 trains a day with 60 cars per train causing damage, 500,000 cycles are accumulated in only one year. The 1978 edition of this manual attempted to address this problem with a loading that was more severe than that experienced prior to the 1960's, but not as severe as that experienced with the heaviest unit train lines in the early 1970's.

The 1978 criteria for fatigue were based on an assumed Rayleigh probability density function to represent the distribution of load and may still be appropriate in some instances (see AISC Bridge Fatigue Guide—Design and Details, 1977 edition (38). A Rayleigh Distribution in the form assumed is not appropriate for heavy haul railroads or lines with a substantial number of heavy cars. The essence of the 1978 revision is as follows:

(1) The assumed characteristic load was based on limited experimental data (30) obtained on older structures which had been designed for E 72 and higher loadings including impact. The Rayleigh frequency distribution was used to obtain a relationship between the maximum E loading and the root mean square (RMS) E loading. Subsequent research indicated that the root mean cube (RMC) is more appropriate; it correlates better with a fracture mechanics approach, and also gives a better fit to Miner's rule for fatigue damage.

(2) The maximum and minimum E loadings for the Rayleigh function were selected assuming E 80 loading and also assuming that the regular traffic would be between E 40 and E 55 with only occasional heavier loadings.

(3) Applying the 1978 procedure for E 80 loading gave RMS values between E 28.6 and E 36.7 for Classifications I & III, and E 38.7 for Classification II. (Classifications II and III were subsequently combined.)

(4) The projected number of variable stress cycles corresponded to an average mainline volume of 60 daily trains over an 80 year period. The 1978 commentary suggested that if more specific data were available for a bridge, those values could be used to estimate the stress cycles. If more precise estimates of alpha (α) are available, they can also be substituted for the values listed in

Table 9.1.13A. Likewise, the actual frequency distribution, if known, could be used in place of the Rayleigh distribution.

The relationship between the allowable fatigue stress ranges, S_{Rfat}, and the equivalent number of constant stress cycles, N, for the current edition of the Manual was determined as described hereunder.

Impact values used in design are estimated to have a probability of occurrence of 1% or less. Considering that a railroad bridge is normally designed for a service life of 80 years, this level of impact is quite likely to occur at least once during the bridge life and most probably more frequently. For fatigue design the mean value of impact is more appropriate.

Extensive observations on 37 spans with span lengths between 30 and 140 ft, summarized by W. G. Byers (47), indicates that mean impact values fall below 65% of the values used for design. Tests on 15 bridges on Canadian National Railways done between 1975 and 1988 (reported to Committee 15, May 1988, by R. A. P. Sweeney) indicated mean values of 34% on spans less than 80 ft, and 65% on longer spans. The mean impact will be a function of the geometry of the track and how well it is maintained up to and across the bridge, along with the maintenance standards for out-of-roundness of wheels and for wheel flats. Until a more extensive data base becomes available the committee recommended that the 65% value should be used for spans exceeding 30 ft and the full impact on shorter spans.

Existing cars (1988) with gross weights of 315,000 lb and certain double stack cars are approaching E 80 loading values on short spans. In order to provide sufficient fatigue capacity under solid trains of these types of vehicles the number of design cycles shown in Table 1.3.13A was derived by prorating the fatigue curve formula,

$$N = N_V \times (A \times S_R)^{-3}, \qquad \text{Eq. 1}$$

to an equivalent number of cycles of E 80 loading. In this formula N is the number of cycles, A is a constant, and S_R is the stress range characteristic of E 80 loading. The total projected number of variable stress cycles, N_V, shown in Column 5 of Table 9.1.3.13A, is obtained by multiplying columns 2, 3 and 4.

It was assumed that 315,000 lb cars in 150 car unit trains at a frequence of 100 trains per day will be possible within the 80 year bridge service period. The number of cycles per train is the result of extensive work by G. Oommen, S. Beisler and R. A. P. Sweeney as reported to Committee 15 in 1987 and 1988.

The assumed values of alpha (α) are listed in Column 6 of Table 9.1.3.13A. Assuming an RMC loading of E 60 (315,000 lb cars on longer spans) and the values of alpha listed in Column 6, and using equation 1, the N_V values of Column 5 are transformed to the 2 million or greater case in Column 8. These are the values used for Classification I in the manual in Table 1.3.13A. The greater than 2 million cycle group is represented in Table 1.3.13B by the threshold or probable constant amplitude fatigue limit for each category.

Structures designed to the fatigue criteria of Article 1.3.13 should be adequate for continuous unit trains with equivalent uniform load not exceeding 6000 lbs per foot of track and axle loads not exceeding 80,000 lb, or other variations of higher load with fewer cycles. This should be adequate for mainlines of Class I railroads, and for most heavy haul lines.

The fatigue live load specified in Article 1.3.13 (e) may be lowered to E 65 (roughly 0.8 × E 80) for lines expected to carry less than 5 and 15 million gross tons per mile per annum throughout their service lives and E 40 (0.5 × E 80) for lines expected to carry less than 5 million gross tons per mile (MGTM) per annum throughout their service lives. For such cases the characteristic fatigue load has been lowered, instead of reducing both the cycles and load. The recommended reduction is such as to produce the same effect. For non-Class I railroads and non-heavy haul lines the recommended procedure should be adequate to handle a mix of cars up to the 315,000 lb gross type, with the loadings given for the light traffic volumes specified above.

On spans exceeding 100 ft it may be necessary to increase the number of cycles per train if a consistent operating pattern of loaded cars followed by empty cars is repeated throughout the design train, throughout the service life of the bridge. It is theoretically possible to get 75 cycles on spans close to 100 ft if the pattern is 2 loaded cars followed by 2 empty cars. Nevertheless, the committee assumed 5 cycles of loaded-empty combinations in its design 150 car train as a more likely maximum on spans exceeding 100 ft.

It must be kept in mind that the number of variable cycles leading to the greater-than-2-million category in Table 1.3.13B is different for each category of detail, varying from 5 to 52 cycles per 150-car train on spans exceeding 100 ft.

For span lengths exceeding 300 ft an analysis is required for each bridge using influence lines and the preceding car types and load frequencies, accounting for the effect of lightly loaded vehicles interspaced within the design train.

The revised stress range values given in Tables 1.3.13B and 1.14.11 are from Reference 48. For designs where lower numbers of cycles than those listed in the Manual are appropriate, the values listed in Tables 5 and 7 of Reference 48 are recommended.

Table 9.1.3.13A—Parameters used to develop Tables 1.3.13A and 1.3.13B

Classification 1

1	2	3	4	5	6	7	8
Span Length L Ft	**Life in Days 80 yr**	**No. of Daily Trains**	**Stress Cycles per Train Crossing**	**Projected N_V Million**	**Alpha (α)**	**N col. 5 × (Alpha x 6/8)$^{-3}$ Million**	**N used in Table 1.3.13A Million**
L > 100	29200	100	5	14.6	0.70	2.1	2
100 ≥ L > 75	29200	100	8	23.4	0.80	5.0	>2
75 ≥ L > 50	29200	100	75	219	0.85	57	>2
50 ≥ L	29200	100	150	438	0.85	113	>2

Table is based on 150-vehicle train. Critical characteristic load is assumed to be 3/4, i.e. 60/80, of design load E 80.

Where fasteners and connected material are proportioned in accordance with Article 1.3.13 and Section 1.4, the fasteners will have greater fatigue life than the connected material. Thus, no categories for bolts or rivets in shear or bearing are required to replace the 1969 formulas.

For the usual design condition, only S_R derived from bending needs to be considered for details, such as transverse stiffeners, which are subjected to shear stresses as well. The design detail categories have taken shear into account; therefore, principal stresses need not be considered in the usual design condition. For unusual design conditions, the principal stresses may need to be considered.

Article 9.1.4.2 and 9.2.4.2 Weld Metal

Revise existing articles to read:

The allowable unit stresses on weld metal specified in Arts. 1.4.2 (a) and 2.4.2 (a) are close to those permitted by AWS D1.5.

Article 9.1.10.1 Transition of Thicknesses or Widths in Welded Butt Joints and Article 9.1.10.2 Prohibited Types of Joints and Welds

Replace "AWS D1.1" in Articles 9.1.10.1 and 9.1.10.2 with "AWS D1.5."

Article 9.1.14.1 Scope

Replace "AWS D1.1" in the second sentence of the second paragraph of existing Article 9.1.14.1 with "AWS D1.5."

Article 9.1.14.9 Welding Procedures

Replace "AWS D1.1" in the second sentence of the sixth paragraph of existing Article 9.1.14.9 with "AWS D1.5."

Article 9.3.1.6 Flame Cutting

Replace "AWS D1.5" in the first sentence of existing Article 9.3.1.6 with "AWS D1.5."

Section 9.7 Existing Bridges

Revise the WELDING INDEX following Section 9.7 by:

1. Adding the following "Subject" with "Article Reference" between "Bearings" and "Butt joints":

Bridge welding code, AWS D1.5	1.2.2; 1.10.2 (a); 1.10.6; 1.14.1 (f); 1.14.8 (a); 1.14.8 (j); 1.14.9.3; 1.14.9.4 (h) 9 and 14; 3.3.1 (a); 3.3.6; 3.5.5 (b); 9.1.2.2; 9.1.4.2; 9.2.4.2; 9.3.1.6

2. Deleting the Subject "Structural welding code" and associated article references in its entirety.

3. Revising the following article references in the Welding Index to:
Seam Welding 6.7.9.35 (c) change to 6.7.5.35 (c)
Spot Welding 6.7.9.35 (c) change to 6.7.5.35 (c)

BIBLIOGRAPHY

Add to Bibliography:

(47) W. G. Byers, "Impact From Railway Loading on Steel Girder Spans" J. Struct. Div., A.S.C.E., June 1970.

(48) NCHRP Report 286, "Evaluation of Fatigue Tests and Design Criteria on Welded Details," by R. B. Keating and J. W. Fisher.

Proposed 1991 Manual Revisions To Chapter 22—Economics of Railway Construction & Maintenance

Parts 1, 2 and 4 of Chapter 22 have been reviewed and totally rewritten. The three new parts follow on pages 85, 90, and 101 respectively.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Part 1

Organization

INTRODUCTION

It is necessary to designate responsibility for the physical property of a railroad, no matter how large or small the organization is. This part defines basic ***functions*** to perform, ***methods*** to accomplish the work, and ***training*** to do the work properly and safely.

1.1 FUNCTIONS

Functions consist of construction, inspection, maintenance and repair of track, roadway, bridges, and other structures.

1.1.1 Construction

(a) Evaluate, plan and schedule the construction of new railroad track and other facilities to achieve maximum economic efficiency.

(b) Direct the construction of new railroad track and other facilities consistent with plans, specifications and regulations.

1.1.2 Inspection

(a) Inspect new railroad track and other facilities consistent with plans, specifications and regulations.

(a) Inspect existing facilities on an appropriate schedule consistent with established standards, operating conditions, emergency and natural conditions and regulatory requirements in order to maintain safe operating conditions in order to maximize economic service life.

(c) Inspect maintenance and heavy repair work to verify it is performed consistent with established standards and with regulatory requirements in order to maintain safe operating conditions and to maximize economic service life.

1.1.3 Planned Maintenance

Maintain the track, bridges and other existing facilities on an appropriate schedule consistent with established standards, operating requirements and regulatory requirements in order to maintain safe operating conditions and in order to achieve maximum economic service life.

1.1.4 Repair

Organize and direct the repair of railroad track and other facilities consistent with established standards, operating requirements and regulatory requirements to restore safe operating conditions.

1.2 METHODS

The methods used to construct, inspect, maintain and repair railroad track and other facilities are extremely variable, depending on organization size, goals, resources, union and regulatory requirements, etc. The responsible manager must constantly innovate and improve methods to maximize economical results. Whether the work is done by established employees or by contractors, the manager has a variety of resources available to establish the proper methods. This includes the following:

1) internal organization ideas and standards
2) AREA and AAR standards and publications
3) industry and construction trade periodicals
4) vendors and suppliers
5) consultants and contractors

6) regulatory standards

1.2.1 Construction

Track and Roadway

Scheduling and planning track and roadway construction require knowledge of operating conditions, safety requirements, regulatory requirements, and local environmental considerations, including weather, soil conditions, population, etc. Plan and perform construction in accordance with established standards and regulations. The approval of regulatory and law enforcement agencies is sometimes necessary.

Frequently specialized material, equipment and personnel are necessary to perform construction. The manager must know where to locate and how to obtain such equipment and personnel.

Bridges and Other Structures

Scheduling and planning bridge and structures construction require knowledge of operating conditions, safety requirements, regulatory requirements, and local environmental considerations, including weather, soil conditions, population, etc. Plan and perform construction in accordance with established standards and regulations. The approval of regulatory and law enforcement agencies is sometimes necessary.

Frequently specialized material, equipment and personnel are necessary to perform construction. The manager must know where to locate and how to obtain such material, equipment, and personnel.

1.2.2 Inspection

Track and Roadway

Scheduling and planning track and roadway inspections require knowledge of operating conditions, safety requirements, regulatory requirements, and local environmental considerations, including weather, soil conditions, population, etc. Inspection standards exist to maintain safe and economical operations under all conditions. Clearly establish emergency procedures and clearly define communcation methods. Inspection must fulfill any applicable government requirements.

Track and roadway inspection generally requires specialized (on-track) vehicles for mobility. Track inspectors or inspection gangs usually perform minor repair work, general policing and emergency patrols in addition to inspecting and reporting defects. Inspectors must be appropriately qualified by both the employing organization and by the appropriate regulatory agencies. Inspectors must also submit reports in the proper format to the employing organization and, where applicable, to the appropriate regulatory agencies.

Bridges and Other Structures

Scheduling and planning bridge structures inspections requires knowledge of operating conditions, safety requirements, regulatory requirements, and local environmental considerations, including weather, soil conditions, population, etc. Inspection standards exist to maintain safe and economical operations under all conditions. Clearly establish emergency procedures and clearly define communication methods.

Inspecting bridges, structures and other appurtenances (heating, ventilation, plumbing, etc.) generally requires specialized knowledge in the appropriate area. Inspectors should be qualified by both the employing organization and by the appropriate regulatory agencies.

Inspectors must also submit reports in the proper format to the employing organization and, where applicable, to the appropriate regulatory agencies.

1.2.3 Maintenance

Track and Roadway

Scheduling and planning track and roadway maintenance require knowledge of operating conditions, safety requirements, regulatory requirements, and local environmental considerations, including weather, soil conditions, population, etc. The manager must know what resources and limitations exist both within and outside his organization. Maintain the track and roadway in accordance with safety and service requirements and within established economic guidelines.

Track maintenance methods evolve constantly, changing with improved material, equipment, and techniques. Those performing the work must know how to use the material and equipment. There are also many regulatory requirements pertaining to supervisory qualifications, safety equipment, and safety training.

Bridges and Other Structures

Scheduling and planning bridge and structures maintenance require knowledge of operating conditions, safety requirements, regulatory requirements, and local environmental considerations, including weather, soil conditions, population, etc. Maintenance standards are developed to maintain a safe and economical operation in these conditions.

Maintenance of bridges, structures and other appurtenances (heating, ventilation, plumbing, etc.) generally requires specialized knowledge in the appropriate area. Maintenance personnel must be qualified by the employing organization and by the appropriate regulatory agencies.

1.2.4 Repair

Track and Roadway

Repair includes both major rehabilitation and emergency restoration. Scheduling and planning track and roadway repairs require knowledge of operating conditions, safety requirements, regulatory requirements, and local environmental considerations, including weather, soil conditions, population, etc. In emergency restoration plans consider time requirements as an important part of the economics involved. The active involvement of regulatory and law enforcement agencies is also a possibility to consider.

Frequently specialized material, equipment and personnel are necessary to perform the restoration or repair. The manager must know where to locate and how to obtain such equipment and personnel.

Bridges and Other Structures

Repair includes both major rehabilitation and emergency restoration. Scheduling and planning bridge and structures repairs require knowledge of operating conditions, safety requirements, regulatory requirements, and local environmental considerations, including weather, soil conditions, population, etc. In emergency restoration plans consider time requirements as an important part of the economics involved. The active involvement of regulatory and law enforcement agencies is also a possibility to consider.

Frequently specialized material, equipment and personnel are necessary to perform the restoration or repair. The manager must know where to locate and how to obtain such equipment and personnel. The use of contractors requires knowledge of the contractors' abilities and resources.

1.3 ORGANIZATION

Organization of forces to perform construction, inspection, maintenance, and repair functions can and should be varied to reflect the goals, resources, and operating conditions of the railroad involved. Either employees or contractors can perform these functions. The economics of maintaining a staff to perform any part or all the necessary functions must be carefully examined. The work can be performed entirely with employees, entirely by contractors or a combination of the two.

1.3.1 Track

(a) *Supervisors*—evaluate, plan, schedule, and inspect the work. Qualifications generally include a combination of engineering education, technical training and practical experience. Qualifications should be consistent with company policy and regulatory requirements. The size of the supervisory staff depends on the company's size and policy requirements.

(b) *Inspection/patrol gang*—performs inspection, general policing, minor repairs; reports defects;

and completes necessary reports. Qualifications must be consistent with company policy and regulatory requirements.

(c) *Maintenance gang*—performs general and routine light to medium maintenance work. This typically includes the following:

- spot renewals of ties and rails
- spot track surfacing
- turnout maintenance
- grade crossing maintenance
- brush control
- track welding
- snow removal
- rail lubricator maintenance

(d) *Program gang*—performs large programmed and specialized track work. This typically includes the following:

- track renewal
- out-of-face tie renewal
- out-of-face rail renewal
- turnout renewal
- out-of-face track surfacing
- grade crossing renewal
- undercutting
- major track welding

(e) *Contractors*—perform large programmed and specialized track work. This includes any of the work previously mentioned and the following:

- vegetation control (chemical or mechanical)
- rail grinding
- ballast shoulder cleaning

1.3.2 Bridges

(a) *Supervisors*—evaluate, plan, schedule, and inspect the work. Qualifications may generally include a combination of engineering education, technical training and practical experience. Qualifications should be consistent with company policy and regulatory requirements. The size of the supervisory staff depends on the company's size and policy requirements.

(b) *Inspectors*—perform inspection, general policing; report defects; and complete necessary reports. Qualifications should be consistent with company policy and regulatory requirements.

(c) *Bridge/structures gang*—performs construction, maintenance and repairs; and paints assigned bridges and structures. The gang may perform general tasks or be assigned a specialized function such as concrete repair.

(d) *Contractors*—perform large programmed and/or specialized construction or maintenance. This includes any of the work previously mentioned and the following:

- steel fabrication and erection
- timber bridge rehabilitation
- tunnel repairs

1.3.3 Structures

(a) *Supervisors*—evaluate, plan, schedule, and inspect the work. Qualifications generally include a combination of engineering education, technical training and practical experience. Qualifications should be consistent with company policy and regulatory requirements. The size of the supervisory staff depends on the company's size and policy requirements. Highly specialized functions and those functions readily available from local contractors may be contracted.

(b) *Inspectors*—perform inspections, report defects and completes necessary reports. Qualifications should be consistent with company policy and regulatory requirements. Inspection of structures and other appurtenances (Heating, ventilation, plumbing, etc.) generally requires specialized knowledge.

(c) *Bridge/structures gang*—performs construction, maintenance, repairs; and paints assigned structures. The gang may perform general types of tasks or be assigned a specialized function such as plumbing or electrical installation.

(d) *Contractors*—perform large programmed and/or specialized construction or maintenance. This includes any of the work previously mentioned and the following:

1) steel fabrication and erection
2) electrical and plumbing construction or maintenance
3) overall building maintenance

1.4 TRAINING

Training is necessary to fulfill internal and regulatory requirements for job performance at nearly all levels in a construction/maintenance organization. Both job safety requirements and the need to maintain safe train operations require a well-qualified work force.

(a) *Supervisors*—Training may occur both before and following assignment to a supervisory position. Training and qualification generally include a combination of engineering education, technical training, and practical experience and should be consistent with company and regulatory requirements. The candidate must have shown the potential to do the job and may be trained by one or more of the following:

- on the job training in various assignments
- technical training on the job, through formal in-house programs and from commercial and public educational institutions
- education in company policies and procedures in the various departments
- management training from in-house, commercial and institutional sources

(b) *Inspectors*—Training and qualification must be consistent with company and regulatory requirements. Inspection of structures and other appurtenances (heating, ventilation, plumbing, etc.) requires specialized knowledge. This training is available from a variety of sources:

- on the job training in various assignments
- technical training on the job, through formal in-house programs and from commercial and public educational institutions
- education in company policies and procedures in the various departments

(c) *Gang members and other staff*—Training and qualification vary with job assignment and skills required. There are imperative minimal safety and health training requirements from various regulatory agencies. Training as needed can be made available through the following:

- on the job training in various assignments
- technical training on the job, through formal in-house programs and from commercial and public educational institutions
- education in company policies and procedures in the various departments.

(d) *Consultants and Contractors*—There are mandatory minimal safety and health training requirements from various regulatory agencies and specific company policies relating to contractors. Division of responsibility for such training may be spelled out in the contract, along with any specific rules and regulations in effect by the company.

Part 2

Programming Work

2.1 FOREWORD/INTRODUCTION

2.1.1 Foreword:

Part 2 of Chapter 22 was formerly titled "Programming Work and Budgeting." However, during the re-write, Chapter 11 introduced a new section—Part 4 "Planning, Budgeting and Controls" which had significant similarities. When viewed together, Part 2 Chapter 22 and Part 4 Chapter 11 form a synergistic approach to the importance of good planning and programming to the efficient and economical maintenance, rehabilitation and construction of railroad infrastructure. Both sections reinforce the importance of the optimal utilization of corporate resources in the attainment of corporate goals.

2.1.2 Introduction

This section will deal primarily with the methods and procedures utilized in the development, implementation and control of work programs. Good short term and long term planning is essential to the effective allocation of finite resources by Engineering managers. Through a proactive approach of cyclical maintenance, timely and comprehensive inspections, and efficient and strategic application of resources, physical plants can remain safe and reliable. This section is applicable to both centralized and decentralized corporate structures and will remain general in nature.

2.2 PROGRAM DEVELOPMENT

The effective utilization of corporate resources in the maintenance, replacement and addition of fixed assets is attained through a step-by-step process which utilizes such factors as economy-of-scale material ordering, forecasting, product uniformity, mechanization and stabilization of forces. These factors are all components of a good work program be it annual or some other period of time. Chapter 11 Part 4 "Planning, Budgeting and Control" describes in detail the long term planning and budget process which complements this section.

2.2.1 General Considerations

Preparation of a detailed program provides the basis for the scheduling of work in a most effective manner. Long and short term programming allows work to be progressed economically, seasonally, harmoniously with traffic conditions, and in conjunction with manpower and material availability.

a) A program of work and material procurement should be developed coincidentally with the annual budget; thus allowing resources to be allocated to the work essential to meet the corporate goals for the budget period.

b) The balancing of expenditures throughout the year, where practical, allows for an effective economic approach to scheduling of work. A uniform budget allows for stabilization of forces, good inventory control, good cash flow management, etc.

c) Sudden fluctuations in maintenance forces adversely affects the quality and quantity of work, thus increasing unit cost. A balanced force of experienced workers ultimately is far more effective and efficient than a fluctuating force. Stabilization of the work force in the Maintenance of Way and Structures areas is accomplished by establishing a base force that can be employed economically throughout the year and utilizing temporary forces as required to perform project or capital program work beyond the normal operating needs. (Refer to Chapter 11 Page 11-1-11 Section 1.5 Capital Expenditure or Operating Expense.)

d) During the execution of the maintenance program, prompt tracking of detailed costs and productivity will allow identification of problems in a timely manner, thus maximizing economy. The monitoring of expenses versus work complete, time elapsed, manpower utilization, etc. are examples of indicators necessary for good economic management of the labor force.

2.2.2 Methodology

a) Replacement cycles should be developed for all major maintenance items such as ties, rail, surfacing, bridge painting, switches, crossings, etc. Based on these cycles, the average annual maintenance expense in terms of labor, material and equipment is determined.

b) Establish priorities by location for each maintenance component based on inspection reports and projected traffic levels.

c) The annual program is categorized by major operation, location, units of labor and units of material.

d) The annual program is subdivided into capital budget and operating (expense) budget on a monthly or a quarterly basis. (Chapter 11 Part 4 Section 4.4.4 and 4.4.5 provides a step-by-step approach to developing a capital and operating budget in a traditional railroad organization.

e) Supporting information such as bar or line graphs and other scheduling tools can be utilized to enhance the progression of work.

f) Major projects which are complex in nature and involve integration of several parties and multiple functions may require the use of critical path methodology and time-cost relationship analysis.

g) Review of cost data versus work complete should be performed to monitor effectiveness of the program.

2.2.2.1 Inspections

Inspection of track and structures provides information for development of work programs and budgets. All railroad facilities and structures should be inspected annually as a minimum, and when necessary, inspections should be made more frequently to determine work required to establish annual programs.

Methods of Performing

Track Geometry Vehicles:

The use of track geometry vehicles can be a valuable tool for determining the general condition of the track structure. The information generated by these vehicles has proven useful in the development of annual programs as well as establishing immediate priorities for the utilization of manpower and equipment. However, the use of these geometry recording vehicles does not eliminate the necessity of the walking or slow moving vehicular (visual) track inspections.

Visual Inspections:

Track inspections may be performed by walking or by riding in a vehicle operating at a speed that allows visual inspection of the track structure. Structures must also undergo regularly scheduled visual inspections.

Inspection Reports:

The Railroad should keep an accurate record of various types of track and structure inspections performed. These records should be in complete compliance with the requirements of all regulatory agencies. The results of inspections must be forwarded to those individuals responsible for the development of the annual programs in order to insure the proper allocation of resources in the most effective (economic) manner.

2.2.2.2 Analysis of Component Replacement

The utilization of life cycle analyses of maintenance components in conjunction with proper track and structure condition evaluation creates a highly effective basis for planning of maintenance work, establishing maintenance budgets, anticipating future expenses and developing an orderly controlled maintenance program.

Component Service Life:

Service life expectancy for track components is difficult to determine. However, utilizing practical knowledge and experience in maintenance activities and analyzing material usage and evaluation records, field observations and maintenance activity records, reasonable maintenance cycles can be established.

It is necessary not only to determine the service life for various items, but also the life for each item in a specific class of service, i.e. yard, secondary, main, etc. The traffic specific life cycle determinations will be the basis for the maintenance programs.

Due to the changes in technology in the industry, service life expectancies for new components can be estimated utilizing laboratory testing and computer generated forecasting. The utilization of computers is ideal for analyzing and developing service lives from historic maintenance records. This data base can be very useful in long range planning of maintenance programs.

Renewal Cycles:

Due to the individual character of every railroad's operation and maintenance and construction standards, renewal frequencies must be system or region specific. These renewal cycles then become the standard for the railroad and must be the basis for maintaining a given component on a given portion of the railroad. Deviation from the established renewal cycle, if properly established, will result in a change in track or structure condition. However, the forecasted renewal cycles cannot solely drive the programming of work. Field conditions, as noted on inspection reports, must also be evaluated during the annual program development phase, since there are many variables contributing to maintenance requirements.

As an example, a newly constructed yard or other track may not require tie or rail replacement for a considerable period. If this track is a large portion of the area for which a study is being made, it may greatly decrease the number of ties requiring immediate or near future replacement, thus understating the long term component replacement per maintenance cycle. On the other hand, a tie renewal frequency determined by dividing total ties in track by the average life of a tie may not reflect the tie renewal rate required for a given track for a given cycle. All factors must be considered and extreme care taken in development of cycles if they are to be pragmatic.

Once established, a renewal cycle should not be considered an absolute requirement, but should be utilized as a guide. Constant monitoring of the fixed plant and operations should be performed to determine the adequacy of any prescribed cycle. For example, changing traffic densities (including tonnage, vehicle type and type of lading) is an important factor affecting component change-outs, and the replacement cycles must be adjusted accordingly to any upswing or downturn in usage.

Component (material) life and cycle replacement can be very important tools to the maintenance engineer, if properly and intelligently developed and utilized. All possible records should be utilized and forecasted changes to operations considered in the development and adjustment of any maintenance component replacement cycle.

2.2.2.3 Production

Production involves the work done by various organizations (i.e. rail laying, tie installation, etc.) with results stated in units of work such as linear feet, number of ties, number of feet surfaced, number of feet of track constructed, etc. Production output data is necessary for historical records and useful for program development. Output is not only dependent on the type and number of machines utilized, but is also affected by the labor force, supervision, location and track time availability. An improvement in production should reduce total maintenance and transportation costs and increase the economy of the work force.

2.2.3 Program Forms

To provide effective maintenance and capital programs, it is necessary to tabulate all inspection reports compiled by various levels of engineering managers and supervision. The final report can then be assembled and set down on program forms.

Program forms depend on railroad size and concomitant estimates of money available for such programs. Some systems utilize semi-annual, annual and even five year programs. Where large estimates are anticipated, they could be distributed in multi-year programs. In many cases, systems utilize long term (five, ten and twenty year) programs to forecast future needs.

Personal computers and scheduling techniques such as Pert and Critical Path are utilized to monitor production, costs and other economic factors, as well as for compilation of the programs and budgets themselves. Chapter 11 Section 4.5 "Authorization Process" describes the departmental responsibilities and documentation process related to short and long term planning and program development.

2.3 ECONOMICS

When it becomes necessary to consider the replacement of an existing facility by reason of deterioration, damage, obsolescence or other cause, it is prudent that an economic comparison be made of the various alternatives for replacement. This mathematical (economic) analysis can identify the most financially advantageous expenditure. One of the alternatives should consider the economy of repairing the facility for continued service for one or more years.

2.3.1 General Considerations

If a facility needs to be replaced, a careful analysis of all the elements of cost should be made. This analysis should be based on initial purchase and/or construction cost (including the expense for maintaining traffic during construction) anticipated service life, time-value of the initial capital investment, annual maintenance and operation costs, and effect of taxes and depreciation. (Refer to Chapter 11 Part 1 Section 1.7 "Depreciation Accounting" and Part 3 "Taxes" for clarification of the effects taxes and depreciation have in this process.)

Economic comparisons of the type treated herein should not include any charges for past expenditures (sunk cost) or existing investment value. It is prudent, however, to include the present value of future work to an existing facility which will be necessary to carry it to the end of its service life when comparing to an alternate under consideration.

It must be kept in mind that economic analyses are seldom the sole criteria to be considered during the decision making process. Economic comparisons are reliable only in proportion to the sound judgement utilized in establishing the criteria used in the comparisons. In addition, outside influences such as politics, safety, labor issues, etc. may have an effect in the decision making process.

2.3.2 Service Life

The estimated service life of a facility is usually the key to the validity of the economic comparisons to a greater extent than any other assumption. In selecting a service life and allowance for maintenance, the probable manner of renewal must be considered. A timber trestle, if maintained by partial replacement, may be assigned a service life equal to that of the railroad line, although no part of the trestle may last more than a fraction of that time. If it is to be renewed as a whole, however, its service life will closely agree with that of the timber itself. In the first instance, the annual maintenance allowance must be sufficient to cover all partial replacements; in the latter case, maintenance will be limited to surfacing, replacement of defective timbers, etc.

Consideration should also be given to the possibility of future line revision or abandonment in forecasting the service life of the proposed work. When there is any occasion for doubt, a conservative estimate of service life should be made.

In any comparison involving differing fire hazards, it is proper to include this element of expense, if it can be evaluated. In many cases, damage or loss of a facility itself will not be as important a factor as the assumed accident, delay and detour costs incident to traffic.

2.3.3 Methods of Analysis

The two methods of analysis most favored by statisticians are (1) computation of the annual sum which will cover all present and future investment and maintenance charges on the proposed structure, and (2) computation of the total capital which, if invested, will furnish funds to build and perpetually maintain the facility. The first method will herein be called the Annual Cost Method; the second, the Capitalization Method.

Both methods require assumptions as to interest rates and manner of compounding interest and service life. They require the use of formulas, or tables, which can be found in any engineering economics reference book. A third method, based on straight-line depreciation, is also widely used and is illustrated in the examples.

In projects of such magnitude that special loans must be obtained, the probable terms of such loans will govern the interest. In ordinary projects, the money may be taken from current earnings or working capital. The interest rates should be based on the value of the railroad's money at the time of the proposal, since the comparison demonstrates the relativity of one proposal to another.

The three methods are explained in greater detail as follows:

1. Annual Cost Methods—The annual cost is the sum of (a) simple interest on the first cost; (b) an annual sum which, with compound interest added, will accumulate a sinking fund equal to the first cost or the replacement cost at the end of the service life; and (c) the estimated average annual maintenance expense.

2. Capitalization Method—A fund is computed which is the sum of (a) the first cost of the project; (b) an amount on which the accumulated compound interest, exclusive of the principal, will equal the first (or replacement) cost of the project at the end of its service life; and (c) an amount on which the simple interest equals the average amount required yearly for maintenance. Amount (c) is the estimated annual maintenance divided by the (decimal) rate of interest. Theoretically, with unchanging costs and interest rates, the total fund so accumulated will build the structure and provide for its perpetual maintenance and periodic replacement in kind.

(In investment accounting, sinking fund usually amortizes the original investment, so that accounts will be cleared of any overlapping charges when a replacement is to be financed. Usually, in methods (1) and (2) assumption of a different cost level for future replacement is considered too speculative for conservative accounting. However, in comparing a structure of short service life with one which may extend through two or more renewals of the first, the future cost of such renewals during the life of the more permanent alternative is of concern in the comparison. If changing cost levels are considered to be definitely indicated, items (b) in the foregoing methods should be based on future replacement cost rather than on present cost. This may be important in affecting the validity of the comparison).

3. Straight-Line Method—The straight-line depreciation method of comparative analysis, while mathematically only approximate, is frequently used for its simplicity. It involves the division of first cost by the estimated service life. To this annual charge, interest and maintenance are added. In keeping with the simplicity of the method, the reduced interest on the diminishing principal may be approximated by figuring straight interest on one-half the total cost. Maintenance cost is added as under the annual cost method.

While computations by the straight-line method can be made without involved calculations, or reference to tables, this method is not ordinarily recommended. It is more approximate than methods (1) and (2) and does not permit present and future work to be considered in correct relationship. This can be done under the first two methods by computing the present worth of future expenditures. Thus, work at various future dates may be brought to a common basis for comparison.

This discussion has purposely not included economic formulas or interest tables. There are numerous texts on engineering economics that go into greater depth than is permitted here. (See 2.3.3.1).

Examples of Use of Methods of Analysis:

Example 1—A pile trestle is near the end of its service life. It can be maintained for 2 years at a cost of $4,000, or replaced with a creosoted open-deck trestle having an estimated life of 35 years, at a cost of $36,000, or replaced with earth fill and a concrete culvert, having an assumed life of 80 years, at a cost of $54,000. What is the economical thing to do?

Solution of Problem (Assumed Interest Rate 12 Percent)

	Repairs	**Treated Open-Deck Trestle**	**Fill and Concrete Culvert**
Given:			
Estimated life	2 years	35 years	80 years
Estimated cost	$4,000	$36,000	$54,000
Annual maintenance (average)		$ 350	$ 200
1. Annual Cost Method:			
Interest	$ 480	$ 4,320	$ 6,480
Sinking fund	$1,887	$ 84	$ 8
Maintenance		$ 350	$ 200
Total Annual Cost	$2,367	$ 4,754	$ 6,688
2. Capitalization Method:			
First cost	Not	$36,000	$54,000
Capitalized replacement	Applicable	$ 695	$ 6
Capitalized maintenance		$ 2,917	$ 1,667
Total Capital		$39,612	$55,673
3. Straight-Line Method:			
Annual proportion of cost	$2,000	$ 1,029	$ 675
Interest	$ 240	$ 2,160	$ 3,240
Maintenance		$ 350	$ 200
Total Annual Cost	$2,240	$ 3,539	$ 4,115

The computations are as follows:

1. Annual Cost Method—Repairs. Interest, 0.12 × $4,000 = $480. Sinking fund for 2 years, 0.47170 × $4,000 = $1,887. Maintenance, none (included in the $4,000). Total annual cost, $2,367. Treated trestle: Interest, 0.12 × $36,000 = $4,320. Sinking fund for 35 years, 0.00232 × $36,000 = $84. Maintenance, $350. Total annual cost, $4,754. Fill and culvert: Interest, 0.12 × $54,000 = $6,480. Sinking fund for 80 years, 0.000139 × $54,000 = $8. Maintenance, $200. Total $6,688.

2. Capitalization Method—Treated trestle: First cost, $36,000; capital to produce $36,000 every 35 years. 0.01931 × $36,000 = $695; capital to produce estimated maintenance of $350 per year, 350 ÷ 0.12 = $2,917; total, $39,612. Fill and culvert. First cost, $54,000; capital to produce $54,000 every 80 years, 0.00012 × $54,000 = $6; capital to produce $200 per year for maintenance, $200 ÷ 0.12 = $1,667; total $55,673. (A capitalization of the repair alternate, cannot be considered).
3. Straight-Line Method—Repairs: Annual proportion of total cost, $4,000 ÷ 2 = $2,000; interest 0.12 × $4,000 ÷ 2 = $240; Maintenance (included in the $4,000). Total, $2,240. Treated trestle: Annual proportion $36,000 ÷ 35 = $1,029; Interest, 0.12 × $36,000 ÷ 2 = $2,160; Maintenance, $350. Total, $3,539. Fill and culvert: Annual proportion $54,000 ÷ 80 = $675; Interest, 0.12 × $54,000 ÷ 2 = $3,240; Maintenance, $200. Total $4,115.

By methods (1) and (3), the comparison indicates that the present structure can be economically carried 2 years longer by repairs; methods (1), (2) and (3) indicate that there would be some economical advantage to rebuilding it as a treated pile trestle rather than filling it. However, the elimination of fire risk by filling, though not set up in the comparison, might well be adjudged of value enough to make filling preferable. If the structure in this location might be affected by line change or abandonment, the shortened service life of the fill and culvert would give the trestle a more decided economic advantage.

Example 2—On a projected new route, estimates have been made for a steel bridge on concrete substructure, and for an alternate treated timber ballasted-deck bridge, as follows: Steel bridge, cost $117,000, life 75 years; timber deck $4,000, life 35 years; estimated annual maintenance, $300, including painting. Timber bridge cost $90,000, life 45 years; estimated maintenance $400 per year.

Solution of Problem (Assumed Interest Rate 12 Percent)*

	Steel Bridge		Timber Bridge	
1. Annual Cost Method				
Interest	0.12 × 121,000	$14,520	0.12 × 90,000	$10,800
Sinking fund	0.00002 × 117,000	2	0.00074 × 90,000	66
	0.00232 × 4,000	9		
Maintenance		300		400
Total		$14,831		$11,266

*The I.C.C. at times develops the cost of capital that may be used for opportunity costs in connection with line abandonments.

	Steel Bridge		Timber Bridge	
2. Capitalization Method:				
First cost		$121,000		$90,000
Capitalized replacement ..	0.00020 × 117,000	23	0.00614 × 90,000	553
	0.01931 × 4,000	77		
Capitalized maintenance	$300 ÷ 0.12	$ 2,500	$400 ÷ 0.12	$ 3,333
Total		$122,600		$93,886
3. Straight-Line Method:				
Annual proportion	117,000 ÷ 75	$ 1,560	90,000 ÷ 45	$ 2,000
	4,000 ÷ 35	114		
Interest	0.12 × 121,000 ÷ 2	$ 7,260	0.12 × 90,000 ÷ 2	$ 5,400
Maintenance		300		400
Total		$ 9,234		$ 7,800

The comparison shows by all three methods that the treated timber ballasted deck bridge is not only lower in first cost, but also more economical in the long run. Therefore, in this instance, the timber bridge should be constructed unless the relative fire immunity of the steel bridge is considered to have an annual value of over $3,500.

Example 3—A large steel bridge will require heavy repairs and renewals which could be programmed approximately as follows:

This year $100,000
Next 4 years .... $ 30,000 per year
Tenth year ..... $ 70,000 (this is an average date for a probable series of further repairs more extensive than ordinary maintenance.)

It is anticipated that the railway line has a forseeable useful life of 40 years, and that no other renewals will be needed during this time, other than an average maintenance cost of $3,000 annually, which includes painting, pier protections, track upkeep, etc. If the bridge is abandoned in favor of an available alternate route, the cost of demolishing it will be $50,000 in excess of salvage. New connections will cost $5,000. The problem is, how much can we afford to pay in annual charges for the use of the alternate route? (It is assumed that there is no difference in mileage, or train operation and other costs, and no operating objection.)

Expenditures for Continued Use of Existing Bridge

	Expenditure	Present Worth Factor	Amount (12% Interest)
This year	$100,000	1.00000	$100,000
One year hence	30,000	0.89286	26,786
Two years hence	30,000	0.79719	23,916
Three years hence	30,000	0.71178	21,353
Four years hence	30,000	0.63552	19,066
Tenth year hence	70,000	0.32197	22,538
Present worth of programmed renewals			$213,659
Less alternate cost of demolition and connections			55,000
New present worth of amount to be saved by abandonment			$158,659
Annual cost to be saved by abandonment:			
Interest	0.12 × $158,659		$ 19,039
Fifty-year sinking fund	0.00042 × $158,659		67
Annual maintenance			3,000
Total			$ 22,106

Hence, if it appears possible to obtain the use of an acceptable alternate route for an annual charge, for rental and maintenance, of $22,106 or less, this possibility should be thoroughly investigated before undertaking heavy work on the existing bridge. (In some instances, removal of the structure would result in a reduction of taxes which could be added to the saving.)

The foregoing problems have been prepared for illustration only, and are not intended to imply any intrinsic economy in one kind of construction over another. Each case must be analyzed independently, except where acquired judgment, or management policy, may make certain of the comparisons unnecessary.

2.3.3.1 References:

(1) Hay, W. W. *Railroad Engineering*, John Wiley & Sons, New York, 1982.

(2) Grant, E. L. and Ireson, W. G. *Principles of Engineering Economy*, The Ronald Press Company, New York, 1960.

(3) DeGarmo, E. P. *Engineering Economy* (4th Edition), The Macmillan Company, New York, 1967.

(4) Thuesen, H. G. and Fabrysky, W. J. *Engineering Economy* (3rd Edition), Prentice Hall, Inc., Englewood Cliffs, New Jersey, 1964.

(5) Railway Systems and Management Association, *Engineering Economic Analysis in Railroad Planning and Operations*, Chicago, 1969.

2.4 ESTIMATING

The step between "Program Development" and "Budget Development" is "Cost Estimation"of the components of work which make up the program. This costing of work units is integral to the budget process. The budget process is covered in detail in Chapter 11 Part 4 and will not be re-developed here. However, the important relationship between these two subjects, Estimating and Budgeting, cannot be over emphasized.

2.4.1 Unit Cost

When analyzing the economics of railway construction and maintenance activities, it is necessary to develop the unit costs of various methods and procedures to ensure the same incremental costs be included in the formulation of cost per unit of work for each method considered. Chapter 11 Section 1.3 "Definition or Unit of Property" briefly defines 'unit of property' and 'cost of each unit.'

Unit cost includes the cost of labor, equipment, material and all other costs incurred in a particular operation.

a) Labor—This cost should include all the wages and expenses for those employees performing work on the activity being analyzed. Included in this group are the foreman and employees directly performing the task, i.e. rail installation, tie installation, switch renewal, etc., as well as any wages for supervision above the rank of foreman whose time is dedicated solely to the specified function.

Since work rules vary considerably on different properties in regard to fringe benefits, facilities furnished, travel time, mileage, etc., all items of expense must be considered if paid for as wages.

Total labor cost per unit of work performed may be determined by adding the following and dividing the total by the units of work completed:

Cost of Supervision Above Rank of Foreman Salary + Benefits + Expenses	$ ________
Cost of Foreman Total Wages + Benefits + Expenses	$ ________
Cost of Employees Below Rank of Foreman Total Wages + Benefits + Expenses	$ ________
Total Labor Cost	$ ________

b) Equipment—In order to develop the cost of equipment per unit production, the following information must be known:

1. Name and Description of Machine.
2. Date Purchased New.
3. Initial Cost.
4. Estimated Gross Salvage Value.
5. Average Useful Life.
6. Interest Rate.
7. Taxes and Insurance (Refer to Chapter 11 Part 3).
8. Annual Maintenance Cost.
9. Annual Cost of Fuel and Supplies.
10. Average Number of Days Machine is Utilized During the Year.

With the information known, the cost of operating any capital machine can be developed by the following procedure:

$$\text{Depreciation} = \frac{\text{Initial Cost} - \text{Estimated Gross Salvage Value}}{\text{Average Useful Life in Years} \times \text{No. of Days Used Per Year}}$$

$$\text{Maintenance Costs} = \frac{\text{Annual Equipment Maintenance Costs}}{\text{Number of Days Used Per Year}}$$

$$\text{Fuel and Supplies} = \frac{\text{Annual Cost of Fuel and Supplies}}{\text{Number of Days Used Per Year}}$$

The sum of these three items (taxes and insurance should also be included) may be used as the total cost per day for each capital machine used in an operation. The total equipment cost for any operation is the summation of the daily costs for every capitalized piece of equipment multiplied by the days utilized in the particular operation.

c) Material—The cost of material includes the actual or average unit price of the components being installed (e.g. ties, spikes) as well as freight and material handling costs. The material handling costs could include an overhead expense for the Stores or Material personnel who receive, store, and deliver the components beyond those captured in the labor costs identified in a) of this section.

1. Unit Material Cost = Sum Total of Average Unit Prices of all Components Used in Operation.
2. Material Handling Cost = Overhead Percentage × Unit Material Cost.

   Total Unit Material Cost = 1. + 2.

$$\text{Unit Cost} = \frac{\text{Total Labor Cost} + \text{Total Equipment Cost}}{\text{Number of Units Completed}} + \text{Total Unit Material Costs}$$

Costs for the following activities should be developed in the units shown:

Activity	Cost Per
Rail Laying	Lineal Foot of Rail
Tie Installation	Tie
Surfacing Track	Track-Foot
Ballasting	Ton/Cu. Yd.
Ballast Cleaning (shoulder)	Track-Foot
Plowing or Undercutting (not including tie renewal)	Track-Foot
Road Crossing Installation or Renewal	Track-Foot
Turnout Construction (incl. ties)	Turnout (specify T.O. size)
Turnout Renewal (steel only)	Turnout (specify T.O.size)
Field Weld	Weld
Shop Weld	Weld
Track Construction	Track-Foot

Note: Unit costs for any other activity can be determined in the same manner as outlined above.

2.5 CONTROL

2.5.1 General

Track and structures work performance and expenditures must be analyzed regularly to rate the effectiveness of the program. This analysis has two major components; "analysis of cost" to ensure proper control over all project expenditures; and "analysis of performance" to ensure proper control over schedule and labor utilization. Chapter 11 Section 4.6 "Control Functions" describes the former and this section will develop the latter. However, both chapters are equally important in terms of evaluating the effectiveness of a program and its associated budget.

2.5.2 Performance Standards/Permanent Data Base

a) Develop a "Methods Description" for each major operation. This is a step-by-step progression of work identifying personnel and equipment utilized and function performed. Schematics of men and equipment are very useful in this function.

b) Establish a time standard for each Methods Description e.g. man-hour/tie and man-hour/lineal foot of rail, etc.

c) Measure performance by comparing the actual production versus the standard identified in the Methods Description.

d) Timely reporting of essential information from the field is necessary for the evaluation of performance.

e) Subsequent time studies in the field are useful to refine the method and improve performance.

f) Utilize historical records as the data base for developing and adjusting performance standards for site specific conditions. This data base should include all production information related to improvements, construction, and maintenance.

2.5.3 Monitoring Results

a) Quantitative:

1. Use of regular performance reports on which is listed each Methods Description and actual vs. standard production currently and on a year-to-date basis is useful.
2. Performance is also measured by utilizing graphs, charts, schematic drawings and plotting progress against scheduled target dates.
3. Regular or periodic updating of these control devices is necessary. Computers are very useful in accomplishing this task.

b) Qualitative:

1. Inspections should be made both before and after the work is performed. These inspections may range from the walking visual type, or riding trains to utilization of sophisticated track geometry analyzers.
2. Annual comparison of pre- and post-work defects identified in terms of cause and quantity are useful in determining the effectiveness of the program.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Part 4

Equated Mileage Parameters

4.1 PURPOSE

The equated mileage parameters provide a means to establish comparability of track maintenance. They allow the user to make comparison of track maintenance for sections of track that are changing in use and/or physical composition and between existing or planned track sections.

4.2 DEFINITION

The parameters consist of decimalized numbers representing the type of track, track components, track geometry and traffic loadings. The factors assigned to each of these items are further refined for the effect of speed and distributed by the Federal Railroad Administration (FRA) speed classifications. Unity (1.00) has been assigned as the factor for Class 4, first main track. Other factors were derived by comparing the fixed and variable expenditures required for maintaining the particular item relative to that of Class 4 first main track.

Track maintenance comparisons are made by totaling the factors that represent each section of track being studied. The resulting numbers are related to provide a ratio. The ratio is the comparative level of maintenance required for one track versus the other. Cost comparison can be made if the maintenance cost for one of the track sections being studied is known. The comparable cost is obtained by applying the ratio.

4.3 The equated mileage parameter factors are to be used as a starting point for analysis. It is also suggested for today's world of roadway rationalization and rapidly changing traffic flows, axle loadings and densities, that assessment of economics must be site specific and time sensitive. For the most part electronic information systems, track assessment systems and computer systems permit many roads to measure, distribute and redistribute resources in a business like manner. Specific items that should be considered when using these parameters include:

a) This approach, implies a steady state life cycle condition for major track components. For railroads or major corridors, the implication may be true; however, between specific study areas, conditions and the associated labor and materials cost differentials can be significant. If maintenance programs are cyclical, component condition assessment is necessary to determine the point in the cycle for each specific study area.

b) Many factors important to the overall maintenance requirements of a rail line are not included in these formulas and are not uniform from one track segment to the next. They include:

1. Structures
2. Grade
3. The nature of the subgrade (track support modulus).
4. Prevailing weather; including snowfall and rainfall.
5. Type of tie.

c) Tables only reflect annual tonnages of up to and above 35 mgt. The maintenance requirements created by tonnages over 35 mgt annually are significant. The effect of this additional tonnage is non-linear and unquantifiable in this kind of exercise.

d) Tables reflect unit train usage of under 5 trains per day and over 5 trains per day. As in number 3 above, they are not adequate to cover unit train utilization at higher levels. Tables do not reflect the implications of high volumes nor the implications of traffic mix, i.e. the costs of maintaining heavy haul routes to also accommodate high speed intermodal and passenger traffic. An expanded analysis based on these parameters should deal with the entire traffic and wheel load spectrum.

4.4 TABLES

Table 1: Track Type and Track Components

The total factor for track type and its components is found by adding the factors representing the track section to be studied.

Table 2: Track Component, Track Geometry and Traffic Loading

The factors in the table are applied to the factors in Table 1 to adjust for their effect on track maintenance. No upper limit for over 5 unit trains per day has been provided. This factor is intended to be used with reason and not for the extreme.

Table 3

This tabulation permits a comparison between various FRA track classes in relationship to the annual tonnages the track carries. It uses Class 4 track with 20 to 25 million gross tons per year as the unity figure. This is to be used independently of Tables 1 and 2. No upper limit for over 35 MGT has been provided. This factor is intended to be used with reason and not for the extreme.

Note: Equated mileage parameter factors to be used have not changed from those currently in the Manual, therefore they are not included here. A copy of the factors and examples to be included in the new Part 4 are available by writing to A.R.E.A. headquarters and enclosing $2.00.

Proposed 1991 Manual Revisions To Chapter 27—Maintenance of Way Work Equipment

Proposed revisions to Chapter 27, Part 1 include revisions to the recommended color specifications for painting M/W equipment, a rewrite of the specifications for the care and operation of M/W equipment, and a substantially amplified rewrite of the specifications for wire rope as used on roadway work equipment. Changes to Part 2—Roadway Machines include a rewrite and replacement with a separate set of specifications for track motor cars and railway push cars. Proposed material for Parts 1 and 2 follow, except for the wire rope specifications which are available by writing to A.R.E.A. headquarters and enclosing $2.00.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Part 1

General

AREA Yellow

Recommended Colors for Painting Motor-Cars, Roadway Machines and Work Equipment

The most suitable colors for painting Motor Cars, Roadway Equipment and Work Equipment are as follows:

Motor Cars	Yellow*
Roadway Equipment	Yellow*
Roadway Work Equipment (cranes, etc.)	Yellow*
Work Equipment (Jordan Spreaders, etc.)	Mineral Red

*The yellow recommended is the same Standard Yellow as used for Highway Signs of the U.S. Bureau of Public Roads. The predominant colors of equipment may be a specified color, but some parts of components may require custom painting (reference AREA Committee 27 Specifications for On-Track Roadway Equipment Section 17-Paint). Some of the more notable items are listed below:

Gasoline tank	Red
Diesel Fuel tank	Green
Hydraulic Reservoir	Blue
Coolant Reservoir	Gray
Lifting Lugs	Black
Safety Locks	Red

It should be understood that various Railroads may have special painting requirements which will supersede the above recommended practices or guidelines.

General Care and Maintenance of Maintenance of Way Equipment

The varying conditions on different railroads does not permit the universal acceptance, in all details, of any specific outline or an organization for the use, maintenance and repair of Maintenance of Way equipment. To determine the proper organization best adapted to produce maximum service and productivity, at a minimum cost, from its fleet of Roadway Work Equipment each railroad must review and analyze various conditions which will greatly influence these factors. Some of the more important areas are listed below.

1. The quantity and age of the major and minor units of Roadway Equipment.
2. The level of mechanization and sophistication of the equipment.
3. The type of managerial organization established for utilizing, supervising and maintaining the equipment.
4. Geographic location and total trackage involved with the railroad.
5. Organization of Roadway Equipment Repair Shops, i.e., centralized or decentralized, Engineering or Mechanical jurisdiction, manpower, etc.

However, there are certain principles in the use and maintenance of machinery which will be found desirable, if not essential, if the equipment is to be maintained and used economically. Special attention should be directed to the following areas:

1. The organization for supervising and maintaining Maintenance of Way equipment should be headed by a practical railroad man, with sufficient executive ability and sound mechanical knowledge to supervise the maintenance and operation of all equipment on the system. The Work Equipment Department should have authority, and sufficient personnel to institute and enforce regulations for the maintenance and operation of the equipment. Duties should embrace direct or indirect control of mechanical details of the equipment, in both field and shop, the supervision of maintainers, involvement with necessary reports and managing data base information. He should work closely with the Maintenance of Way Supervisory forces in the assignment and use of the equipment. He must also work very closely with the Purchasing and Material Department as it relates to acquisition of new equipment, component parts and the distribution of supplies required for the maintenance and repair of equipment.
2. It is desirable that adequate instructions for the care and operation of Maintenance of Way equipment be issued. Such instructions, developed by the AREA, were first published in the proceedings in 1947 and were later reprinted in handbook form under the title "Manual of Instructions for Care and Operation of Maintenance of Way Work Equipment." This manual is presently in the process of being revised.
3. Cooperation on the part of Maintenance of Way supervisory officers in seeing the instructions are carried out are of the utmost importance. This cannot be secured unless each such officer recognizes the importance of the work he is supervising in an effort to keep the equipment in operation. In order to achieve maximum results of equipment productivity and availability, through proper operation and preventive maintenance procedures and practices, the local and upper management levels must give their full support to the program.
4. Prevention of disabling conditions in any machine is as truly maintenance as is the correction of such conditions after they have developed; and prevention will save the loss of time and money required for repairs.
5. As a result of following a thorough preventive maintenance program, the need for emergency and/or unscheduled repairs can be substantially reduced. A preventive maintenance program is basically a repair prior to failure philosophy and can be characterized by the following:
   a) Keeping the machinery or equipment clean.
   b) Operating the machinery safely and within its limit of capacity.
   c) Well controlled lubrication program.
   d) Performing required inspection, adjustments and scheduled maintenance at the proper intervals.
   e) Utilizing a formal record keeping system i.e. operators and maintenance personnel, daily log, machine history file, failure reporting system, cost involved with equipment use, which will provide a solid foundation for a computerized record keeping and cost capturing system.
   f) Ongoing training program for operator and service/maintenance personnel.

6. Material Department operations should be properly located and adequately stocked so that repair parts, when needed, can be supplied with the least delay. This area can be streamlined with the use of highway type van trailers, properly sized, well organized, and adequately stocked to eliminate some of the current problems associated with using rolling stock tool cars. Some of these problems are delay in timely spotting of the car at the work site and damages to the parts inventory due to rough handling. The use of relief machines and power plants will reduce delays in the event of machine failures.

7. In scheduling the shopping of machines for major repairs, consideration should be given to the capacity of the shop as well as the conditions of the machine. In so far as possible, the machines used in seasonal work should be overhauled during the slack season.

8. Shops for the repair of roadway equipment should be centrally located and entirely under the control of Maintenance of Way Department. Roadway Equipment Shops should be equipped with the necessary tools, shop machinery and in general provide repairs in the most timely and cost effective method.

9. The expense of maintaining Roadway Equipment can be reduced through the adoption by each railroad, of the fewest number of makes and types of machine required to meet its needs. Such a restriction to adopt its standards will reduce investment in stock parts and lower maintenance costs.

10. Adequate reports and records should be prepared as a means of maintaining close check on the use being made of the equipment, the care of it, and to assist in passing judgment on purchase of new equipment.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Part 2

Roadway Machines

Specifications for Track Motor Cars

1.0 GENERAL DESCRIPTION

1.1 This specification covers a TRACK MOTOR CAR for railway use on 4′8-1/2″ standard gauge track, constructed with bolted and/or continuous welded rail up to 136 lbs, head contact and/or head free, on wood and/or concrete track ties, in slag and/or crushed rock ballast, on ballast deck and/or timber deck bridges.

1.2 All equipment and components furnished under this specification shall be new, unused and of current manufacture, and shall equal or exceed the following unless otherwise specified.

1.3 Design, construction and materials used in the unit shall assure that it will function reliably and efficiently in sustained operation under hard usage in an adverse railway environment.

1.4 Each unit shall be free from defects such as incomplete welds, welds that cross welds, corrosion, loose or improper fastenings, leaks or contamination and any other defects that could impair its operation or serviceability.

1.5 The design of the unit shall provide for ease of service, replacement and adjustment of components, including filters and fluids, with a minimum disturbance of other components.

1.6 All units shall comply with all Federal and State/Provincial environment, safety and health regulations and the current AREA specifications in force at the time of delivery. In the event of conflict or variation between the regulations and these specifications, the most restrictive requirement will apply.

2.0 OPERATIONAL REQUIREMENTS

2.1 Units must be capable of seating the following: **Inspection** - two men; **Section** - four men; and **Gang** - six men; safely and comfortably, and have room for two additional men in emergency situations. The unit must have sufficient power and speed to enable railway employees to conduct normal operation and maintenance procedures (inspections, pulling loads of rail, ties, etc.)

2.2 The unit is to be equipped with a drive system that is suitable for the intended use. Manufacturer is to provide details of this drive system in the quotation.

2.3 Gross Weights:

a. Gross weight of the inspection car is not to exceed 950 lbs (empty).

b. Gross weight of the section car is not to exceed 1,150 lbs (empty).

c. The gross weight of the gang motor car, complete with cab and all accessories, is not to exceed 2,150 lbs (empty).

2.4 Lifting Weights:

a. For inspection car, lifting weight is not to exceed 200 lbs.

b. For section car, lifting weight is not to exceed 200 lbs.

c. The lifting weight of the gang motor car, with lift handles fully extended to the normal position, is not to exceed 400 lbs.

2.5 Manufacturer is to supply *and* apply "Safe Lifting Procedure" decals to both ends of the car, between the lifting handles.

2.6 Units must be insulated against activation of track signals at all times.

2.7 The unit must also be equipped with the following:

a. Demountable pressed steel wheels (16" x 5/16" x 4-1/2").

b. Safety rails and front pipe skids.

c. Extension lift handles with a device that will not allow the handle to vibrate out during travel.

d. Blade type adjustable rail sweeps on the front and rear.

e. Bumper bars - front and rear.

f. Safety coupler.

2.8 Inspection motor cars must also be equipped with two cushioned seats with backrests (one each side).

3.0 ENGINE

3.1 The engine supplied for this unit is to meet all horsepower and rpm requirements of the work mode and travel mode of the unit within the continuous rating of the engine.

3.2 The engine's intermittent rating power availability is to be reserved and available for extreme power requirements (i.e., extra high track curvature and excessive adverse grades). The latest S.A.E. Diesel Engine Rating Code is to apply.

3.3 Please state the make, model and horsepower rating of the engine supplied, and provide the unit's horsepower requirements, under maximum load in the work mode and in the travel mode.

3.4 Please provide the engine's fuel consumption figures, in Imperial and U.S. gallons per hour, at the engine's maximum intermittent output rating, *and* maximum continuous output rating.

3.5 Please provide a detailed list of the engine manufacturer's service and parts supply outlets that are available.

3.6 Diesel engines are to be fitted with a one-piece combination silencer/spark arrestor with rain cap, adequately sized for the engine supplied, and must conform with the eight-hour exposure of applicable Noise Control Regulations of the Federal, State, Local or Labor Code.

3.7 The engine is to be equipped with a spin-on type oil filter and fuel filters.

3.8 Engine starting shall be by a positive type of gear engaging starter. A minimum 75 amp. hour battery is to be provided.

Engine shall start within 2/3 of the cranking system's time rating.

3.9 Engine offered shall provide ample power with clean exhaust for all equipment functions under the following conditions:

a. Altitude - 0 to 900 meters ASL

b. Temperature - Minus 40 C (-40°F) - Plus 40 C (104°F)

c. Atmosphere - Extreme dust to 1" rain per hour

3.10 Engine compartment to be fully enclosed, sound dampened and lockable with hook and hasp type fixtures for use with padlocks. All covers are to be hinged to facilitate ease of servicing.

3.11 Unit must have sufficient power to propel itself up an equipment loading ramp onto a railway flat car (approximately 6% grade).

4.0 FRAME, WHEELS, AXLES AND BEARINGS

4.1 The frame, axles, wheels and bearings must be designed to withstand maximum stresses induced under normal operating and traveling conditions. The machine shall withstand a free drop of six inches without damage.

4.2 All welding and joint preparation is to follow the latest welding code.

4.3 Lifting points (suitable for lifting the machine *level* with equal length cables) and jacking pads must be provided and *clearly indicated.*

4.4 Unit is to be protected from undercarriage damage by derail skids front and rear. Stop blocks are to be welded inboard and outboard of rail head area to prevent unit from leaving track area in case of derailment. Skids are to be manufactured in such a way as to not deform should machine derail.

4.5 Wheels and axles are to be in alignment and gauge, with the following allowable tolerances:

a. Gauge: 1/8″ maximum tolerance (56.375″-56.5″)

b. Tram: ± 1/8″ maximum tolerance.

c. Diagonal measurement:
   1. ± 3/16″ maximum tolerance for wheel bases up to 9 feet.
   2. ± 1/8″ maximum tolerance for wheel bases greater than 9 feet.

4.6 No excessive vibration, wobble or eccentric action is to occur at any speed for which the machine is intended.

4.7 Wheel contour and gauge shall comply with the standards set by AREA (Engineering Division) or AAR (Mechanical Division) as required for size and type of wheels furnished. (See Fig. 1)

4.8 Wheels shall be firmly fixed to axles that are supported in anti-friction bearings.

4.9 Axle material is to have a minimum Charpy value of 20 ft.-lbs at minus 30 degrees F.

4.10 The axle sprocket (if applicable) shall be of the split sprocket type and to be connected to the axle by means of a taper-lock bushing and hub (similar to the Browning Taper-Loc).

4.11 Chain drive (if applicable) is to be double roller chain with chain lubricator.

5.0 SUSPENSION

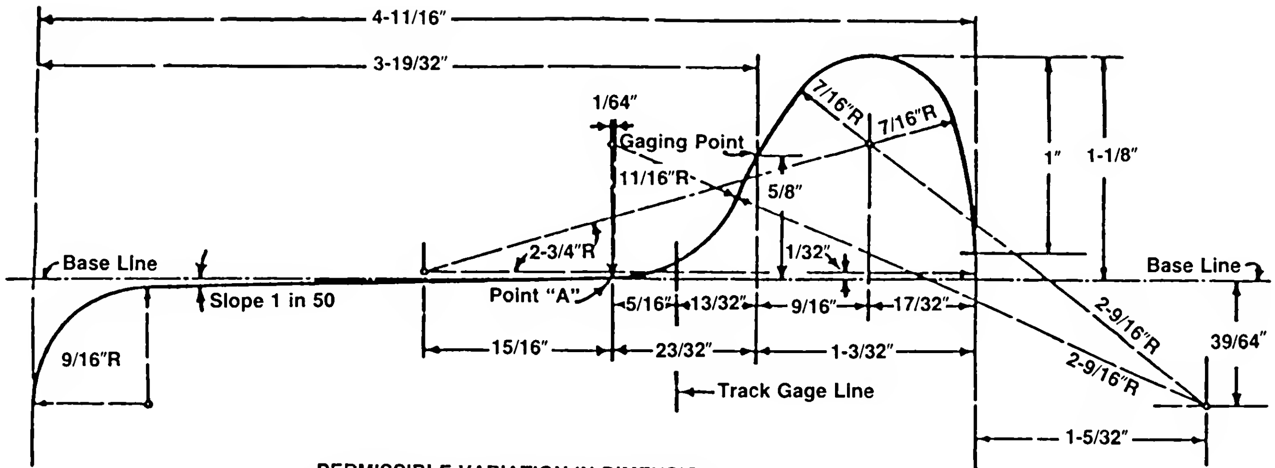
5.1 A suspension system is to be provided to ensure a safe and comfortable ride (coil spring, leaf spring, air bag, etc.).

5.2 The suspension must be sufficiently flexible, or at least *one axle must be spring mounted,* to allow any wheel to drop below the plane established by the other three wheels. This amount of drop in inches shall be equal to or more than the wheelbase in feet divided by eight.

6.0 FUEL TANK

6.1 It must be adequate to provide fuel for 12 hours operation of the engine producing at its maximum continuous horsepower rating. If two or more tanks are provided, fillers are required on all tanks to facilitate faster fueling.

6.2 Fuel tanks shall be in a location to eliminate any fire hazard from spilling, overflow or draining of fuel and shall be protected from impact damage due to collision.



PERMISSIBLE VARIATION IN DIMENSIONS

DIMENSIONS	NOMINAL	OVER	UNDER
Flange height	1-1/8"	1/16"	1/16"
Flange thickness	1-3/32"	1/16"	1/16"
Depth of metal back of flange	1"	1/8"	1/8"
Gaging point to beginning of tread slope	23/32"	1/32"	1/32"
Gaging point to centerline of nose curve	9/16"	1/16"	1/16"
Rate of slope on tread	1 in 50	1 in 40	flat
Diameter of wheel (measured at Point "A")	16 or 20	1/16"	1/16"
Radii of curves	as shown	1/16" either way at any point of theoretical contour	

Fig. 1 —AREA wheel and flange for 14-in, 16-in and 20-in wheels on motor cars, trailers and push cars.

6.3 Diesel fuel and gasoline tanks are to be equipped with hook and hasp type fixtures for use with padlocks.

6.4 The filler opening is not to be located such that a filler can or nozzle could possibly contact an electrically-energized component or connection.

6.5 Gas lines must be equipped with an in-line fuel filter.

6.6 Diesel fuel systems are to be equipped with a water separator/filter assembly.

7.0 HYDRAULIC SYSTEM

7.1 The system shall conform to the recommendations of the National Fluid Power Association (NFPA), American National Standards Institute (ANSI), and the International Standards Organization (ISO).

7.2 Upon completion of manufacture and before any operation, all parts of the system shall be clean and free of contaminants. Threads, holes, cuts, flares and machining must be deburred and cleaned.

7.3 All fluid must be pre-filtered through a 10-micron nominal or finer filtering system before being added to the system.

7.4 The hydraulic components and the design of the system shall be suitable for the intended service. The system must be capable of maintaining an operating temperature not exceeding 70°C (158°F) at ambient temperatures of 40°C (104°F).

7.5 All return oil (pilot and case drains excepted) must be manifolded and filtered through 10-micron nominal filters.

7.6 Hydraulic hoses are to have a minimum of two wire braid reinforcement (*return lines excepted*) with a bursting pressure safety factor of 4:1, and are to be in accordance with S.A.E. Specification J-517 (latest revision).

7.7 Reusable hose fittings are required throughout the unit (Hydrostatic systems excepted).

7.8 Hoses are *not* to be:

a. Flexed to less than their rated minimum bend radius.

b. Installed or routed to expose them to temperatures above or below their rated operating temperature ranges.

c. Subjected to any twisting, pulling, kinking, crushing or abrasion.

If necessary, hoses subject to excessive abrasion are to be wrapped with an abrasion resistant wrapping or sleeve.

7.9 If tubing is used, it must be steel and SAE 37 degree flared ends are required.

7.10 Tubing and piping is to be mounted to minimize vibration. Tubing bends shall have a radius of *not less than three times the ID*.

7.11 Vacuum at the pump inlets is not to exceed 60 percent of the pump manufacturer's recommendation or four inches of mercury, whichever is less, under normal operating conditions. A test port is to be provided.

7.12 Heavy duty chrome is required on all hydraulic cylinder rods. Please specify the chrome type and thickness.

7.13 Reservoir must be equipped with the following:

a. a lockable drain tap (minimum 3/4″ pipe).

b. lockable suction oil shut-off valves (if reservoir oil level is above pumps).

c. a raised inspection/cleaning cover.

d. a combined thermometer and static fluid level gauge, in plain view, protected from damage and located as near to the intake lines as possible.

e. a 10-micron absolute filtered breather (sealed and pressurized systems excepted).

7.14 Pressure testing tees shall be provided at locations to provide easy access for checking hydraulic pressures on all circuits. Tees are to incorporate a male quick-disconnect coupling, c/w protective cap. An adequately sized gauge connected to an equally sized female quick-disconnect coupling is to be provided and stored in the tool box.

7.15 Hydraulic reservoirs are to be filled with a hydraulic oil as specified by the 'Railroad.'

8.0 PNEUMATIC SYSTEM

8.1 Air reservoirs must be constructed in accordance with the following:

a. The capacity of the reservoir *must* be less than five cubic feet.

b. The diameter of the reservoir *must* be less than six inches.

8.2 Extra reservoirs must be added in parallel if larger capacity is required.

8.3 If the reservoir is greater than five cubic feet capacity and/or greater than six inches in diameter, the reservoir is to be manufactured per the following:

a. A metal tag or badge plate is to be firmly attached to the reservoir indicating the serial number and the authorized working pressure.

b. The reservoir(s) are to be telltale drilled over the entire surface, both shell and head, with standard 3/16″ drill, spaced not more than 12 inches apart, measured longitudinally and circumferentially, to a minimum depth determined by the following formula:

D = 0.6PR/S-0.6P

Where,

D = minimum depth of telltale holes in inches, but in no case less than 1/16 inch

P = design pressure in pounds per square inch

S = 1/5 of the minimum specified tensile strength of the material in pounds per square inch

R = inside radius of the reservoir in inches

c. On horizontal reservoirs, one row of holes shall be drilled lengthwise in a line at the bottom of the reservoir.

d. On vertical reservoirs, one row of holes shall be drilled on a line passing through the lowest point of the reservoir.

e. The holes drilled in each head shall be radially in line with the longitudinal rows of holes in the shell.

f. Flange connections, longitudinal seams or other permanent connections to the air reservoir that interfere with the telltale hole lines or circles must be cleared by at least 1 inch.

g. Each reservoir, after drilling, shall be hydrostatically tested to a pressure at least 25 percent greater than the design pressure, before being installed on the unit.

h. The following information must be forwarded to the System Manager Work Equipment prior to the unit being accepted:

Manufactured by:		
Manufacturer No.	Constructed at:	Date:
Design Pressure:	lbs/sq.in.	Factor of Safety
Authorized working pressure	lbs./sq./in.	
Diameter of Reservoir	Radius of Heads	Top and Bottom
Material of Shell Plates	Minimum of Tensile lbs./sq.in.	
Material of Heads	Minimum of Tensile lbs./sq.in.	
Thickness of Shell Plates		
Thickness of Heads		
Welded or Riveted Construction		
Diameter of Rivets in Shell		
Diameter of Rivets in Circumferential Seams		
Diameter of Rivets in Heads		
Number and Size of Manholes		
Position of Reservoir - Vertical or Horizontal		
Number, Size, Make and Model of Safety Valves		
Location of Safety Valves (on Reservoir, in Supply Line, etc.)		
Safety Valve or Valves Set at		
Telltale Drill Depth		

Attach copy of drawing used for manufacturing reservoir to the affidavit.

8.4 *All* air reservoirs must be provided with an automatic condensation drain valve AND a manual drain valve, located at the lowest part of the reservoir.

8.5 System must be provided with an air dryer *and* a lubricator.

9.0 BRAKE SYSTEMS

9.1 The brakes are to be individually adjustable and hand operated.

9.2 The brake system is to consist of four (4) self-centering shoes with renewable metal liners.

NOTE: ALTERNATE SYSTEMS WILL NOT BE CONSIDERED.

10. TRAVEL SPEED AND PERFORMANCE

10.1 Unit must be self-propelled and must achieve and maintain the following speed parameters in both the forward and reverse directions, on *any* straight or curved, bolted or CWR track rated at 50 mph or more for freight trains:

0% grade - 35 mph
1% adverse grade - 25 mph
2% adverse grade - 20 mph

10.2 Tractive effort/drawbar pull:

a. Inspection and section motor cars must be capable of pulling a load up to 4,000 lbs. at a speed of 20 mph.

b. Gang Motor Cars must be capable of pulling a load of up to 6,000 lbs., at a speed of 35 mph.

11.0 CAB

11.1 Materials

a. Cabs are to be constructed with Vibrin Gelcoat H-604 or equivalent, to a thickness of not less than 20 mils. The body and doors are to be constructed of fire retardant Vibrin Polyester Resin F-1007 or equivalent, to meet A.S.T.M. Self Extinguishing Specifications D-636 (latest revision).

b. Reinforcement is to consist of a layer of 1.5 oz. per sq. ft. chopped strand mat, followed by a layer of 24 oz. woven roving, followed by another layer of 1.5 oz. per sq. ft. chopped strand mat, to make up and approximate laminated thickness of 3/16 inches.

c. All materials used in the construction are to be of top quality and must be rot, rust and mildew proof.

NOTE: *ALTERNATE MATERIALS WILL BE CONSIDERED.*

11.2 Construction

a. All leading edge supports, window frames, door frames and roof, front and rear of cab, are to be reinforced with plywood or other suitable material.

b. All openings, such as doors, windows, engine shroud areas, etc., are to be reinforced with extra layers of chopped strand mat in such a manner as to eliminate cracking in these areas and to add enough rigidity to allow proper closing of doors and installation of window glass.

c. Doors are to have extra reinforcement to reduce flexing and provide a uniform fit, and are to be provided with a good quality weather stripping.

d. Plastic conduit (1/2" ID) is to be molded into the cab interior walls for concealing electrical wiring harnesses.

e. Cabs are to be cast in molds of good construction and finish in order to furnish a good quality and product.

11.3 Finish

a. The interior finish of the cab is to be smooth textured and free from all unsightly and/or sharp protrusions.

b. Interior of cab is to be painted a light blue.

c. Finished Gelcoat shall have a hardness of Barcol 45-55, shall be smooth, glossy, weather resistant, and shall be free of pin holes, bubbles, ripples, cracks or chipping of any kind and shall not appreciably fade or dull in normal service.

d. Color of the cab will be advised and is to be free from any streaking or blotching.

e. All exposed, trimmed or cut edges are to be true to line and smooth.

f. All exposed rivets or bolts are to be free of sharp edges and coated for appearance and protection.

11.4 Windows

a. Front windows (25.5"W × 21" H) and rear window (36"W × 12"H) are to be laminated safety glass in accordance with applicable Motor Vehicle Safety Standards.

b. All side windows are to be 3/16 inch high mar-resistant Lexan or equivalent.

c. Windows in doors are to be approximately 26"W × 14.5"H in the gang cars.

d. All windows are to be mounted to the cab with rubber window channel.

11.5 Doors

a. Doors are to be hinged at the rear to allow for "head-wind" assist in emergency opening.

b. Doors are to be equipped with "T" type door handles c/w latch and striker plate, and located at the midpoint between the top and bottom of the door, at the leading edge, also a hook and hasp fixture for use with padlock.

c. Doors for section car are to be 34.5 inches wide by 46 inches high.

d. Doors for inspection car are to be 28.5 inches wide by 46 inches high.

11.6 Others

Cars *must* also include the following:

a. Front and rear defroster fans.

b. Heavy duty windshield wipers (motors, arms and blades), front and rear.

c. Fire extinguisher (5 lb. dry chemical, ABC type).

d. Interior cab lights (Dominion Auto #72-2802 or equivalent).

e. Fully lighted instrumentation (where applicable):

1. Engine hourmeter
2. Oil pressure gauge
3. Air pressure gauge
4. Water temperature gauge (engine temp)
5. Ammeter
6. Fuel gauge

f. Pre-operation check list and lubricration chart to be displayed in cab (in specified languages).

g. Separate fused, 12/24 volt, 25 watt circuit for a two-way radio.

h. Interior adjustable rear view mirrors.

i. Two containers for manuals and timetables, etc., to be provided.

j. Adjustable sun visors.

Cab and machine to conform to applicable Labor Code, Material Handling Regulations and Noise Control Regulations for 8-hour exposure level (latest revisions).

12.0 STANDARD EQUIPMENT

12.1 Safety

a. All equipment produced should be free from nicks, gauges tool cuts, weld spotter, feather edges caused by cutting or shearing. Sharp corners should be avoided or protected.

b. Hose lines, electrical wires, conduits and such should be adequately clamped. They should be located so that they are not used as hand holds.

c. Mechanical safety locks on all attachments.

d. No component is to be less than 3 inches (76 mm) from top of rail, either between the rails or for 30 inches (762 mm) outside each rail, when in the travel mode.

e. All components that could be a hazard to the operator, mechanic or bystanders are to be protected with a guard.

f. Handrails and/or grab irons are to be provided where it is intended that personnel mount the unit. The lowest step used for mounting the unit is not to be more than 12 inches (305 mm) above the top of rail. Any area that is more than 3 feet (915 mm) above the top of rail, where persons are expected to walk or pass, is to be protected by rigidly fastened handrails, 42 inches (1067 mm) high, with a secondary rail at 24 inches (610 mm) high. This area is also to have a non-skid walking surface.

12.2 Materials

a. All steel plates, shapes, bars and sheets shall be of a quality that has good weldability, high impact resistance and high notch toughness at low temperatures (-20° C/-4° F to -40° C/-40° F). Steel items shall be of alloy and grades normally used for Maintenance of Way equipment. Design of structural members subject to normal working loads shall have a minimum design factor of 2 to 1. If structural members are subjected to impact stresses, a minimum design factor of 3 to 1 shall be utilized.

It is generally recognized this is only a minimum recommended guideline and increased design factors may be required as necessary.

b. All bolted applications must have at least two full threads protruding beyond the nut after the fastener has been properly torqued.

c. All non-ferrous metals shall be of alloys having strength and corrosion resistance suitable for the intended use.

12.3 Electrical

a. Electrical systems shall conform to recommendations of the American National Standards Institute (ANSI) and the International Standards Organization (ISO), where applicable.

b. Upon completion of manufacture and prior to operation, all parts shall be clean and free from scale, rust, water or any contaminants. All material and workmanship must be of good quality for the use intended.

c. Components shall be interchangeable, wherever possible.

d. Except in protected areas, thin wall conduit shall not be used. All cable is to be routed in such a manner as to prevent damage.

e. DC systems, when grounded, are to be negative ground. Battery boxes are to be vented, lockable and are to have a drain hole incorporated.

f. Electrical cabinets are to be weatherproof, and are to be adequately lighted.

g. Interior metal surface walls must be painted with electrical insulating paint or covered with other approved electrical insulating material, and nominal voltages used must be clearly indicated on the outside of the cabinet.

h. Wires are to be equipped with good quality terminals and identified with permanent numbered markers and must be color coded where practical. Terminal strips are also to be plainly marked. All wires must be neatly dressed and clamped.

i. Charging circuit alternator is to be of sufficient capacity to handle full load requirements (i.e., the use of all electrical accessories simultaneously) at idle and full R.P.M.

13.0 MISCELLANEOUS

Unit delivered *must* include the following equipment:

13.1 Concealed master cutoff switch for electrical system (Cole Hersee or equal).

13.2 Battery cable is to be encased at the battery box to prevent wear and shorting.

13.3 Engine ignition switch is to be 4-terminal, spring return, and connected to control all accessories (Delco Model D-1460 or equal).

13.4 Unit must be equipped with a device to prevent starting of the engine if the travel mechanism is engaged.

13.5 Roof-mounted amber *revolving* light with wire mesh vandalism protection (Dominion Auto No. 74-5147 or equal).

13.6* Traveling lights, 2 front and 2 rear, independently operated (Dominion Auto No. 72-5040 with G. E. Sealed Beam No. 4413 or equal).

13.7* Red marker lights, 2 front and 2 rear, independently operated (Dominion Auto No. 70-6070 or equal).

*One pair white, opposite pair red lights to operate simultaneously.

13.8 Dual electric or air horns to the front (Dominion Auto No. 77-7046, air or equal).

13.9 Tool box attached to machine, and any *specialized* tools. (List tools supplied.)

13.10 Axle mounted hubodometer to record actual distances traveled, regardless of direction of movement of machine (Engler model, kilometers).

13.11 Tow bar connections front and rear (14″-plus or minus 1/2″ above top of rail).

13.12 All threads to be U.S. standard.

13.13 All filler and vent caps must be lockable with hook and hasp type fixtures for use with padlocks.

13.14 All controls and machine functions are to be labeled, using universal symbols as outlined by S.A.E. J-298 (latest revision). Specified language labeling will be required on all charts and also locations where universal symbols cannot be used. These are to be on etched plates, firmly affixed to machine.

13.15 Complete sets of all operation, maintenance, parts and service manuals, lubrication data and spare parts list.

Parts and operation manuals are to contain complete and easily read diagrams of all systems on the unit, including schematics for hydraulic, pneumatic and electrical systems and shall employ American Standard symbols and notations.

The maintenance portion of these manuals must include a *"trouble shooting guide"*, listing in order of likelihood those systems or subsystems which should be checked upon failure of any portion of the machine operation. Special tools required for regular maintenance must be listed.

14.0 PAINT

14.1 Units are to be cleaned and prime painted.

14.2 The complete unit must be painted to railway specification with the exception of the following:

- Diesel fuel tanks to be painted GREEN.
- Gasoline tank to be painted RED.
- Hydraulic reservoir to be painted BLUE.
- Wheels, handrails, and steps to be painted BLACK.
- Lifting and tie down lugs to be painted BLACK.
- Jacking pads to be painted BLACK.
- Safety locks to be painted RED.
- Stenciling to be BLACK.

14.3 Units are to be safety striped, using 3M "Scotchlite" Series 1480 (6″ wide) Engineer grade orange/white diagonal sheeting or equal as follows:

a. One stripe across front and rear of unit.

b. One stripe along the complete length of each side.

15.0 STENCILING

15.1 All stenciling must be bilingual (in specified languages).

15.2 Stenciling must be 1 inch standard lettering.

15.3 Unit is to be stenciled with the following information on both sides, in standard and metric measures:

a. Total weight of unit.

b. Overall length.

c. Overall width.

d. Overall height.

15.4 Manufacturer is to affix the railway logo and the machine running number at four locations: front, back and both sides. The logo and running numbers are to be in 3-inch figures. Manufacturer to be advised on purchase order of the running numbers.

16.0 OPTIONAL EQUIPMENT

Quote separately on the following:

16.1 Cab only, manufactured per Item 10 of this specification, not including installation. (replacement cabs)

16.2 Unit per this specification but with 8-man seating capacity. (For Gang Motor Car requirement only)

16.3 Aluminum cab without doors and windows. (For Gang Motor car requirement only)

16.4 Cab heater using coolant/forced air. (For Gang Motor Car requirement only)

16.5 Cab heater using heat from the engine cylinder head. (Provide details with quotation)

16.6 Carburetor de-icing kit and engine oil pan heater.

16.7 Complete set of parts, operation and maintenance manuals in alternate language.

16.8 Itemized price for a complete manufacturer's recommended spare parts package.

16.9 Vandalism covers for windows and instruments when machine is in storage.

16.10 Any other available options.

17.0 GENERAL

17.1 Noise Exposure

Shall not exceed permissible exposure for operators, assistants and workmen for a continuous eight-hour work day. Noise sources and machine cab shall be treated to bring about total compliance.

Provide in writing with your quotation the sound decibel readings (in DBA) at the operator's station, and also in a three-foot grid pattern on all sides of the unit, to a distance of twelve feet, when the unit is under maximum working conditions.

17.2 Delivery

Bid shall specify delivery date of all equipment offered. At the time of order, date will be reaffirmed or a new date established. A manufacturer's representative shall place equipment in service and instruct purchaser's operators, mechanics and supervisors at a location to be specified by purchaser (not necessarily the machine delivery point).

17.3 The manufacturer must instruct those Railway employees, operators and mechanics designated by the Railway, in the operation and maintenance of the machines, so as to permit these Railway employees to maintain the machine at a top level of performance.

17.4 Suppliers of roadway machines are *required* to maintain a stock of parts as per the supplier's list of "recommended spare parts" in sufficient quantity to protect those machines in service (minimum 10 years).

17.5 Non-Compliance

These specifications are not intended to eliminate any product from the bidding. Where equipment does not comply, bidders shall clearly describe each deviation. These specifications are in full effect unless amended in writing by the purchaser. Purchaser reserves the right to reject any bid and the right to accept bids deviating from the specifications.

DATE: ______________________________ 19 __________

Specifications reviewed and completed by:

SIGNATURE:____

TITLE: ____

COMPANY: ____

TO COVER: MACHINE __________________________ MODEL ___________________________

Specifications for Railway Push Cars

1.0 GENERAL DESCRIPTION

1.1 This specification covers a RAILWAY PUSH CAR, for use on 4′-8-1/2″ standard gauge track, constructed with bolted and/or continuous welded rail up to 136 lbs., head contact and/or head free, on wood and/or concrete track ties, in slag and/or crushed rock ballast.

1.2 All equipment and components furnished under this specification shall be new, unused and of current manufacture, and shall equal or exceed the following unless otherwise specified.

1.3 Design, construction, and materials used in the unit shall assure that it will function reliably and efficiently in sustained operation under hard usage in an adverse railway environment.

1.4 Each unit shall be free from defects such as incomplete welds, welds that cross welds, corrosion, loose or improper fastenings, leaks or contamination, and any other defects that could impair its operation or serviceability.

1.5 The design of the unit shall provide for ease of service, replacement and adjustment of components, including filters and fluids, with a minimum disturbance of other components.

1.6 All units shall comply with all Federal and Provincial environment, safety and health regulations, and the current AREA specifications in force at the time of delivery. In the event of conflict or variation between the regulations and these specifications, the most restrictive requirement will apply.

2.0 OPERATIONAL REQUIREMENTS

2.1 The unit must be capable of carrying and hauling any and all loads up to its capacity and must be sturdy enough to be pulled from either end by a track machine, when fully loaded.

2.2 The unit is to be insulated against the activation of track signals.

2.3 The unit is to be constructed of aluminum alloy frame members, with a wooden deck.

2.4 The unit must be equipped with the following:

a. Differential axles on one end only.

b. Tow bar connections at each end.

c. Safety coupler.

2.5 Dimensions (Approx.-Please state actual)

a. Deck size—48″ × 45″ with steel edges for (1,000# cap push car)
48″ × 65″ with steel edges for (2,000# cap push car)
67″ × 84″ with steel edges for (6,000# cap push car)
67″ × 84″ with steel edges for (10,000# cap push car)
48″ × 45″ for 2,000# cap-2 section push car

b. Height above rail—16″ for 1,000# cap push car
16″ for 2,000# cap push car
18″ for 6,000# cap push car
21″ for 10,000# cap push car
8″ for 2,000# cap-2 section push car

c. Length—5′4″ for 1,000# cap push car
7′ for 2,000# cap push car
8′6″ for 6,000# cap push car
8′6″ for 10,000# cap push car

d. Wheel base—36″ for 1,000# cap push car
36″ for 2,000# cap push car
52″ for 6,000# cap push car
52″ for 10,000# cap push car

e. Weight—280 lbs. for 1,000# cap push car
390 lbs. for 2,000# cap push car
690 lbs. for 6,000# cap push car
895 lbs. for 10,000# cap push car
190 lbs. for (95lb/sec.) for 2,000#-2 section push car

3.0 FRAME, WHEELS, AXLES, AND BEARINGS

3.1 The frame, axles, wheels, and bearings must be designed to withstand maximum stresses induced under normal operating and traveling conditions. The machine shall withstand a free drop of six inches without damage.

3.2 All welding and joint preparation is to follow the latest structural welding code.

3.3 Lifting points (suitable for lifting the machine level with equal length cables) and jacking pads must be provided and clearly indicated.

3.4 Wheels are to be pressed steel, 16″ × 5/16″ × 4-1/2″ except on 2 piece, 2,000 lb. capacity unit.

3.5 Wheels and axles are to be in alignment and gauge, with the following allowable tolerances:

a. Gauge: 1/8″ maximum tolerance (56.375″-56.5″)
b. Tram: ± 1/8″ maximum tolerance.
c. Diagonal measurement:

1. ± 3/16″ maximum tolerance for wheel bases up to 9 feet.
2. ± 1/8″ maximum tolerance for wheel bases greater than 9 feet.

3.6 No excessive vibration, wobble, or eccentric action is to occur at any speed for which the machine is intended.

3.7 Wheel contour and gauge shall comply with the standards set by AREA (Engineering Division) or AAR (Mechanical Division) as required for size and type of wheels furnished.

3.8 Wheels shall be firmly fixed to axles that are supported in antifriction bearings.

3.9 Axle material is to have a minimum Charpy value of 20 ft.-lbs. at minus 30 degrees F.

4.0 SUSPENSION

4.1 The suspension must be sufficiently flexible, or at least *one axle must be spring mounted*, to allow any wheel to drop below the plane established by the other three wheels. This amount of drop in inches shall be equal to, or more than the wheelbase in feet divided by eight.

5.0 STANDARD EQUIPMENT

5.1 Safety

a. All components and/or sharp corners or edges that could be a hazard to the operator, mechanic, or bystanders are to be protected with a guard.

5.2 Material

a. All steel plates, shapes, bars, and sheets shall be of a quality that has good weldability, high impact resistance, and high notch toughness at low temperatures (–20°C/–4°F to –40°C/–40°F). Steel items shall be of alloy and grades normally used for Maintenance of Way Equipment. Design of structural members subject to normal working loads shall have a minimum design factor of 2 to 1. If structural members are subjected to impact stresses, a minimum design factor of 3 to 1 shall be utilized. It is generally recognized this is only a minimum recommended guideline and increased design factors may be required as necessary.

b. All bolted applications must have a least two full threads protruding beyond the nut after the fastener has been properly torqued.

c. All nonferrous metals shall be of alloys having strength and corrosion resistance suitable for the intended use.

6.0 MISCELLANEOUS

Unit delivered *must* include the following equipment:

6.1 All threads to be U.S. standard.

6.2 Complete sets of all operation, maintenance, parts and service manuals, lubrication data, and spare parts lists.

7.0 PAINT

7.1 Units are to be cleaned and prime painted.

7.2 The complete unit must be painted to Railway specification with the exception of the following:

Wheels, hand rails, and steps to be painted BLACK.

Lifting and tie down lugs to be painted BLACK.

Jacking pads to be painted BLACK.

Safety locks to be painted RED.

Stenciling to be BLACK.

7.3 Units are to be safety striped using 3M "Scotchlite" Series 1480 (6″ wide) Engineer grade orange/white diagonal sheeting or equal as follows: (cut to fit)

a. One stripe across front and rear of unit.

b. One stripe along the complete length of each side.

8.0 STENCILING

8.1 All stenciling must be in language choice(s) specified on purchase order.

8.2 Stenciling must be 1 inch standard lettering.

8.3 Unit is to be stenciled with the following information on both sides, in standard and metric measures:

a. Total weight of unit.

b. Overall length.

c. Overall width.

d. Overall height.

8.4 Manufacturer is to affix the railway logo and/or the machine running number at two locations: front, back, or both sides. The logo and running numbers are to be in one inch figures. Manufacturer to be advised on purchase order of the running number.

9.0 OPTIONAL EQUIPMENT

Quote separately on the following:

9.1 Four wheel brakes with metal liners.

9.2 Any other available options.

10.0 GENERAL

10.1 Delivery

Bid shall specify delivery date of all equipment offered. At the time of order, date will be reaffirmed or a new date established. A manufacturer's representative shall place equipment in service and instruct purchaser's operators, mechanics, and supervisors at a location to be specified by purchaser (not necessarily the machine delivery point).

10.2 The manufacturer must instruct those Railway employees, operators, and mechanics designated by the Railway, in the operation and maintenance of the machines, so as to permit these Railway employees to maintain the machine at a top level of performance.

10.3 Suppliers of roadway machines are *required to* maintain a stock of parts as per the suppliers list of "recommended spare parts" in sufficient quantity to protect those machines in service. (Minimum 10 years.)

10.4 Non-Compliance

These spcifications are not intended to eliminate any product from the bidding. Where equipment does not comply, bidders shall clearly describe each deviation. These specifications are in full effect unless amended in writing by the purchaser. Purchaser reserves the right to reject any bid and the right to accept bids deviating from the specifications.

DATE: ______________________ 19 ________

Specifications reviewed and completed by:

SIGNATURE: ______________________________________

TITLE: ______________________________________

COMPANY: ______________________________________

TO COVER: MACHINE ____________________ MODEL ____________________

Proposed 1991 Manual Revisions To Chapter 28 — Clearances

It is proposed to add to Chapter 28, Sections 3.2 and 3.3, a standard base car definition, and to add a new Section 3.11 on "Recommended Procedure for Safe Movement of Oversize and Overweight Shipments on Foreign Trackage/Joint Tracks." The specific changes follow:

Section 3.2 and 3.3

1. In Section 3.2—Suggested Method of Presenting Published Clearances, include as a second sentence of item 4 the following:

The recommended standard car is having maximum truck centers of 50 Ft. 0 In., with 10 Ft. 2 In. overhang from truck center to end sill. (Maximum 70 Ft. 4 In. load length, loaded within end sills.) Coupled length of car not exceeding 73 Ft. 0 In.

In Section 3.3—Suggested Methods for Charting All Obstructions, revise the wording near the top of the diagram concerning the published clearance outline base to:

"Published Clearance Outline based on a standard car having truck centers of 50′0″ with 10′2″ overhang from truck center to end sill (maximum 70′4″ load length, loaded with end sills) and 73′0″ coupled length."

Section 3.11

The new material for Section 3.11 follows:

3.11 RECOMMENDED PROCEDURE FOR SAFE MOVEMENT OF OVERSIZE & OVERWEIGHT SHIPMENTS ON FOREIGN TRACKAGE/JOINT TRACKS

3.11.1 Scope

The following material is a recommended practice for the movement of dimensional shipments (high, wide, heavy, high center of gravity, etc.) when entering into a trackage rights agreement.

Clearance concerns should be addressed prior to entering into such an agreement.

3.11.2 Operations

Owner railroad should establish the overall policies governing the movement of dimensional shipments. These policies should define available access to side switching, yard and interchange tracks.

3.11.3 Priorities

Where applicable, the movement of passenger service should take preference over the movement of a dimensional shipment. The owner railroad should establish operating priorities at their discretion, minimizing delays to foreign dimensional shipments.

3.11.4 Procedures

Prior to the movement of a dimensional shipment, owner railroad must receive timely, advance notice of the movement, preferably using the "Excessive Dimensions Load Report".

Upon receipt of the excessive dimensions load report, owner railroad will establish route and provide restrictions for the safe movement of the shipment. (An exception would be noted where a passenger carrier transfers this responsibility.)

Restrictions should be formatted in a manner which is easily identifiable and understandable. Crews must familiarize themselves with this format.

This information must be distributed to all personnel involved with the movement.

Records of each movement should be retained for future reference.

Any unusual incident or accident occurring during the movement must be immediately reported to all concerned.

3.11.5 Clearance Data

Owner railroad should be responsible for maintaining up-to-date clearance data, both permanent and temporary. Adverse changes must be reported to both parties in a timely manner.

In the event tenant is the clearing party, owner railroad should furnish them with current data, ie: clearance records, operating rules, timetable schedules, track charts, grade and curvature limits, rule books and general orders, etc.

Future planning and improvement projects should not reduce the critical clearance envelope.

3.11.6 Blanket Authority

In the case of repetitive shipments, these shipments may be covered by timetable restriction or special instructions which must be distributed to all concerned.

Tenant dispatcher must notify owning dispatcher of any shipment covered by blanket authority.

In the case of any discrepancy or misunderstanding, dispatchers must consult with their clearance authority.

Proposed 1991 Manual Revisions To Chapter 33 - Electrical Energy Utilization

It is proposed to add to Section 4.2 - Catenary System Design Criteria, new Articles 4.2.7 and 4.2.8 on design criteria for catenary poles and foundations. The proposed new material follows:

4.2.7 Catenary Pole Criteria

Catenary systems are typically supported from poles made of steel, concrete, or wood. The design limit is usually found to be the stress due to bending or the deflection due to wind loads, not buckling caused by vertical loads as is frequently the case in buildings and other structures addressed in local codes or AISC recommendations. Overload and safety factors have a way of being multiplied together in the design process until the overall factor of safety is significantly greater than desired or required. In a similar manner the guaranteed strength of commercially available structural steel and prestressed concrete can be significantly below test results. These two items can combine to produce a catenary pole which is much stronger than necessary, and which will cost more than anticipated. It is, therefore, recommended that some sample poles be tested to failure to ensure that the overall design is reasonable and economical. Mass purchases of poles should be in accordance with a final specification and design, prepared following analysis of test results.

4.2.7.1 Design Loads

(a) It is recommended that the horizontal load be the worst case computed from Section 4.2.2 (including ice loading, as appropriate) acting on the catenary system and any ancillary wires, plus any additional horizontal loading (without ice) imposed either by the pole or by the support hardware. Poles placed on curves should include the additional horizontal load imposed by the various wire tensions acting on the curve.

(b) It is recommended that the vertical load be the worst case computed from Section 4.2.2 (including ice loading, as appropriate) acting on the catenary system and any ancillary wires, plus the additional vertical loading (without ice) imposed by the pole and by the support hardware.

(c) It is recommended that the occasional imposition of additional vertical and horizontal loading, when ice is present on the pole itself or on support hardware, shall be considered as one of the imponderable conditions provided for by the use of safety factors. However, it is also recommended that design checks of worst case scenarios be undertaken to verify the adequacy of selected poles to withstand local icing criteria.

4.2.7.2 Overload Capacity

It is recommended that the following overload factors be applied to the calculated design loads derived from Sections 4.2.2.4 and 4.2.2.5.B, for use in calculation of stresses when using steel or prestressed concrete poles:

(a) Transverse loads	
1. Wind	2.5
2. Wire Tension	1.65
(b) Longitudinal Loads	
1. General	1.1
2. Dead-Ends	1.65
(c) Vertical Loads	1.5

It is recommended that these overload capacity factors be increased when wood poles are used to the following:

(d) Transverse Loads	
1. Wind	4.0
2. Wire Tension	2.0
(e) Longitudinal Loads	
1. General	1.3
2. Dead-Ends	2.0
(f) Vertical Loads	4.0

4.2.7.3 Design Margin

Recognizing that variations occur in the strength of commercially produced steel and other poles, it is recommended that a design margin be used in selecting pole sizes as follows:

(a) Steel Poles	1.05
(b) Prestressed Concrete	1.1
(c) Wood	1.25

4.2.7.4 Electrical Bonding

It is recommended that all poles and catenary support hardware be bonded to assure that insulation faults will be properly detected and circuit breakers operated. This may be achieved by running a return conductor along the top of the poles with intermittent connections to rails (see Section 5.10 of this chapter). The use of concrete or wood poles may require additional consideration regarding the means of bonding to be adopted.

4.2.7.5 Pole Coatings

The environmental conditions which surround a catenary pole frequently dictate the use of a coating or preservative in order to obtain the desired economic life. Wood poles are normally pressure treated with various chemicals to retard decay and repel insects and bacteria. Concrete poles need to be treated to reduce absorption of water, which can be very detrimental during freeze/thaw cycles and causes corrosion of reinforcing steel. Weathering steel poles can be used without coatings unless they are subjected to a high salt atmosphere, such as near the ocean or near some types of chemical manufacturing plants, and provided that associated concrete footings extend sufficiently above natural ground level to inhibit rain-splash of harmful ground-based salts. Plain carbon steel poles are usually hot-dip galvanized, plated or given a multiple coat of paint preservative. Poles should be cleaned of any scale, oil, rust, etc., before coatings are applied.

4.2.8 Catenary Pole Footings/Seatings

Catenary pole footings are provided to transfer the loads imposed on the pole to the supporting ground. Since the predominant forces in the catenary pole are bending, the pole footings are usually designed to maximize side bearing capacity. Catenary poles can be installed in a number of different ways as follows:

(a) Direct implantation into native ground (wood or concrete poles).

(b) Direct implantation into cored concrete footings cast in prepared holes.

(c) Attached to concrete footings cast in prepared holes.

(d) Attached to steel or precast tapered concrete footings driven directly into the ground.

4.2.8.1 Design Loads and Design Methods

It is recommended that catenary pole footings be designed for the loads derived from Section 4.2.7.2 without inclusion of the pole safety factor covered in Section 4.2.7.3. Foundation designs may be checked in accordance with the method outlined in the Uniform Building Code.

4.2.8.2 Ground Conditions

(a) Slopes

Catenary pole footings must frequently be placed on embankments or in cuts where the side bearing strength is not equal to flat terrain. It is recommended that the pole footing depth be increased by the following factors for embankment conditions:

1. 30-degree embankment—1.25

2. 45-degree embankment—1.43

(b) Surface Conditions

The surface of relatively level ground near railroad tracks is frequently composed of loose ballast, cinders, sand and other material with poor side bearing characteristics. It is, therefore, recommended that at least the first one foot of footing depth be excluded when calculating footing depths in flat terrain.

(c) Frost Effects

In order to avoid the detrimental effects of frost heave on catenary poles, it is recommended that the bottom of poles or pole footings be located at least 2 feet below the frost line in all cases.

4.2.8.3 Ground Bearing Strength

The vertical and horizontal bearing strength of native and built-up ground varies widely and should be confirmed on a site-specific basis. Typical values of horizontal bearing strength in normal ground vary from 1,000 to 500 pounds per square foot or less, while a typical vertical bearing strength may be in the range of 8,000 pounds per square foot. These values are given as examples; actual values may be dependent upon the specification adopted.

4.2.8.4 Gravity Footings

Gravity footings are used where the horizontal bearing strength of local ground is so low that it cannot be relied upon to restrain the pole footing horizontally. It is recommended that gravity type footings be designed with a safety factor of 1.5 against overturning forces.

4.2.8.5 Tapered Footings

Precast concrete tapered footings, which are driven into suitable ground without any excavation, compact the earth and significantly increase the horizontal bearing strength of the earth by a factor of 1.3 to 1.5.

4.2.8.6 Rock Footings

Catenary poles may sometimes be placed in rock whose consistency may vary from soft crumbling sandstone to solid granite bedrock. Care must be taken in selecting the proper grout or epoxy agent used to fix the pole or anchor bolts in holes drilled or blasted in the rock to maximize shear strength and long-term stability.

4.2.8.7 Surface Drainage

Except for directly implanted poles, an interface will exist between the pole and its footing. This interface should be sloped away from the pole to assist in drainage and to minimize the corrosive effects of water and dissolved salts at the point where maximum stress is usually found. It is also recommended that additional preservative treatments, in the form of special paints or caulking, should be applied in order to extend the service life of this interface.

Memoir

Earl W. Hodgkins
1919-1990

Earl Hodgkins, fifth of the AREA's six executive directors since the organization was founded in 1899, who served in that position from 1964 to 1979, died November 25 in Salt Lake City.

Mr. Hodgkins was born June 30, 1919 in Woodsville, New Hampshire. In 1936 he went to work for the Railway Express Agency, working in such positions as truck driver and clerk until 1950, except for serving in the Army from 1942 to 1945. He obtained a civil engineering degree at the University of New Hampshire in 1950, after which he spent eight years in the railroad industry, three on the Boston and Maine and five on the Maine Central, where he reached the position of assistant engineer of structures. In 1958 he left railroad employment to become associate editor of Railway Track and Structures Magazine, which position he held until becoming executive director of the AREA in 1964.

Mr. Hodgkins led the AREA staff through a difficult period for railroading, when 10 mph slow orders were common on main lines, and railroad revenues before the Staggers act were insufficient to properly maintain tracks in many cases. This period was also characterized by difficulties for the AREA. Despite health problems and with the help of his wife, Ruth, Mr. Hodgkins helped bring the AREA through this period intact, and many have positive memories of his AREA service.

Mr. Hodgkins also had been active in Boy Scout leadership and participated in many professional associations.

AREA

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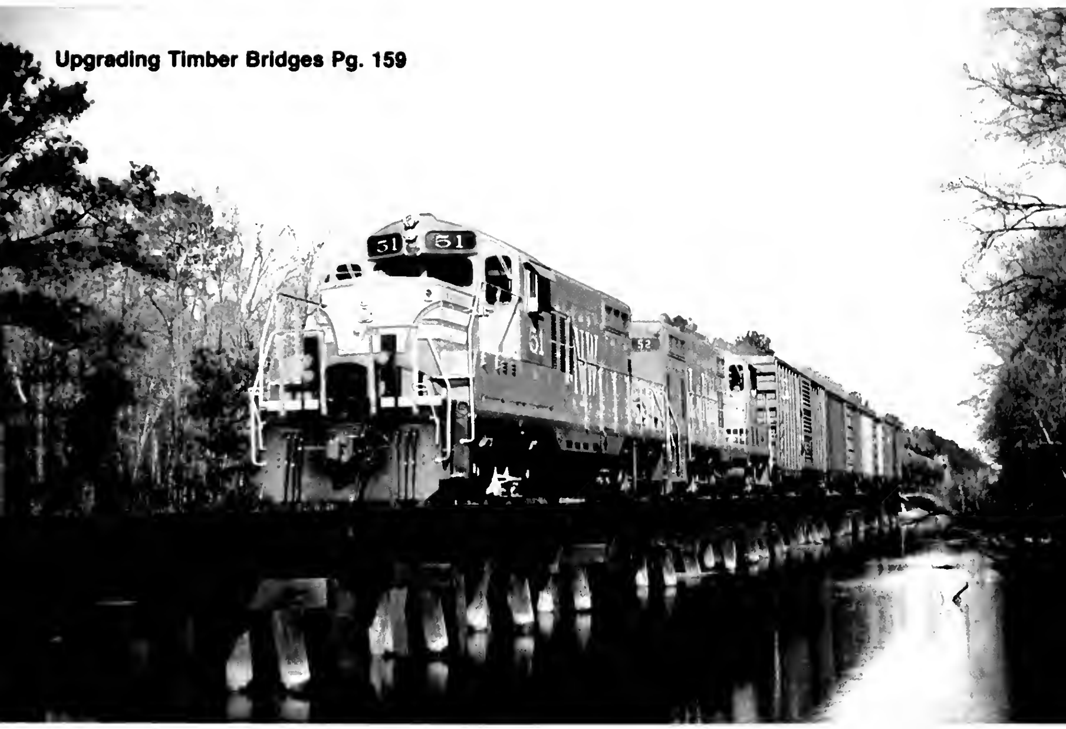

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Front Cover: Low timber trestle carries Louisiana and Northwest train south of Magnolia, Arkansas. Photo by Alton B. Lanier.

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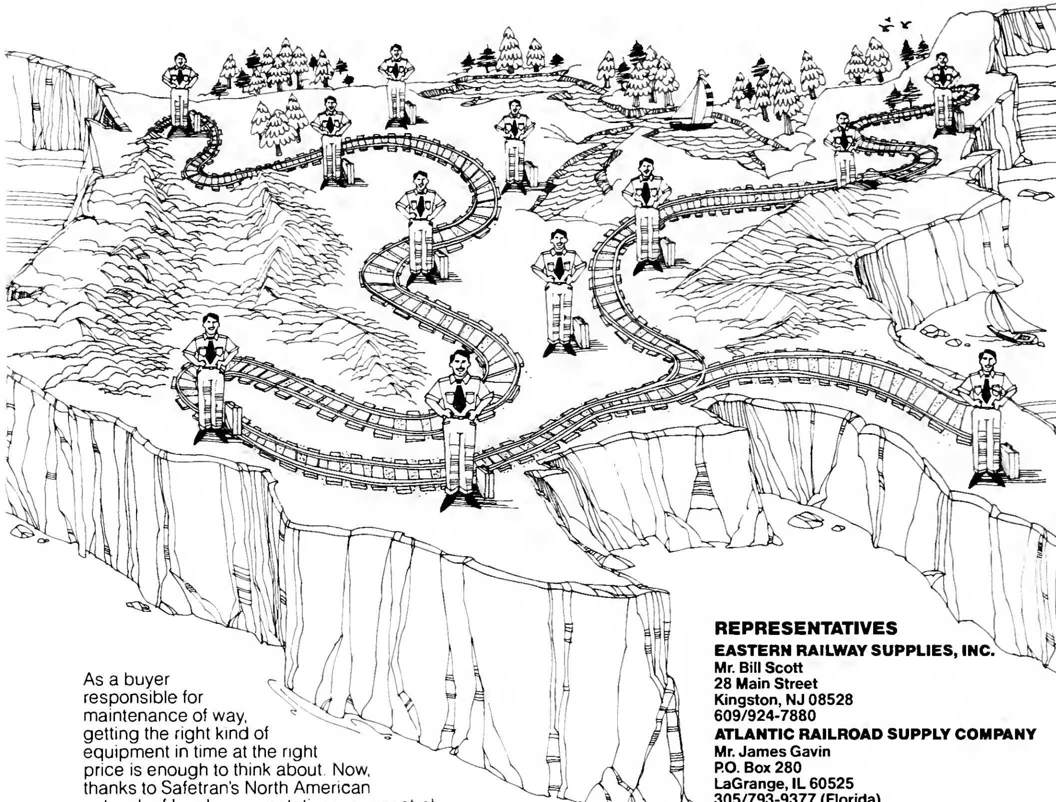

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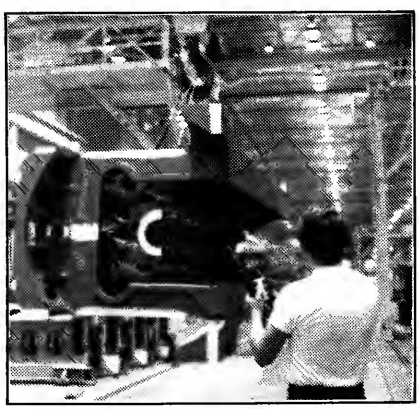

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New wood tie track before ballasting on C&NW coal line west of Lusk, Nebraska in 1984. Old Chadron-Casper Line is on right.

IMPROVED WOOD TIE PERFORMANCE

By: J. L. Watt*

All railroads are continuously attempting to improve the quality and performance of their materials. We at Norfolk Southern are no exception. One area of particular concern to us from a track maintenance standpoint is that of the treated wood crosstie. Although we have experimented with alternative crosstie materials, the treated wood tie will continue to be the backbone of our system for years to come. Norfolk Southern intends to install approximately 1.8 million new treated wood crossties in 1991, which represents about 1/6 of the projected 1991 Class 1 wood tie purchases. This involves a considerable amount of money, and we are very interested in protecting and maximizing our investment.

Norfolk Southern specifications are designed to reflect the geographical environments through which we operate. Much of our system lies within the severe and high rot areas of the mid-Atlantic and southeastern United States. Obviously, our wood tie treating requirements will be different from Canadian and far western roads. On many Norfolk Southern line segments, decay is a primary factor in premature tie failure, rathern than mechanical wear; in other words, our ties have been rotting out rather than wearing out. Even on our high tonnage lines, decay is a contributing factor to premature tie removal from mechanical wear.

Factors which adversely affect the performance and reduce the useful life of treated wood crossties can be divided into two principle categories: physical defects and processing defects. Physical defects are deficiencies found in the tie itself prior to treating. Some of the more obvious defects are shake, bark seams, holes, and decay.

A shake is a concentric separation of the growth rings. Large shakes create a fracture zone which can break lengthwise in a crosstie when spikes are driven. Shakes no wider than 3″ and no closer than 1″ to the surface are acceptable to the Norfolk Southern. A bark seam is bark from a large tree branch that became encased in the wood as the tree continued to grow. This seam is a zone of weakness which

*Chairman of Committee 3—Ties and Wood Preservation, Quality Assurance Engineer, Norfolk Southern

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will not hold spikes properly. The NS rejects any bark seam in the R.B.A. (rail-bearing area) that is greater than 2″ deep and longer than 10″.

Holes are cavities generally created by insects. Sound 1/2″ worm holes are allowed in the R.B.A. Sound holes up to 2″ diameter and 3″deep are allowed outside the R.B.A. Decay is wood that has been destroyed by fungal attack and is not allowed in ties.

Another four obvious defects are wane, bark, mismanufacture and cross-grain. Wane refers to the absence of a square corner on a tie. It results when the saw blade intersects the round surface of the tree trunk. One inch of wane is acceptable in the R.B.A. of Norfolk Southern ties. Ties must have at least half the face width on the top of the ties and no wane on the bottom outside the R.B.A.

Bark is not allowed on ties because the inner bark, which lies just beneath the rough exterior layer, severely inhibits the penetration of creosote. The mismanufacturing of ties relates to unsquare ends, thickness and length variations, and unparallel surfaces. Unacceptable cross-grain is a slanted grain of more than 1″ in 15″ of longitudinal length.

In addition to the obvious physical defects just discussed, wood crossties may also be supplied with several less obvious defects. These subtle defects are checks, splits, and incipient decay. Checks are wood separations which appear on only one surface. Splits extend from one surface to an opposite or adjacent surface. Incipient decay is the early stages of wood deterioration from fungal attack.

Any check that is 3/8″ wide *and* 1″ deep *and* 36″ long is rejected on NS. Any nail-plated split that is over 3/8″ wide or over 9″ long is also unacceptable. Some incipient decay will always slip through the inspection process. The NS treating specifications kill all existing incipient decay by long heating periods. To insure that all ties get sterilized evenly in the bundles, each layer is separated by two 3/8″ strips.

Physical defects obviously shorten tie life. Processing defects have an even greater effect on tie performance. There are three processing areas to consider. The first is moisture removal. The NS uses air-drying and boultonizing to bring the moisture content down to a maximum of 50% for oak and 40% for mixed hardwoods. If not enough moisture is removed from ties, they do not treat deeply. Exposure to the sun later dries the wood which causes much surface checking. These checks reveal the white, untreated wood just beneath the surface of freshly-treated ties. These ties will decay quickly because of poor treatment and heavy check development.

Over-drying is detrimental to tie life, because it breaks apart the wood structure. Large heart checks, which run the length of the tie and show treated wood deep into the check, reveal this problem. The tie is severely weakened from this "burst-checking" that is evident soon after treatment.

Preboring of ties is a second process which shortens tie life. Inspection of ties recently removed from track have revealed no checking or splitting which originated from spiking unbored ties. The NS has conducted many tests to compare creosote distribution in unbored and bored crossties. Some ties have even been bored in one end only as a comparison within the same tie. The unbored end has a much better creosote distribution. Some ties, with excellent treatment everywhere, had the least treatment in the bored area.

Rot development, in 29 year-old ties that were ripped in half perpendicular to the vertical holes, was clustered around the prebored holes in the R.B.A. in all cases. The holes allowed water into the heart area to irrigate the fungi living there. Preboring concentrates rot development in the critical rail-bearing area.

The third processing area that is critical to extending tie life is heat sterilization to kill the fungi living in the heartwood of air-dried ties. Sterilization is coupled with proper treating cycles and retention of creosote to properly protect the wood for years to come. All of our tests have proven one point. No wood has rotted that has been penetrated by creosote. The rot fungi will grow until they contact treated wood fibers. After contact, the fungus seeks out other untreated areas.

Table I.
Temperatures and Times Required to Sterilize Wood*

Temperature (°F)	Time (Minutes)
150	75
170	30
180	20
200	10
212	5

(M. S. Chidester, 1939)

*Heat transfers through wood at the rate of 1″ per hour. From 3 to 4 hours is needed to heat the center of a tie to 150°F.

Table I illustrates the time factor involved in the sterilization of crossties. Boultonized and vapor-dried ties are always sterilized to the heart because of the long 12 to 16-hour drying cycles involved. They will then treat deeper, because all the wood fibers are hot so that the creosote remains thin and flows freely under pressure.

The average treating time for Norfolk Southern air-dried crosstie charges is 10.5 hours for mixed hardwoods and 11.5 hours for oak. The preheating times that we now use to heat the wood for sterilization allows us to get the deeper penetration of creosote into air-dried ties. Air-dried hickory penetration is now down to 3″ in certain species just like the Boulton hickories.

Table II.
1962 Blackgum Sterilization/Treating Test

Plain-numbered ties.	"A" air-dried ties.
Same 17′ log.	Same 17′ log.
Incipient decay present in heartwood.	Incipient decay present in heartwood.
Prebored.	Prebored.
Sterilized with 8 hours at 285°F during vapor-drying.	Air-dried outdoors. Ties *not* sterilized.
Treated in same cylinder with identical pressure and heating time.	Treated in same cylinder with identical pressure and heating time.

Table II highlights the 29 year-old test that forms the basis for the changes in Norfolk Southern drying and treating procedures. Crucial to this test is the fact that each pair of ties came from the same 17′ log—from the same tree. Even the butts and tips of this log were rotated when each tie of the pair was numbered with an "A" or left with just a plain number. These points underscore the fact that this test yields results that are not affected by the many differences between individual ties. These results show the differences in processes alone.

The immediate results in 1962 were that the plain-numbered ties treated to 10 pounds of creosote per cubic foot of wood, while the initially cold air-dried ties only heated sufficiently to take 8 pounds with identical pressure time.

Not only did these test ties show different retentions, but the creosote penetration was much better in the ties with the longer heat cycle. In comparative tests of air-dried ties alone, the preheated ties

PRESENTATIONS TO THE A.R.E.A. TECHNICAL CONFERENCE CHICAGO, ILLINOIS MARCH 18, 19, and 20, 1991

always treat more deeply than the short cycle ties. It is important to note that the heat must be applied *before* the pressure cycle. The wood fibers and pores must be hot inside so that the creosote stays thin enough to penetrate deeply before cooling and plugging the pores.

Seventy-six ties were put in the test site in 1962. We have ripped 54 ties to date. After 16 years, 22% of the "A" ties were rotten. After 20 years, 89% were rotten. Currently, after 29 years, 94% of the "A" ties have rotted extensively, while none of the sterilized ties show any appreciable decay. This indicates at least 9-13 years extra tie life for blackgum ties, and we're still counting. There are 11 pairs still in the damp, rot-conducive site to be ripped in the future.

These 54 ripped ties have conclusively shown that when all the rot fungi are killed inside a tie during drying and treating, and then the interior is well-preserved with creosote, the tie can only be attacked by new fungi entering from the outside. Only one 26 year-old sterilized tie showed a small half-dollar size patch of rot near a prebored hole. Fungal spores had landed every day for 26 years and only now has the creosote concentration gotten low enough to allow germination and growth in an untreated area. The prebored hole allowed the spore easy access to the heart of the tie. These 1962 ties were treated with a 50/50 mix of creosote and fuel oil. We now use the 60/40 creosote and coal tar solution, which works better in our environment. This new treating solution should have prevented the first germination of a spore at 26 years.

Based on thorough study and analysis of tests such as those previously discussed, Norfolk Southern has developed specifications covering treated wood crossties which we feel can significantly prolong tie life. The five major components of our specifications are shown in Table III.

Table III.
Norfolk Southern Crosstie Specifications

1. Do not prebore ties.
2. Strip air-dried ties.
   — Two 3/8" strips per layer for all ties - Boulton and Air-Dry.
3. Ensure proper moisture content before treating.
   — Maximum 50% for oaks.
   — Maximum 40% for mixed hardwoods.
4. Sterilize the heartwood.
   — Preheat air-dry ties for 3 hours at +190°F to ensure a minimum of 6 hours at +190°F during the overall treating cycle.
5. Use 10 pounds of creosote per cubic foot of wood in mixed hardwoods.
   — Use 8 pounds for oak in high-rot areas.

The moisture content provisions are especially critical. No amount of preheating and pressure time will be effective if the ties are too wet to allow creosote to enter the cell walls. The sap water must be removed before creosote can replace it.

In conclusion, the treated wood crosstie continues to be a major component of the modern track structure. Our present-value analyses have shown that extra creosote is one of the most cost-efficient means of increasing tie life in high-rot areas. Our heavier creosote retentions, sterilization, and inspection will prevent early tie failure and give us long-lasting track with well-treated ties.

AREA PRESIDENT'S ADDRESS

By: Donald E. Turney, Jr.*

Good morning ladies and gentlemen. I'd like to talk with you a few minutes about my view of the Railway Industry today from a maintenance engineer's perpective. I hope you will bear with me while I first reminisce about where we've been and then proceed to discuss our current situation as well as the challenges that I see ahead. Speaking of where we have been, I suspect if I asked for a show of hands of those who worked on the old Wabash Railroad, I doubt if anyone here other than me would raise his hand. I started out as a Junior Engineer on the Wabash Railroad at Moberly, Missouri in 1960 after graduating from the University of Missouri. The building I first worked in has now been boarded up. In fact, some of the lumber from this building was used to make the gavel I used to open today's ceremony. I recall that one of my primary jobs as a young engineer was to run top of rail levels on every mile of main track that we surfaced, plot those elevations and establish a new profile with an approximate 2″ raise, then come back and set 2 × 2 oak stakes in the ballast line every 100 feet to surface track. Times certainly have changed. To further illustrate the "Mechanization" of that era, this slide shows what was being done in 1953 on one major road to help tie replacements. Contrary to what some of you might think, that's not me behind the mule.

Some of us have been around long enough to recall all too vividly the dilemma of North American railroads and MW&S Managers in the 1960's and early 70's. Because of the regulatory straitjacket we were operating in, few of our roads had enough return on investment to make the necessary expenditures to properly maintain our physical plants. Our efforts were directed more toward fighting fires and picking up derailments than maintaining our property. We had more physical plant than we needed for our traffic levels, and were drowning in regulation. To say the least, the 60's and early 70's were tough times for maintenance engineers.

Then came the Staggers Act, and railroad management was turned loose to do the things that needed to be done to enable us to manage like most other businesses in the private sector. With more freedom to set rates and service levels, and with relief from maintaining unproductive tracks, our industry set about upgrading track and bridges. Photos 1 and 2 show how our basic barometers for maintenance activity, new rail installed, and timbering work increased in the 70's and started tapering off in the 80's as the condition of our physical plants improved. We were finally able to take off our fire hats and put on hard hats to go about the business that we do best—maintain our physical plants.

Now let's look more specifically at what happened during the last few years. Line rationalizations started to take shape and roads were able to divest themselves of unprofitable lines either through short lines or outright abandonments. A reduction of 23% in the total miles of Class I railroads has occurred over the past few years. During this same period revenue ton mile increased 10% over 1980 and 27% over 1982 levels. Accordingly, revenue ton miles, per track mile and per route mile increased a significant 44% from 1980 to 1989.

Perhaps the most important statistic to our industry has been the improvement in Safety of operations. Derailments from all causes have decreased by 67% since 1980. Furthermore, train accidents from MW&S causes decreased by 70% during this same period. According to AAR statistics, employee safety improved from 7.65 lost time injuries per 200,000 manhours in 1980 to 5.1 in 1989—an improvement of 33%. This is one area in which I feel we can do better as an industry and I'm happy to see that some roads appear to be placing a greater emphasis on employee safety. There is no question that this is true on Norfolk Southern.

At this point I need to brag a little about my home road, Norfolk Southern. As you may know, NS won the Harriman Gold Award in 1989 and it appears we will also win this award in 1990. In 1988, our management committed us to a 30% reduction in injuries for 1989, and we did it. They followed that with a goal for a 25% reduction in 1990, and we were very close with a 24.7% improvement. Photo 3 shows how we compare to the industry average with the NS ratio of FRA reportable injuries. Our ratio

*President, American Railway Engineering Association, 1990-1991, Chief Engineer—Line Maintenance, Norfolk Southern.

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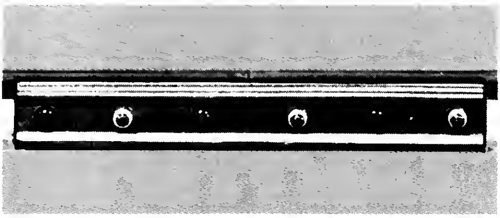

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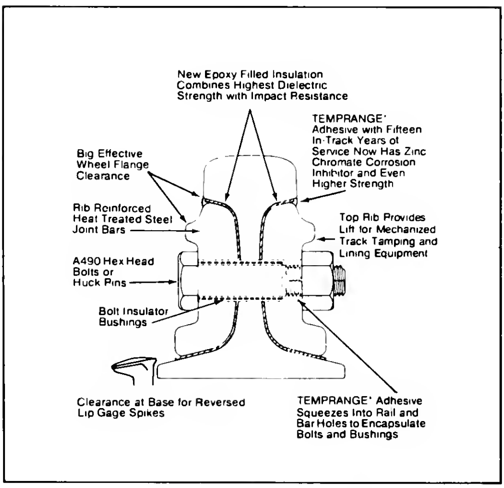

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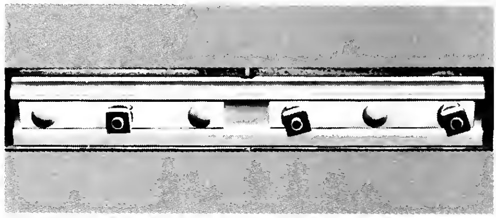

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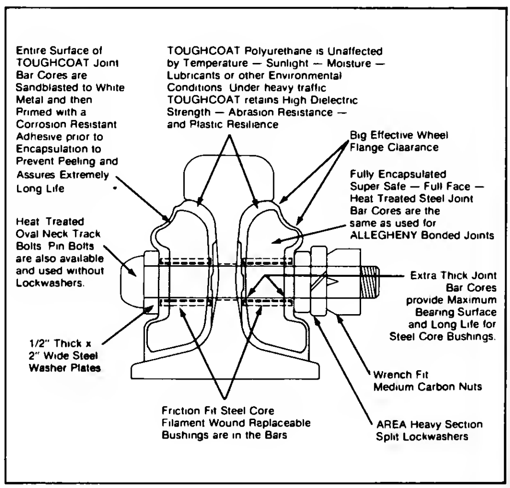

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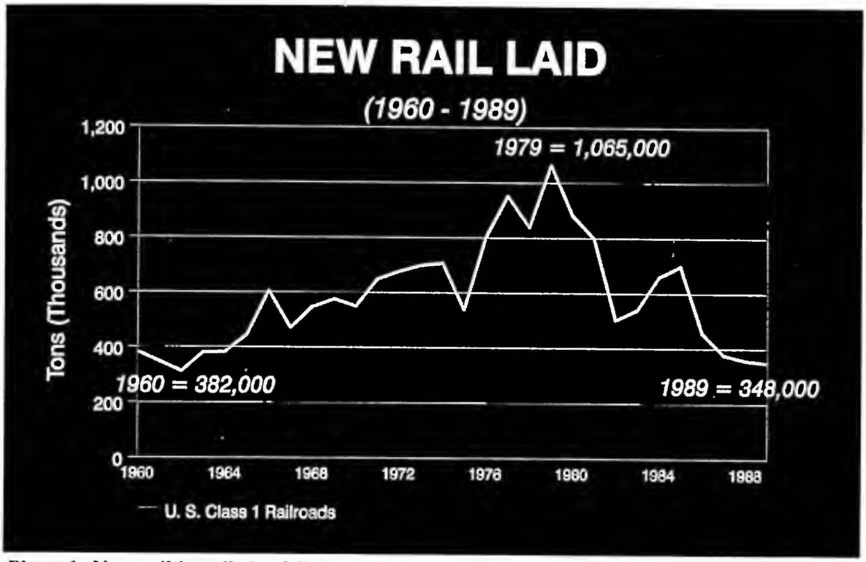


Photo 1. New rail installed, 1960 to 1988.

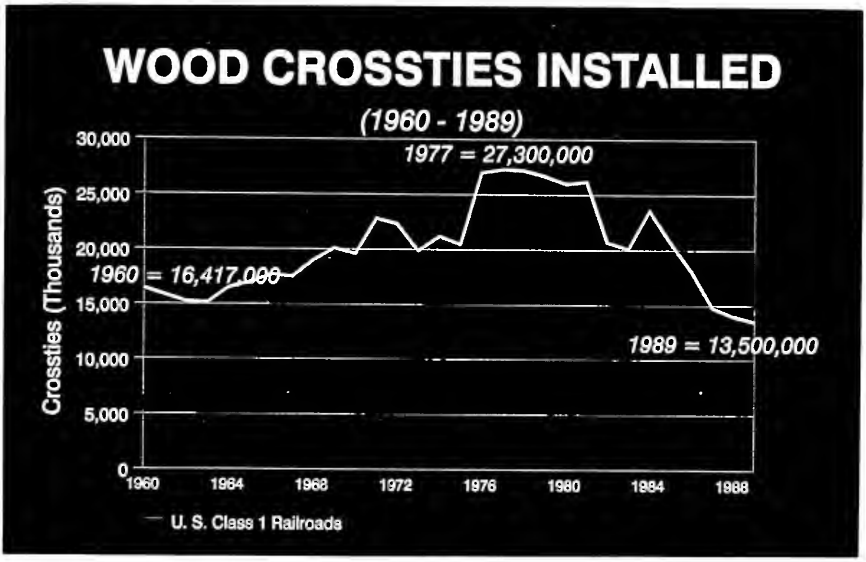


Photo 2. Wood crossties installed, 1960 to 1988.

dropped from 5.9 in 1988 to 3.90 in 1990—a 34% improvement over the two year period. Furthermore, we have established a corporate goal for an FRA reportable injury ratio of 2.00 in 1994, and we are confident we can obtain it. What has NS done to make this improvement? I can't take the time now to describe our entire program, but the basic component is total commitment to Safety from top management on down. Top management put our program in focus, and gave us the tools with which to

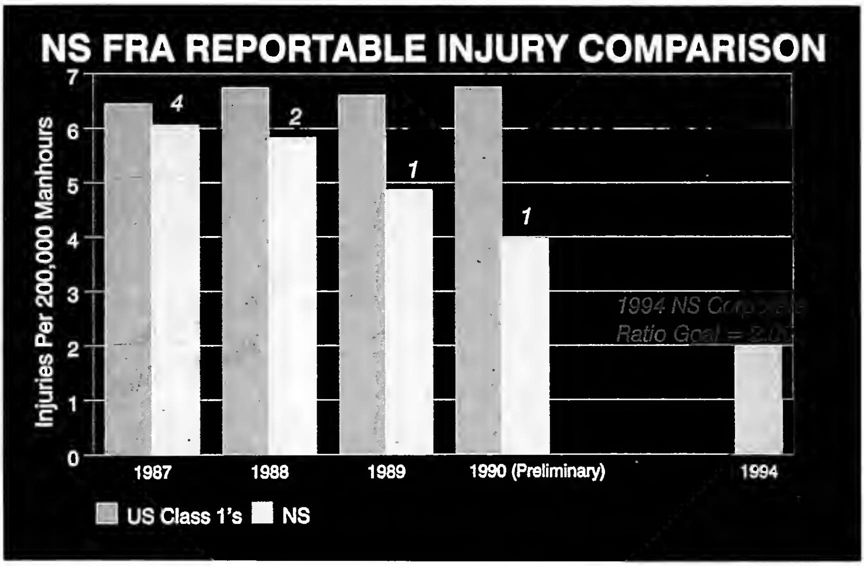


Photo 3. NS reportable injury comparison to the industry.

work. One of those tools was the six tenets of safety, an approach which we firmly believe is working for us. The six tenents are:

- All injuries can be prevented.
- All exposures can be safeguarded.
- Supervision is responsible for the prevention of injuries and accidents.
- Training is essential for good safety performance.
- Safety is a condition of employment.
- Safety is good business.

Back to what has happened in the industry. M of W expenditures for Class I roads in the past ten years have been fairly level. At the same time, M of W employment has dropped by 44% since 1980 from a combination of things, including line rationalization and productivity gains. If we assume M of W expenditures have continued to escalate at a normal inflation rate since 1981, our industry spending would have been as shown in Photo 4, which indicates expenditures would have been 44% more than we spent. I doubt that any one of us could have lived with this.

How were the maintenance cost reductions accomplished? The two primary areas were:

a. Line Rationalization
b. Innovation

We are familiar with the line rationalization process in which we are able to divest ourselves of unprofitable trackage either by abandonments or short lines. Many of these new short lines are doing very well because they are able to operate with some different ground rules.

The second item, innovation, covers a wide range of areas. Mechanization and research come to mind as being its major components. The gains in mechanization have resulted from joint railway and railway supplier efforts. There have certainly been significant gains in this area far beyond what it took to eliminate my task as a young engineer of setting 2 × 2 oak stakes every 100′ for miles!

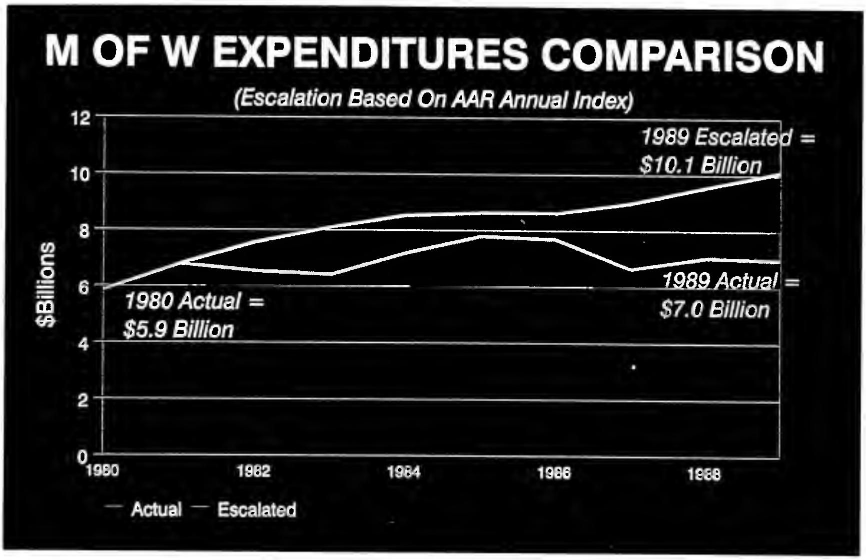


Photo 4. M of W expenditures comparison, 1980 to 1988.

Innovation also includes research by groups such as AREA, AAR, private industry and others. In my opinion, this is where AREA has been invaluable to our industry. This group has been the forum where knowledgeable railway engineers and experts in the field come together to pool their knowledge through our technical committees. For over 87 years, railway engineers have been formulating and upgrading AREA recommended practices and standards to the benefit of all railroads. Where would this industry be if standards such as those that improved the quality of rail had not been developed and progressed through this organization? We wouldn't be considering going to heavier wheel loads today without the better rail.

What are the challenges for the future?

Probably more of the same, where we will be constantly looking for ways to do more with less. We engineers must continue to improve productivity, quality of materials, and practices in order to withstand heavier wheel loads and keep our industry competitive with other modes of transportation. Accordingly, the strengthening of our track, roadbed and structures will be an ongoing challenge to handle heavier loads. However, we engineers must be careful to ensure all costs are included in the study of the economics of the 315,500 lb. car on our individual roads.

While the 80's may have been the era of the line rationalization through abandonments and short lines, the 90's could well be the era where further line rationalization occurs through using each others' tracks where surplus capacity exists. It appears that there is a concerted effort afoot in various transportation departments to recognize these opportunities which could benefit the entire industry.

I think the future is bright for our industry. While significant productivity gains have been made in the past, there are still many opportunities for reduction of the cost to maintain our property. Our 25 technical committees continue to study assignments that will lead to further gains. Again, we have in this organization the best possible forum to bring together the necessary expertise and knowledge to produce recommended standards and specifications which will enable our railroads to remain the safest and most economical means of moving goods.

CHALLENGES TO THE RAILWAY SUPPLY INDUSTRY

By: J. Schumaker*

Thank you, President Turney, conference members and guests. As President of REMSA and a supplier, I am honored and delighted to have this opportunity to address this distinguished assembly.

When I received the request from AREA's Executive Director to speak before this group on the subject of "Challenges to the Supply Industry" it gave me a great feeling of elation and then, pure panic. How can I say what I really feel without getting REMSA or myself into trouble? Should I do what any good salesman does when confronted with an uncomfortable question? Change the subject, talk about golf, the airplane ride, anything but the issue. No, this is a historic first and I must face up to it, so I did what any good President would do, I solicited advice from our REMSA Board to present the issues.

One of the first thoughts I had was to make a subtle change in the title of this speech. It seemed to me that we should call it "Challenges to the Supply Portion of the Railway Industry."

Like most of you, I have grown up in our industry and am proud of it. Our REMSA organization, like AREA, has a long service history . . . 25 years this past year under the REMSA name, and 70 more years from predecessor organizations from which it grew; that's 95 years of tradition. Though the railroads themselves go back a bit further, we consider REMSA and its member companies to be an integral part of this industry.

In the past ten years we've all seen changes occur in our industry, both on the railroads as well as with suppliers. There have been cutbacks, then growth, then lay-offs, mergers and more cutbacks. There's been increased competition from abroad, less government interference, new environmental considerations, more government involvement and restrictions, computerized ordering, quality ratings and a whole host of problems that were not a part of routine considerations just ten or fewer years ago.

Industry Survival is one of the challenges . . . not the only one, but a major one! . . . "Survival" is kind of a desperate word, but in view of what has been happening in the industry, I do not believe it's overly dramatic. Incidentally, for those of you that don't know, Chapter 11 to a supplier is not Engineering Records and Property Accounting, it is a serious uh-oh. I believe if we think about "survival" as a target, a lot of good things can happen along the way to achieving that goal.

Our closer involvement, cooperation and working together can certainly assist in helping to bring about "good things" for all of us. I think that the AREA's asking REMSA to speak on the subject of "Our Challenges to the Supply Portion" is part of that closer involvement and cooperation. If survival is our goal for the whole industry, then this invitation is a life preserver to the supply portion and we have grabbed it with thanks.

Here are just a few thoughts on "Some Challenges to the Supply Portion." We have talked before about cooperation. What we need to assist us in survival is an engineering alliance between the railroad and supplier. Purchasing and sales professionals should place more emphasis on total cost. We all must find ways to stop talking and start measuring product performance in terms of reduced maintenance and life cycle costs.

Having said that, let me talk for a little bit about the AREA as we see it. We think that one of the main objectives of the AREA is to develop standards. We also think that they have. We have noticed, however, that frequently the individual railroads develop their own specifications which differ from AREA standards. This frequently results in higher unit costs. This total industry, supply and railroad, has never been in a more competitive arena with the trucking interests than now. Therefore, we ask that you look at these requirements when they differ from the AREA standard and make certain that the extra cost is justifiable.

For example, we are currently rolling 7 rail sections with a 6″ base in this country. Under these rail sections we have approximately 50 different tie plates, not counting the ones used for resilient fasteners. Whew! Concrete ties, a relatively new concept in this country, already comes in at least 4 different sizes for 6″ rail, 5 or 6 if you count duo-block, and they represent less than 5% of the total ties

*President, Pandrol, Inc.

in North America. Because of time constraints, I won't bother you with joint bars and turnouts. You have by now, I'm sure, figured out what we are trying to say.

Oh yes, we have to make equipment and OTM to fit and handle all these differences and carry an inventory of all sizes and types so we can make emergency shipments to our customers. If you're tired of that drum, I'll beat on another one.

Performance and data collection, here's a challenge for both of us. Many times we're asked to modify a piece of equipment or change material. The changes are made and the cost goes up as a result. Can this increase in cost be justified? We ask this question before we spend, but frequently we never find out or we get a guess or "gut feeling" with no hard data to back it up. We do not want to lose the business so we risk the change, often without any gain in either knowledge or business. As a matter of fact, occasionally we are blamed for the additional, unplanned costs.

Most railroads have cut back their engineering departments. As a result, suppliers are asked for more engineering input. That's great! That's our business, but don't take this new engineered product and put it with its new unique specifications on the street for competitive bidding. We have to recoup these costs in order to continue and support our engineering departments too!

Not every problem that suppliers come upon exists with each and every railroad, but equipment suppliers and the railroads could benefit if railway companies would periodically review their technical specifications, preferably with the concerned suppliers, to see if some concessions or consolidations could be made to reduce costs.

Many railroads have recently formed partnerships with suppliers which include long term commitments for price and quantity. This type of arrangement benefits everyone. Suppliers can plan, and railroads benefit from new ideas as discussions are held without the threat of losing the order, while pricing is firm which allows the railroads to plan their costs.

Another item, when on-site quality audits of a supplier are made by a railroad, we are concerned that this information, good or bad, gets fed back to railroad engineering for use in the equipment or material specifying process.

Another challenge to suppliers and railroads is proper equipment maintenance by the railroad and the use of trained equipment operators, particularly with some of today's sophisticated equipment. Suppliers are often blamed for problems caused by inadequate maintenance and/or the constant rotation of operators and mechanics. Somewhat related to this problem is the situation where suppliers are sometimes required to adopt stringent quality control programs to guarantee performance rates. Such guarantees should not be considered valid when an owner obtains replacement parts and components from other than the original supplier, or when problems have developed either from inadequate maintenance or from operators who have not been adequately trained.

Another item, one with which it may be easier to come to grips, is a problem we encounter with some of the larger railroad engineering departments. These departments have numerous functions and when dealing with suppliers, each engineering person has his or her own opinion. Mixed signals are therefore sent out and it can be difficult for us to ascertain who is speaking for the Company. It would be helpful and more efficient, during these times when cost containment is fundamental, for the railroad to designate a person to speak on behalf of the entire railroad management.

Please note that, coincidentally, these "challenges" we're discussing involve you, the railroads, too! Enough complaining, let's get positive.

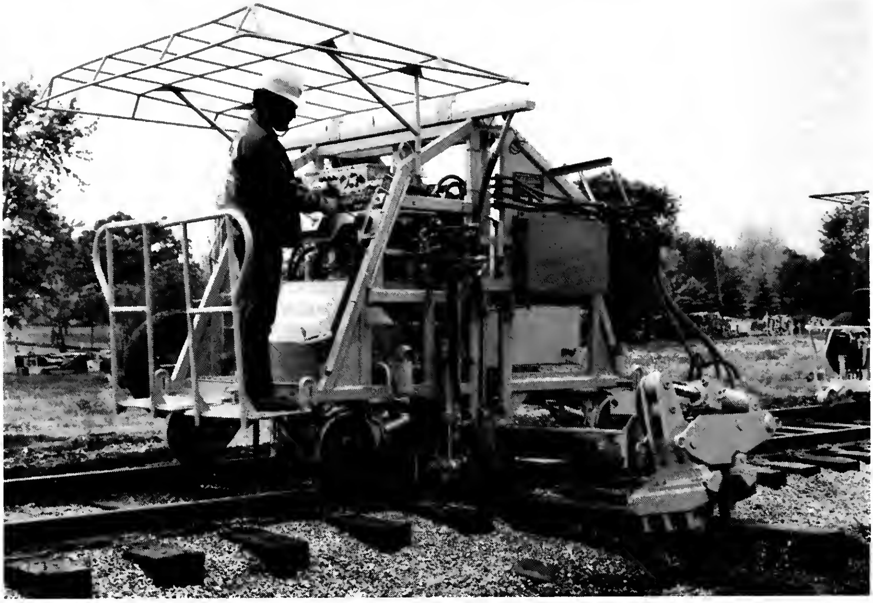
Wouldn't it be great if we, REMSA, could get together with a group of maintenance of way engineers from several railroads, like those on the AREA Board and discuss the annual philosophy or multi-annual philosophies of maintenance of way budgets? A forum, if you will, from which to discuss the advantages and disadvantages of longer term commitments and real standardization. This would help prevent suppliers from having to go from double shifts in the first two quarters to layoffs in the fourth quarter. Why can't the designated REMSA spokesmen meet with their counterparts and peers on the AREA Board once or twice a year to discuss this and other problems pertinent to our industry? Quality would improve; delivery would improve. Cost savings would appear—all kinds of good things.

To return briefly to objectives, I believe both our industries could be served by focusing on:

- Quality 1st
- Delivery 2nd
- Service 3rd
- and Price 4th

The railroad industry (that's all of us) is at a critical point in its history. If there was ever a time that it needed a productive partnership with its various supply companies, it is now. I feel the supply portion of the railway industry is also at a critical point in its history. In short, we need each other more now than ever before. How well we both survive will depend on how well we can communicate and work productively with each other. Assistance given to us, the suppliers, by you the railroad, can be, and is, part of a whole railway industry cycle—a loop, if you will,—that can produce returns for all parts of the industry and make it a better and stronger industry. These "returns," or benefits, can take the form of improved products, lower costs, reduced delays, new efficiencies, and even the "P" word—Profit. The supply portion, just like the railroads, is changing,—meeting the challenges.

I would now like to thank Jim Stallmann and the REMSA Board for their help in giving me the "meat" for this talk. I especially thank you on behalf of REMSA and myself for this wonderful opportunity to speak openly and frankly with you. I sincerely hope that this will be the beginning of many more discussions, and that you enjoyed listening as much as I did speaking.



SOURCES AND CAUSES OF BALLAST FOULING

By: E. T. Selig[1], and V. DelloRusso[2]

Introduction

For the past five years research has been conducted at the University of Massachusetts (UMass), in cooperation with the Association of American Railroads (AAR) and operating railroads, to investigate sources of ballast fouling and their causes. An understanding of this subject is essential for improving ballast specifications and achieving the most cost effective maintenance practice in such areas as track surfacing, ballast cleaning, and ballast selection. The purpose of this paper is to provide information from this recent research which will help to advance the understanding of ballast fouling and correct some misconceptions that may exist.

To date (through 1990) the UMass fouled ballast study has involved visits to over 30 sites in North America. The investigations of the first 15 of these sites are described in Refs. 1 and 2. Reports are not yet available on the remaining sites, but an examination of most of these as well as a more thorough review of the first 15 sites has been completed by the writers. This new work has incorporated additional methods of analysis to eliminate areas of uncertainty in the earlier conclusions.

A preliminary report on this research was presented at the AREA Technical Conference in March 1988 (Ref. 3). The UMass study has advanced substantially since that time and has reached the stage where some important general conclusions can be established.

This paper will summarize the scope of the study, outline the procedures used in determining the sources of fouling material, categorize the observed sources, and finally, report on the prevalence of each of the sources based on the documented cases from this study.

Cases Considered

Most sites included in the study were selected in consultation with individual railroads to provide a wide range of track conditions with fouled ballast. The exceptions were two locations with eight sites on revenue track where comparative durability studies of a variety of ballasts were being conducted. In these cases the ballast was only partially fouled at the time of sampling.

About half of the sites showed mud at the ballast surface which was generally thought to be derived from fine subgrade soil pumping up into the ballast. This study showed that, with only two exceptions, none of the mud at these sites came from the subgrade.

The locations considered were primarily main line track with wood ties and continuously welded rails. However, some locations had concrete ties and some had jointed rail. In several cases geotextiles were present as a separating layer. Drainage ranged from very poor to excellent, with track in cuts, on fills, on flat ground, and on ballasted bridge decks. Subgrade conditions ranged from bedrock to coarse-grained sands and gravels, to fine-grained silts and clays. The annual traffic varied from about 10 to about 100 MGT (million gross tons) among the sites. The railroads represented included ATSF, BN, CP, Conrail, CSX, ICG, NS, and UP. These railroad sites were spread throughout North America, and hence included a wide variety of environmental conditions. Ballast types present included basalt, quartzite, granite, syenite, dolomite, limestone, and slag.

As a group, these sites are not stipulated to provide a statistical representation of North America, and admittedly do not cover all combinations of existing conditions. However, the results of these investigations provide important insights into the mechanisms of ballast fouling and justifies some generalizations.

Method of Investigation

The following description of the methods of investigation represents the general approach; however, variations occurred in individual cases.

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[1]Professor of Civil Engineering, University of Massachusetts
[2]Geologist, University of Massachusetts

First, a site visit was made to observe conditions and to collect samples of ballast, subballast and subgrade. Whenever possible, a trench was dug with a backhoe to permit examination of the roadbed layers, and to facilitate sampling. However, in some cases only hand excavation was done, or cores were taken with Conrail's on-track boring machine. The track characteristics, ground topography, and drainage conditions were documented, and information on traffic conditions and maintenance experience was obtained from the railroads.

In the laboratory, all samples were visually examined and then described according to ASTM D2488 (Ref. 4). The fouled ballast samples and at least the samples from the one or two layers immediately below the ballast were wash-sieved and separated into as many as eight individual size fractions for compositional analysis. The wash water was carefully saved to permit recovery of the fines (silt and clay sizes).

For the fouled ballast samples, the particles smaller than 3/8 in. diameter (9.5 mm) were assumed to represent the fouling components. The coarse fouling components consist of particles between 3/8 in. (9.5 mm) and 0.075 mm (#200 sieve) diameter. These are mainly sand sizes. The fine fouling components, termed fines, consists of those particles finer than 0.075 mm, which represent the silt and clay sizes.

The particles of each fraction were then subdivided by composition. The composition of the ballast particles and the coarse-sand-size fouling material could be determined with a hand lens (10-20X), while the identification of the medium- and fine-sand-size fouling material required a microscope (30-100X). After the sorting was completed the percentage of each particle type in each size fraction was determined by weight, count or visual estimation.

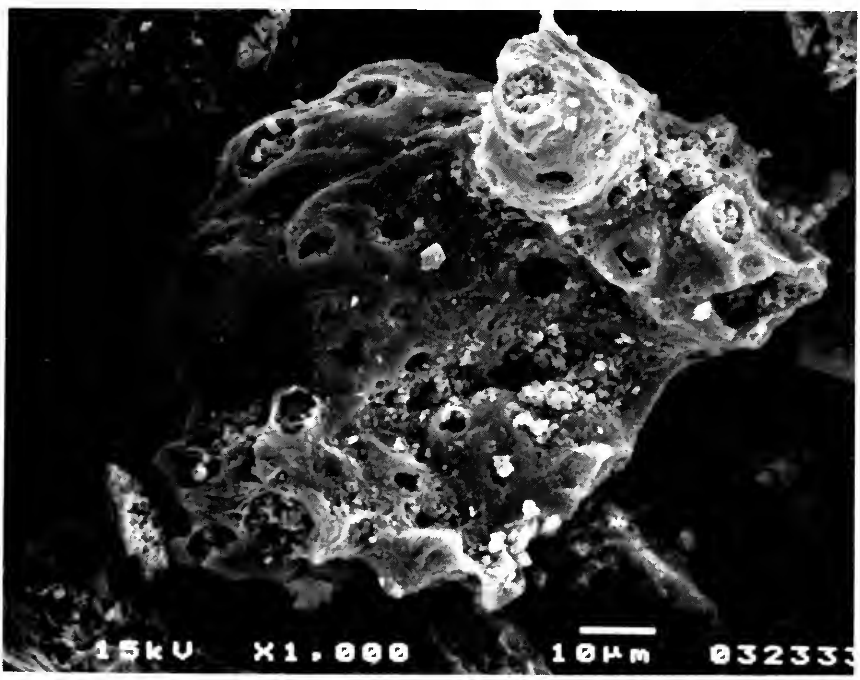


Fig. 1 SEM Photograph of Cinder Particle Magnified 1000X.

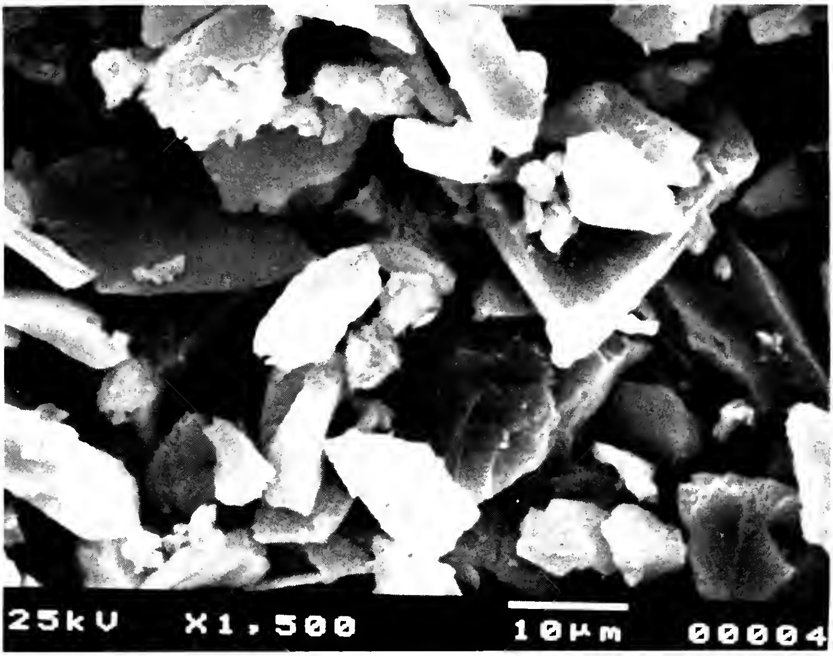
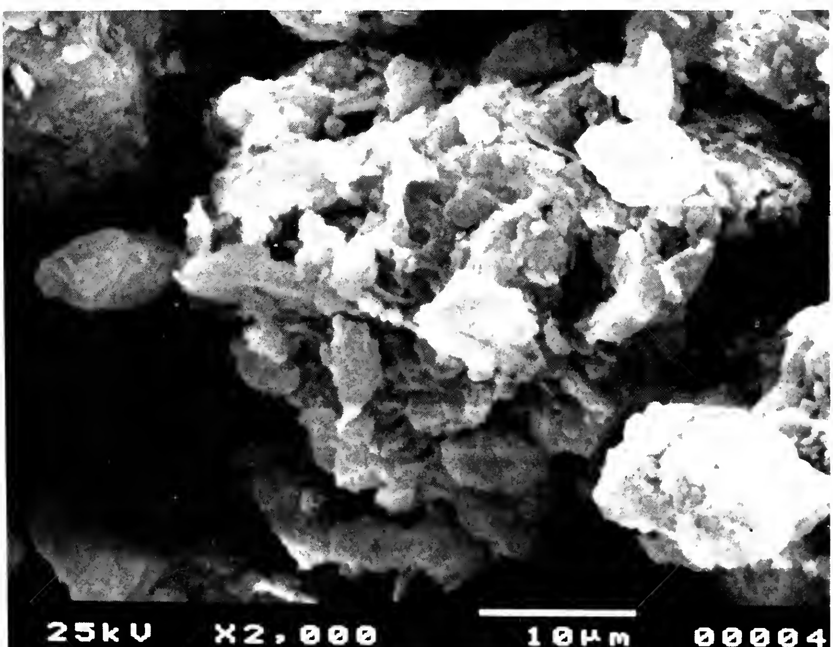


Fig. 2 SEM Photographs: Top shows Ballast Fragments Magnified 1500X; Bottom is Subgrade Clay Aggregate Magnified 2000X.



The silt- and clay-size particles could not be adequately identified using an optical microscope. Instead, the scanning electron microscope (SEM) was employed to determine the shape and characteristics of particles using magnifications of up to 5000 times. With this technique, particles of clay, rock and cinders could be distinguished (Figs. 1 and 2). X-ray diffraction analysis (XRD) also was performed to help determine the source of clay at a few sites. In cases involving carbonate ballasts, insoluble residue analysis facilitated identifying the fines composition. From the results of these tests the proportion of each fouling component in the total fines was estimated.

The results of the laboratory investigation were compiled in terms of percent of each particle composition in each size fraction, and percent of each size fraction in the total fouled ballast sample. These values were plotted in the form of bar charts to help visualize the distribution of the various fouling components. Subsequently, the percentage of each particle composition in the fouling material (less than 3/8 in.) was calculated using the known sample gradation.

An example is given in Fig. 3 which compares the composition of the fouled syenite ballast at one site with that of the subballast. The ballast sample, selected from a mud spot in the crib, was highly degraded, with only 49% of the particles being of ballast size. The remaining 51% consisted of 24% coarse fouling component and 27% fine fouling component (silt and clay sizes). Most of the fouling material (coarse and fine) was a result of ballast breakdown. However, an appreciable amount of subballast particles and wood from tie degradation was also present. The subballast is a natural, broadly-graded gravel with sand composed primarily of well-rounded quartz particles, but with a minor amount of coal and/or cinders. Hence, the subballast particles were easy to distinguish from the ballast particles. The fines components represent less than 1% of the total sample, and so are not represented.

The subgrade was a clay rich loess deposit described using the ASTM procedure (Ref. 4) as a sandy lean clay. About 40% of the soil was fine sand and 60% was silt and clay. The SEM and XRD analyses showed that there was little clay in the ballast fines and that the clay minerals in the ballast fines were compositionally distinct from those in the subgrade soil.

The final step in this research was to determine the source of the fouling components at each site. The field observations and laboratory data were considered together for this purpose. Ballast breakdown, infiltration from the layer immediately below the ballast, and surface infiltration sources were evaluated first. If these sources did not correlate with the composition of the fouling material, then the search was extended to lower layers using the laboratory techniques described. In addition, the general site conditions were considered to ensure that the conclusions about fouling were consistent with these conditions, and that alternative sources were not equally likely. As a result of this approach, the interpretation of the fouling sources in most cases was straight forward.

Sources and Causes of Fouling

A review of the information from the 30 documented cases and visits to additional sites permitted a general categorization of the causes of ballast fouling. The causes in each case could be grouped into one or more of the following five categories shown in Figs. 4, 5 and 6: 1) ballast breakdown, 2) surface infiltration, 3) tie wear, 4) infiltration from the underlying granular layer, and 5) subgrade infiltration.

Fig. 4 shows an ideal substructure with a durable gravelly sand subballast on a stable subgrade and with good drainage. The subballast is assumed to be properly graded to prevent upward migration of the subgrade and subballast particles into the ballast voids. In this situation there are only three sources of fouling material. The first source, which is always present to some degree, is ballast breakdown. Of course, part of this breakage could have occurred in shipping and handling the ballast, and hence could have been present when the ballast was delivered. The degree of fouling from this source is not always greatest directly beneath the tie bearing area. This is partly because the breakdown is from mechanical weathering (freeze-thaw and temperature effects) and tamping as well as from traffic loading, and also because the fouling particles migrate as a result of tamping, traffic vibration and the movement of water. The second source is surface infiltration from car droppings, and wind or water transported particles. The third is tie wear, which is likely to be more noticeable for wood tie track than for concrete tie track.

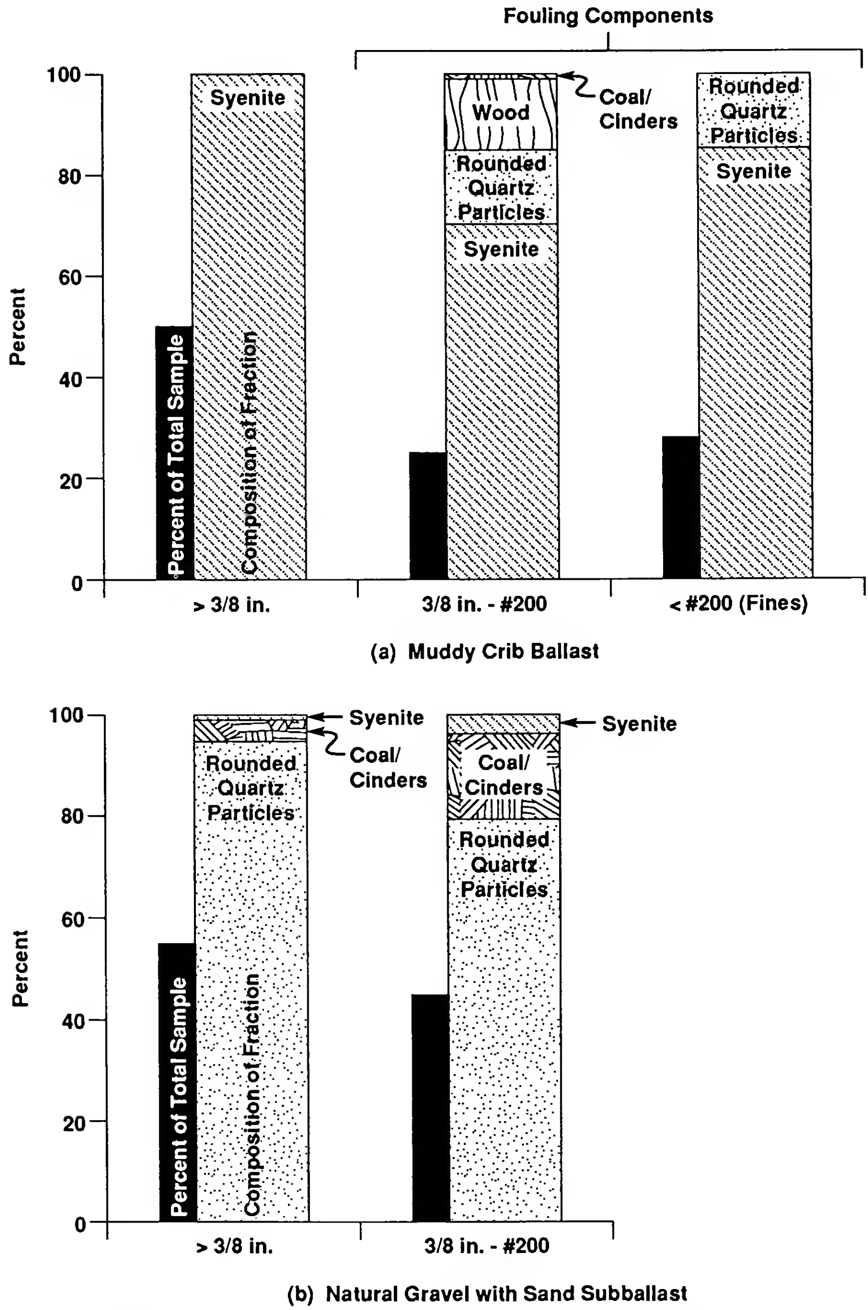


Fig. 3 Composition of Ballast and Subballast Layers at a Mud Pumping Site.

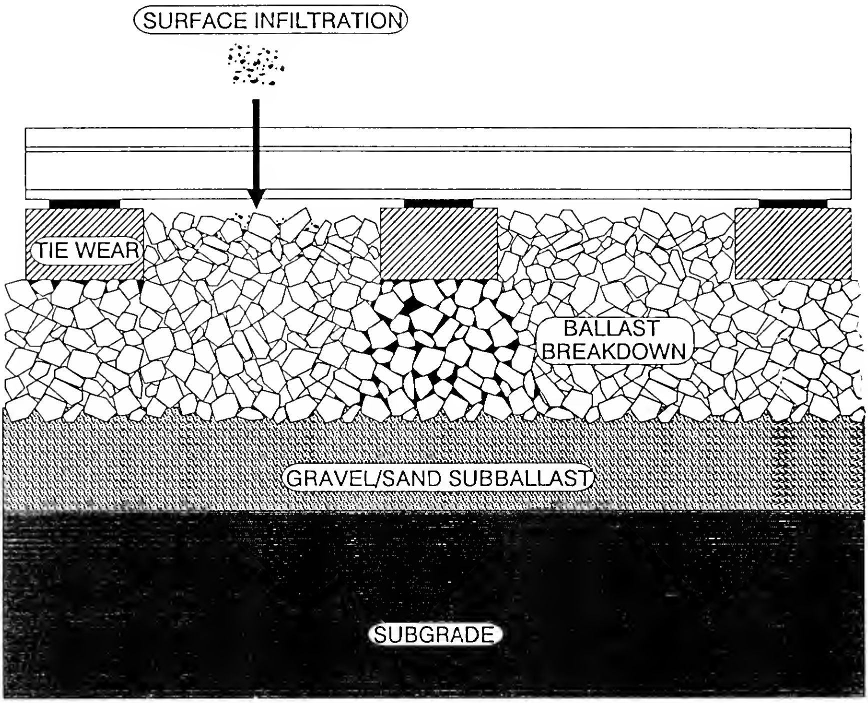


Fig. 4 Ballast Breakdown, Tie Wear, and Surface Infiltration Causing Ballast Fouling.

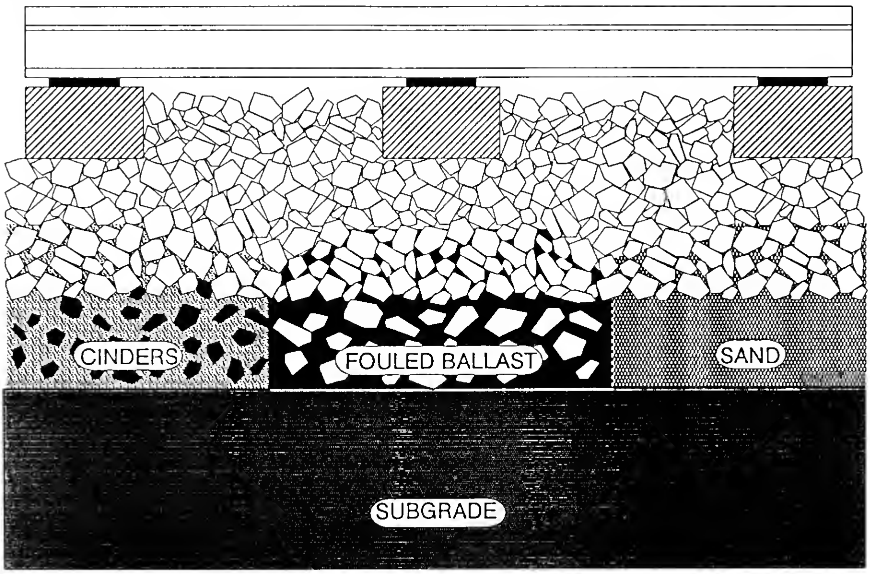


Fig. 5 Underlying Granular Layer Infiltration Causing Ballast Fouling.

Fig. 5 shows the layer beneath the ballast as the fourth source of fouling through particle migration into the ballast voids. This layer would normally be called the subballast because of its location and intended function, but it may be subballast by default, such as when it is created in track reconstruction as a remnant of the old roadbed. Often it is the lower part of the old fouled ballast layer which has not been removed, or a layer of crushable cinders or slag. These materials can degrade under traffic to produce fine particles. Alternatively, the subballast may consist primarily of sand particles which, even though durable, do not satisfy the gradation requirements to maintain separation from the ballast. In these three situations, migration is increased when water saturates the subballast because of the pumping action of traffic.

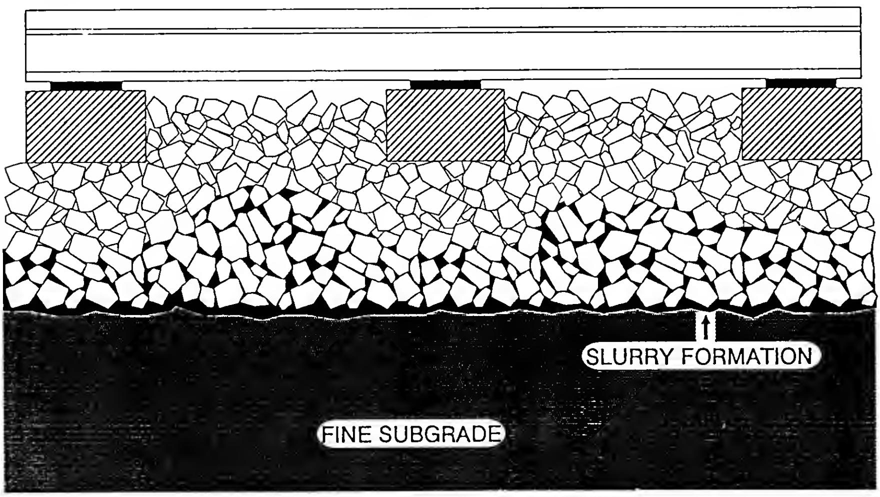


Fig. 6 Subgrade Infiltration Causing Ballast Fouling.

The fifth source of fouling is the subgrade as shown in Fig. 6. Recent research at UMass (Ref. 5) as well as field observations indicate that this source is not a result of soft subgrade. In fact, the only location found in this study in which subgrade was the main source of fouling had a hard subgrade (mudstone). The track section was in a cut with water up to the ballast layer. The cause of the fouling at this location is believed to be the wearing away of the clay rich mudstone surface by repeated stresses from overlying coarse rock particles in the presence of water. Water not only helps weaken the hard mudstone surface, but also it mixes with the subgrade particles to form a clay slurry which pumps up through layer voids. For one section of track at this location geotextiles were placed below the ballast to prevent (or reduce) this source of fouling. However, the ballast in this section was as fouled as that at an adjacent section without a geotextile. As a result it is apparent that the clay particles in the slurry were too fine to be blocked by the geotextile. The effective solution is a proper subballast (graded sand and gravel) combined with adequate external drainage. There is evidence (Ref. 5) that the primary role of the subballast in this case may be to prevent slurry formation by eliminating the subgrade attrition, rather than to prevent slurry from migrating into the ballast voids. However, a further study of subgrade pumping is needed to clarify the mechanisms.

At the completion of the investigation, a table was prepared listing the percent of fouling at each site from each of the five described sources. An average percent for each source was then calculated. The result is shown in Fig. 7. By far the most important source of fouling was ballast breakdown, which accounted for 76% of the fouling particles. This includes effects of shipping and handling, physical

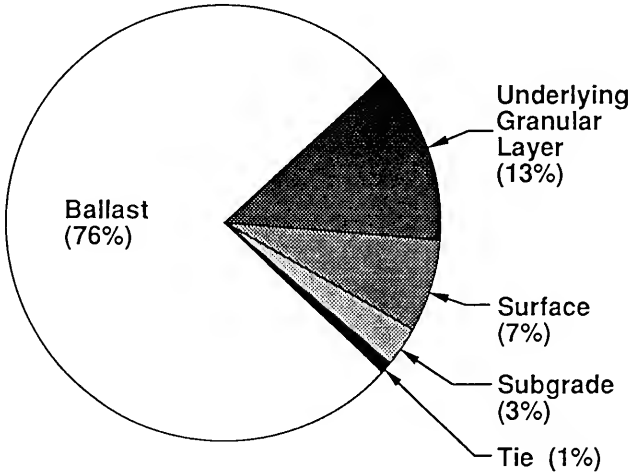


Fig. 7 Sources of Ballast Fouling for all Sites Combined.

weathering, and tamping, in addition to traffic loading. Second, but much less common was infiltration from the underlying granular layer, which accounted for 13% of the fouling. Surface infiltration was often observed, but generally as a minor source, contributing about 7%. Subgrade infiltration was an uncommon source, comprising only 3% of the fouling overall. Tie wear was an insignificant fouling source.

Summary and Conclusions

A careful study of the sources and causes of ballast fouling was conducted covering more than 30 sites throughout North America. A wide variety of conditions were represented.

The study showed that ballast breakdown is the predominant source of fouling. Infiltration of particles from the underlying granular layer is the second most important source, but a much smaller contributor.

Although track subgrade was expected by many railroaders to be a major source of fouling, the results of this study indicate that it may be only a minor source. Clearly, the study shows that the presence of mud in the ballast does not indicate the existence of a subgrade fouling source. In fact, assuming that the mud is not from the subgrade is far more likely to be correct.

In general, a combination of sources of fouling may be expected at individual locations, the mix depending on site specific conditions. The interpretation, in any one case, requires a proper subsurface investigation, since the clues cannot be obtained from surface inspection alone. However, a review of the fouling mechanisms described in this paper will provide the basis for an accurate interpretation of the cause of fouling in most cases, without the need for the detailed laboratory investigation used in this research. Exceptions to the conclusions about fouling in this study may exist. The writers would be interested in investigating these cases, for only in documenting such cases can the state of knowledge be reliably advanced.

Acknowledgments

This research was sponsored by AAR under the cognizance 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. Particularly valuable was the encouragement and suggestions provided by Merle J. Klassen of CP Rail in the early stages of the study. AAR engineers Steven Chrismer and Ken Laine actively participated in the work.

Many graduate students at UMass assisted with the lab and field tasks in addition to those whose theses were referenced. The assistance provided by the many railroads whose sites were visited was vital to the success of the study, and is greatly appreciated. Finally, helpful comments were received from presentations at AREA Committee 1 meetings.

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WAYS OF UPGRADING AND EXTENDING THE LIFE OF TIMBER BRIDGES

By: W. Benton III*

Report of AREA Committee 7, Subcommittee D-5-89

Timber railroad bridges are a critical link in today's transportation system. Several Class 1 railroads report that they still have 30 to 40 percent of their bridge structures as timber. The increase in regional or short line railroads, mainly from sales of marginal lines with lower tonnage, have a majority of timber bridges which has caused a critical need for an understanding of how to keep these bridges as long as possible. Both Class 1 and regional railroads are operating in a world of tight economics, where we all need to maximize the benefit of our budget dollar.

Timber has always been one of the most economical building materials in North America. However, at the same time competitive economics are being thrust upon the railroads, the source of this material is drying up and the cost to treat this material to prevent decay has increased immensely, not to mention the cost of meeting E.P.A. regulations. In today's world, we as engineers must choose economically justifiable structures to continue to carry the tracks. As important as proper structure design is our choice based on economics of the replacement, maintain as is, upgrade or replace key components to extend the life of the entire structure. We must ask ourselves: "Through successful maintenance practices, can an outlay of capital money for replacement be delayed or canceled entirely?"

This report is divided into two sections. The first briefly summarizes the critical problem areas of timber bridges. The remainder of the report addresses maintenance practices for extending the life of existing components and looks at various methods of upgrading the structure by adding additional structural components or replacing key components with different materials. Also, a new timber superstructure currently being researched will be discussed.

Problem Areas and Causes

The causes of deterioration in timber structures fall into two categories; natural forces and mechanical wear. Weathering, the action of wind, sun, water and temperature changes not only degrade the wood, but also causes splits and checks that allow biological organisms to attack the wood. These organisms use the wood either as a food source or as shelter. Mechanical wear is caused by crushing, pounding or bending and is usually increased by the effects of natural deterioration. Natural deterioration and mechanical wear seem to occur in areas where the most stress is found or where a lot of fastenings or construction methods have destroyed the protective barrier of the wood cell structure and any preservative treatment. Splitting, checks and shakes provide an opening for decay organisms to get into untreated wood or areas that have received less treatment. They also decrease the ability of the member to carry load. Ice cutting and debris striking the structure causes wear on piling. Loosening of bolts through repeated load cycles combined with the shrinking and swelling of the timber caused by changes in moisture content also increase the mechanical wear through the inability of the connections to transfer stress from one member to another. Loose connections also allow moisture to get into the inner, less treated portion of the member, providing a place for biological organisms to live and destroy wood fibers. A major problem in timber bridge deterioration is decay or the destruction of the timber fibers by microorganisms. Four factors must be present for the organisms to utilize wood cell material as food—free oxygen, favorable temperature, supply of wood cells and moisture. The life span of timber bridges are greatly reduced when these four conditions exist. In other areas, especially in dry arid climates, timber bridges have lasted 70 to 100 years with minimal maintenance.

Given the above criteria for decay growth, one can see the problem areas on a timber structure. Any place water can collect or be trapped such as on tops of caps, piles and stringers and any place the preservative protection is broken, such as splits, checks, bolt holes, drift pins and spikes, is a prime candidate for the occurrence of decay. Another area where decay occurs is at the ground line. A constant high moisture, temperature and protected environment exists there that provides microorganisms a natural home. Decay in piling is usually not visible, as a shell of treated wood is left. It can easily be detected by sounding or boring. It can also be detected when the pile fails. Corbels and

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Photo 1. Decay hazard may vary according to climate.

caps can be visually inspected or drilled and sounded to determine decay presence. Ground line decay can only be detected by excavating. On occasion, the above ground portion of the structure looks good, however, the support which is unseen is basically nonexistent.

Timber deck ties are also subject to decay. They are usually the most exposed surface to the weathering elements while at the same time receive the most abuse from the train traffic and track crews repairing or replacing track components. The timber floors on ballast deck bridges are also susceptible to decay as the ballast generally retains moisture while at the same time hiding problems from easy viewing.

In marine environments, mother nature hands us other small creatures that like to eat wood, marine borers. The damage they cause occurs mainly in the tidal zone and can drastically reduce the pile cross section.

Our former favorite preservative, creosote, is highly regulated by the EPA. This has basically caused most, if not all railroads to stop using it as field treatment for fresh cuts and holes. Today, as in the past, the art of timber bridge building and maintenance involves the use of chain saws, chisels, drills and other hand equipment on creosote treated timber. This results in the plant treatment being broken, and untreated or slightly treated wood being exposed. This provides for increased decay and weathering. It also, in the case of fitting stringers, provides a stress point for structural cracking, as in field sized stringers without any field treatment for the cut.

Mechanical wear is becoming more prevalent in these days of heavy axle unit trains. The problems created by this have decreased the life span of our bridges. On an open deck of a NS timber bridge you can find mechanical wear in the tie plate area. Some of this wear has been caused by rail relays and subsequent adzing of the ties. This reduces the section, causes spike hole wear, thus increasing the possibility of decay. In many cases, tie pads are not reinstalled causing additional tie plate wear. Cutting of the wood in the tie to stringer area can be found in 8″ × 8″ ties which used to be sufficient to handle the load. Over the past ten years some NS track has seen a drastic increase in coal traffic. The advent of heavier unit traffic has seen an increase in the mechanical wear on structural components.

Not following good design practice has also created problems. On a timber bridge on a skew, you will sometimes find that adequate bearing area does not exist for the stringers to transfer the deck loads onto the caps. You will also note that heavy loads cause the cap to crush and start to crack.

Pile pumping and frost heave or differential settlement bothers not only the bridge grade but also alignment. Not only is pile movement a problem, but mechanical wear is harder to determine other than outright crushing, as it looks very similar to splits and checks. Adding additional caps or shims to alleviate uneven piling decreases bent stability. Special care must be taken to ensure the longitudinal and lateral bracing is adequate. Any freshly exposed untreated timber must also have field treatment applied.

Placing additional ballast increases the dead load of a structure. The deeper deck section requires better designed ballast retainers. A single bolt through the retainer every third or fourth deck plank, especially with deeper retainers or stacked retainers, will not resist the loads of trains, track and deep ballast.

The back walls and/or wing walls retain the track subgrade and ballast. These are susceptible to decay as they provide an ideal growth environment for microorganisms. They are also subject to mechanical wear if the track is not maintained properly. Washouts and other erosion occur underneath the back wall causing loss of soil which is reflected all the way into the track structure.

The way we handle treated timber can also create future problems. Specifications call for the use of web slings or ropes that do not break the surface treatment. The use of hooks, tie clamps, chains or wire rope will break the treated surface and create areas where the decay process can easily begin.

Extending the Life and Upgrading the Structure

The critical problem areas of timber structures were summarized as a reference for the following discussion of ways to extend the life and upgrade the structure. Performing periodic maintenance will extend the life of timber structures. Replacing components with stronger parts or adding structural capacity not only extends the lifespan but upgrades the structure for heavier loading capability. In all cases, the cause of the deterioration of the structural components should be found prior to making the repair or upgrade. Cost effective maintenance or upgrading not only corrects existing deficiencies, but also takes proper corrective measures to prevent future problems, or the reoccurrence of existing ones.

Damage caused by decay is the major cause of deterioration in timber bridges. Controlling the amount of moisture present is the single most economical way of reducing the hazard of decay. Moisture control is simply a common sense approach to determining where areas of visible wetting or high moisture content are, locating the source of water, and taking action to eliminate the source. Removing dirt and debris from the deck surface, ensuring drainage on timber ballast decks, providing adequate support surface or cushioning of tie pads to prevent tie plate cutting will extend the life of a deck. Ensuring that adequate waterproofing systems are installed on new ballast decks not only increases the life span, but will protect the superstructure and substructure below.

Decay can be arrested, once it has started and has not advanced too far, by field application of preservative chemicals. These can be liquids, semi-solid grease or pastes or fumigants which can be solid or liquid. Liquids can be brushed, squirted or sprayed on the surface. Semi-solid preservatives are spread on the affected area. They are mostly used in ground line applications. Fumigants are normally injected into the wood. Fumigants can be liquid or solid and are placed in prebored holes to arrest internal decay. There are recommended guidelines for placement of these chemicals and suggested practices to allow for the most effective application. It must be noted that in-place preservatives are highly regulated by state or federal laws. When used properly by trained and licensed applicators they are not harmful to the surrounding environment.

If decay has not been checked by the earlier simpler methods, or mechanical wear has damaged components, the timely repair of the structure is necessary. It must be pointed out that Chapter 7, Part 3 of the AREA Manual contains notes on recommended practices for the replacing, bracing or adding of components to a structure to repair deficiencies. This section limits the amount of posting allowed on a bent before the entire bent is recommended to be replaced or framed. It recommends renewal for individual caps, sills, braces, or struts when they have been weakened beyond their ability to perform their function. It also mentions stringer support, double capping and shimming of stringers to provide correct cross-level.

The one for one replacement of structurally inadequate ties, caps, stringers, bracing and posts in frame bents is a very common occurrence on today's railroads. When members can not be easily replaced or it is impractical to replace them, the addition of material to reinforce or strengthen these weakened members is necessary. It must be remembered that failure of the original member occurred due to a specific cause. Premature failure of the replacement member will occur if the original cause of the failure is not removed or mitigated.

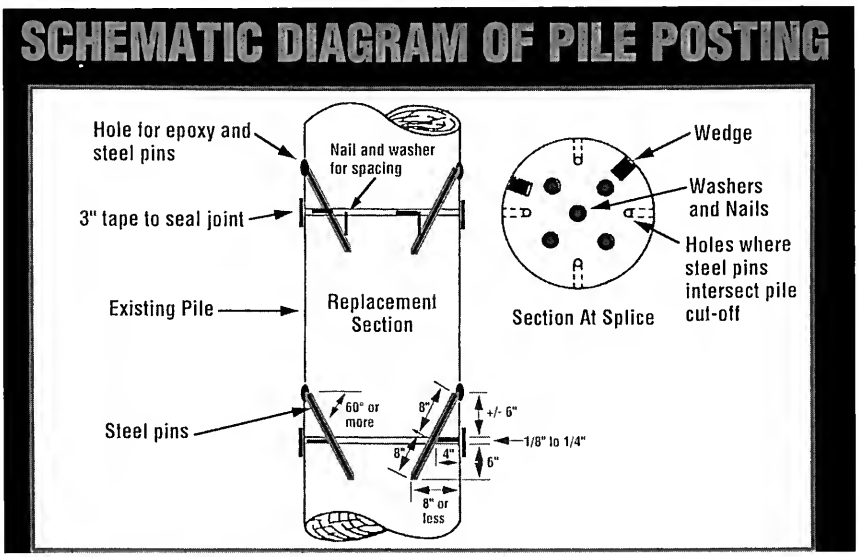

Photo 2. Pile posting practice.

Wood or steel plates attached with bolts are used for the most common strengthening methods of splicing and scabbing. While the two methods are similar, splicing usually involves a small area where load transfer is needed to be restored at a break, split or other defect. Scabbing usually involves adding reinforcing over a substantial portion or all of the member length. Reinforced concrete jackets have been found to be an effective means of restoring a deteriorated pile. The concrete jacket also prevents future deterioration.

As timber ages and dries, a typical problem is the development of longitudinal splits. They develop as a member seasons and checks in place. They may also develop if a member is overloaded or poor design details were used. After determining the cause, clamping or stitching using fasteners or steel assemblies may be used to arrest the cracks or splits. Clamping uses bolts with steel plate assemblies, while stitching uses bolts through the member. No specific design criteria exists for either clamping or stitching. The configuration, number and size of fasteners need to be determined on a case-by-case basis. However, in an ENR article, authors Ketchum, May and Hanrahan made the following recommendations:

"Ordinarily, when bored at a critical stress section of a member, the area of the cross-section removed by the bolt for the stitch bolt should not exceed the cross-sectional area occupied by the maximum knot permitted in the structural grade. When drawing up the stitch bolts, they should be tightened only to the point where the bolt begins to take tension. No attempt should be made to close a split or check as this may extend the split on the other side of the joint. In servicing structures, stitch bolts should be tightened as well as other bolts."

Epoxies have been used extensively by the paint and aircraft industries. On railroads they have been used to repair concrete structures. Since the early '60s they have also been used for timber repairs. Epoxies are used as an adhesive and/or grout for structural and semi-structural repairs. It may be applied as a gel or putty but is commonly injected under pressure. Epoxy is used on pile rehabilitation in two ways. In posting, where a complete damage section of the pile is removed and replaced with a new similar size section it is used as a grout and sealant bonding the old and new together. In restoration, where a damage wedge shaped piece is removed, it is used to bond and fill voids created by the addition of a new wedge shaped piece to replace the damaged portion.

Clark and Eslyn in their Forest Products Laboratory Report state that damage caused by decay may reach 6-12 inches beyond that readily visible. They recommend removing the decayed parts plus an additional 2 feet of the adjacent wood in the grain direction. In addition, as much moisture and excess oil based preservatives, which may affect the bonding, should be removed along with any dirt and debris.

Upgrading the structure to a higher load carrying capacity involves the addition of members, i.e., adding piles, stringers or replacing components with one of higher design strength or load carrying capability. Due to heavier loads, additional piles have been added to bents. Increased bending in the cap has seen a movement towards use of 2-8″ × 16″ timbers bolted together for a cap instead of the solid 14″ × 14″ timber. This also enhances the equal transfer of loading to the piles.

Some railroads have additionally modified the decks by changing an open deck to a ballast deck to provide additional stability, reduce mechanical wear and better distribute the loads to the substructure. This also provides ease of track maintenance, reducing overall maintenance costs.

The availability, cost and lead time of the large sized timbers used in bridges are forcing a new type of timber structure, a composite bridge. When timber pile bents are still structurally adequate, concrete and/or steel is being successfully used to upgrade and extend the life of the structure. Driving piling represents approximately 50 percent of the cost of a new structure. Reusing existing piling saves this 50 percent, and with use of new timber or composite materials, represents a cost effective way to extend the life or upgrade a structure. Railroads are averaging $1500 to $2000 per foot of trestle length for total replacement. Costs are averaging $500 to $800 per foot for composite replacement on existing timber piles.

Engineering analysis shows that due to the load placement and cap deflection, piles do not take an equal share of the load. Inner piles take a proportionately higher loading than the outer ones. The greater the stiffness of the cap, the better the load distribution and more effective load carrying ability of the pile in the bent. The ultimate would be all piles equally carrying the load. This is approached by the concrete slab span on concrete caps. A deflection diagram will show the difference in loading seen by the piling. However, before rushing out and changing caps and superstructure, it is recommended that a thorough inspection of the bent be performed prior to making the repairs. A more even distribution of the loads will decrease the loading to the inner pile but, the loads will increase on the outer pile. The exterior pile are the ones most exposed to weathering, and may not be able to handle an increased load.

A timber alternative to a concrete slab span which combines a superstructure and deck into one is being explored. It is currently being used by highways. Called longitudinal stress lamination, it uses


In products and in service, UNIT is
to quality.
UNIT anchors exceed AREA
power. In fact, our spring anchor
100% at 10,000 pounds, and the
by 60% at 8,000 pounds. And our
so exacting, only a quarter of one
anchors are returned.
We provide complete technical
your rail gangs, with thousands of
field—more than any other anchor
Our record for on-time deliveries is
well, with 95% of our anchor shipments
on-time by our customers' requested
track delivery and service
schedule.
Holding power.
On-time delivery. In short,
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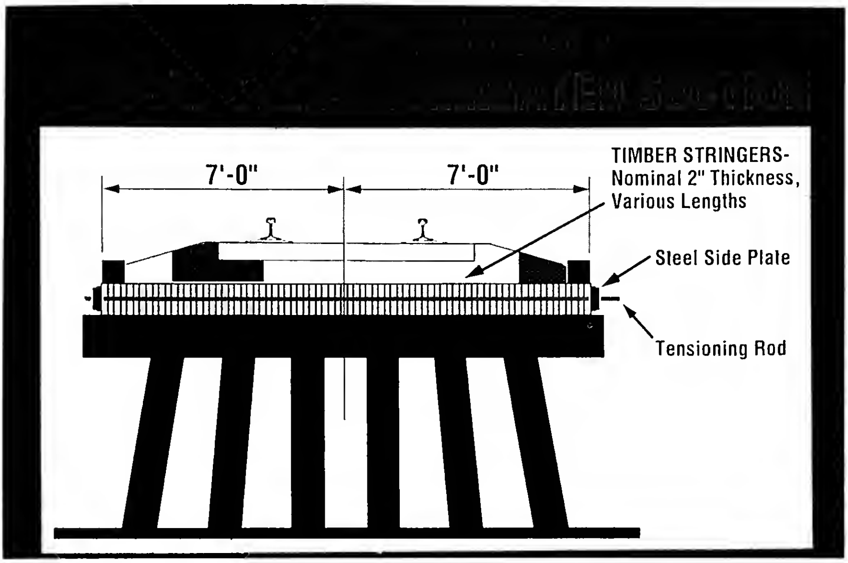


Photo 3. Schematic of longitudinal stress laminated bridge design.

Photo 4. Installed longitudinal stress laminated railroad bridge.

small timbers placed longitudinally as laminations being laterally squeezed with steel bars and rods to form a solid member. It eliminates the need for hard to obtain and expensive large sized stringers and provides a water tight member that virtually eliminates decay. Its relative light weight means it can be placed in multi-span panels. A typical design and installation for railroad use is shown in Photos 3 and 4. One inch rods provide the lateral stress. Stress laminations can also be used in "T" sections or box cells for longer panels. Stress laminated timber may also be an effective way to handle skewed spans on decks.

Summary

We have seen that for various reasons timber bridges will continue to be an integral part of North American railroad bridge structures. We do not have unlimited funds to completely replace these structures with what some have called a permanent steel or concrete structure. Besides, how much more permanent can you get than material that has lasted 70 to 100 years on some railroads? Due to today's operating environment it is crucial that we make sound economic decisions concerning the maintenance or replacement of our structures. Each railroad will use its own costs to determine if the methods described are a cost effective alternative to replacement.

We have looked at ways to extend the life or upgrade timber structures from periodic maintenance of bolt tightening to composite construction involving the use of timber and concrete. A brief look at current research shows that timber is not a 'dead' material. In addition, timber in combination with other construction types can upgrade a structure to handle today's and future needs. Proper maintenance along with sound engineering practice can provide a longer life or upgrade today's structures without having to replace them with a more costly alternative.

BRIDGE REHABILITATION PROJECT ON MONTANA RAIL LINK

By: R. L. Keller*

Background

Montana Rail Link, Inc., is a regional railroad operating approximately 900 miles of trackage in southern and western Montana. It was acquired from the Burlington Northern in 1987. The railroad's trackage is mostly in mountainous territory and it parallels and crosses a number of major rivers via numerous large bridges. One such bridge is Bridge 208 located on the main line between St. Regis and Paradise, Montana and it crosses the Clark Fork River near mile post 208.

This bridge was constructed in 1908 by the Northern Pacific Railroad. It is a 543 foot long, six span bridge consisting of two deck plate girder approach spans on each end with two center 150 foot long deck trusses. Bridge 208 rehabilitation project started by identifying problems in the lateral system, stringer to floor beam connections, top cord to floor beam connections, and bearing systems. The maintenance required seasonably to insure safe operations was in the magnitude of two to three months. The decision was made to consider this bridge for replacement.

Muth Consulting, an engineering consulting firm in Missoula, Montana was hired to investigate the problems and analyze it for remedial work. Analyzation showed that it was feasible and more economical to rehabilitate it, rather than replace it.

Goals and Scope of Work

The goals for rehabilitating the bridge were:

- bring the bridge up to Cooper's E80 live load
- provide for member redundancy
- provide for 50 years of additional life
- provide for a ballast deck bridge
- provide for continuous traffic during the rehabilitation project
- do so as economically as possible.

During the engineering process, we determined the scope of the work for rehabilitation to include:

- installation of vertical stiffners to increase the deck plate girder capacity on the approach spans
- reinforce the columns at piers two and six to increase the load capacity of the column
- enlarge caps at piers three and five to accommodate new foundations for the deck plate girder towers, which eliminated the existing load from the pins of the truss
- install tower frames at piers three and five
- install new expansion bearings
- install a tied Arch System to reinforce the deck trusses
- retire the old floor system from the top cord and install a new floor system, including a composite ballast deck
- flame shorten I-bars, as necessary, on the existing deck truss
- add ballast retainers at both abutments.

Since post-tensioning of the arch is variable, it was decided to contract with the Association of American Railroads to install strain gauges to conduct load tests before the initial rehabilitation, which also enables us to verify the desired stress level in the arch ties after the project was complete. (Note: the post-tensioning is done through the Dywidag bar system, which enables adjustments.)

Another consideration in the design process was to come up with a plan on how we were going to achieve our goal of maintaining train traffic in the rehabilitation process using maximum out-of-service

*Chief Engineer, Montana Rail Link

windows of 10 to 12 hours. Occasional windows of 8 to 10 hours were required to do the bridge substructure work. However, while the new floor system and ballast boxes were installed, a 6-week period requiring 10 to 12 hours every other day was needed.

Figure 1. Completed arch system reinforcement in place on deck truss spans.

The Work

Starting the rehabilitation of the bridge in the Spring of 1989, the first step was to jack up the truss spans and remove the existing bearings, both commonly located at pier four. There was a previous intent to replace these bearings, due to their excessive wear, and we chose to do this procedure before we added additional dead load. We provided a temporary falsework system for the trusses during the bearing replacement process. Due to elevation differences in the new Bronze Lube Light bearings and the old bearings, a concrete pad was poured using quick setting concrete.

Next, the approach deck plate girders were strengthened by adding web stiffeners, which were field drilled and bolted to the four approach spans.

The next sequence of work done was to enlarge the tops of piers three and five to accommodate the support area required by the proposed new tower members and to give us enough room to support the arch bearings.

A cantilevered pier enlargement design was selected at piers three and five as it was felt the bearing capacity of the present piers was sufficient to handle the additional dead load. We first provided staging and form work utilizing the Bork Jacking System. Sandblasting the surface area of the piers affected by the concrete enlargement was done next. Holes were drilled in the pier for the new rebar, which was epoxed into place. After all rebar was in place and tied, 40 cubic yards of concrete was poured at each pier. The concrete was delivered in a one yard concrete bucket via a locomotive crane on the bridge, then through an Elephant Snout System down to the pier, using a PVC pipe and a funnel.

Work progressed onward to reinforcement of the column locations at piers two and six. Staging was set up and the required holes were field drilled to add web stiffener plates to those columns. During the course of construction, we found that the tower caps at both piers two and six were bad and required rehabilitation. We took the time to replace them with rocker plates with pintals included. We also added additional bearing capacity to the end web stiffeners of the existing deck plate girders.

The minimal field welding required on the project was performed by an AWS certified welder.

Next, we shrunk the existing I-bars that were loose on the trusses. We followed the existing AREA Manual procedure but we reduced the area temperature ranges from 1800 degrees to 1300 degrees. Because this was a new process to us, we did not want to get into a heat sensitive position.

Along with the P2 and P6 reinforcement, we progressed the work into the arch installation. We installed the temporary cross bracing and arch support brackets at the same time.

During the course of the project the decision to replace the vertical cross bracing system in the trusses was made, although not originally planned. This enlarged the scope of the project by about six weeks.

Spider staging and aluminum scaffolding was used to provide a safe work place for our work force. We worked as many locations as we possibly could at the same time. During the arch installation, we threaded the three piece arch into position. We utilized a base member of W24 × 62 to compliment the arch. We field drilled the typical connection points where the arch attaches to the existing truss for the arch members at the time of installation, to provide for any slight error in the existing condition over our design. However, several bolt holes were predrilled to allow the arch members to hang during fit-up and then the remaining connection points were field drilled.

The installation of the arch had to be thoroughly planned in order to thread the interior members of the three piece arch into place. We had to work through the existing lateral system of the truss in order to weave the arch members into place. Once in position, they were spliced together and then cover and batten plates were used to bolt the two arches on each truss together. The batten and cover plates were all predrilled, requiring over 7000 A490 bolts for the project.

The Dywidag bars used to tie the arches were threaded through the bearing blocks to provide the tight arch action where the stress reversal occurs. This process totally encompasses the existing truss cords.

Hangers were provided on the truss for the Dywidag bars so that the dead load of the Dywidag bar would not cause a sag problem. They were initially post-tensioned to 52 kips to provide for tight action or to allow the truss to build camber. This process was completed in two phases. The first phase was completed when the arch was installed to cover the existing dead load conditions and the second phase was completed after the new floor system and ballast deck was added.

The tower frames at piers three and five were also installed concurrently with the arch installation. The towers were not to be loaded until the new deck was placed.

The substructure and arch installation work was complete. However, due to additions to the scope of the project, it became too late in the year to attempt the installation of the new floor system and temperature sensitive ballast box deck. The remainder of the project was then delayed until the Summer of 1990.

The next phase of the project required 10 to 12 hour windows, every other day, in order to provide enough time for bridge crews to remove a section of the old floor system and install the new floor system along with the ballast boxes and track.

The final top of rail design required the track to be raised 18 inches. This raise was to be completed in two stages, with the first raise being approximately ten inches. This was accomplished by prebuilding 132# track panels cut to the exact lengths, that conformed to each section of removal in the old floor system of the bridge. This also conformed to each day's work schedule. For the initial raise, track crews raised the track on the ends of the bridge, and bridge crews removed only the existing 115#

rail and tie plates from the bridge ties. Then the prebuilt panels were set, each approximately 26 feet long, on top of the existing bridge ties across the entire bridge, fastening the new cross ties to the bridge ties with lag bolts for stability. This initial raise then would accommodate the additional height of the new floor system and ballast boxes that were installed each day, without the addition of ballast.

Figure 2. Precast ballast box installation on deck plate girder span.

The precasted, prestressed ballast boxes were prefabbed in Missoula, Montana and were post pretensioned at the time of pour. They were delivered to our project by railroad car and stacked in proper sequence, ready for use. A temporary spur track had been installed to store material and equipment for this project, as access to the bridge was limited by other means.

The sequence of deck replacement for the approach spans were to remove the existing bridge ties and sand blast the top flange of the deck plate girder. We then glued a retaining system made of evasote and 50 durometer neoprene to the top flange of the deck plate girder to serve as a gasket for the continuous grouted bearing area to be provided for the ballast boxes. We then set the precast prestressed ballast boxes and welded the Nelson Studs to the top flange of the deck plate girders through the pockets provided in the ballast box. These ballast boxes were placed in series and post tensioned to 92 kips on the job, using the Dywidag system. A continuous grout pad of pyrament concrete was then poured in the pockets, which also flowed between the ballast box and top flange to provide a continuance bearing area. The Nelson Stud System and concrete would make and provide the composite action that we expected through design between the existing deck plate girder and the concrete ballast boxes.

The Pyrament 505 grout was carefully lab tested, prior to actual use on the job, to determine the time duration for set. The project utilized 50,000 pounds of 505 grout. It was determined that we needed 3000 PSI of concrete strength before we could entertain train traffic on the bridge and that it could nominally be obtained in four hours. Concrete cylinders of the grout were taken each day to a lab in Missoula and were strength tested before the track was released for service. Track panels were put back into place, setting directly on the ballast box, while waiting for the concrete to set. The panels were bolted down to the inserts provided in the precasted ballast boxes in order to hold the track panels in place. No ballast was applied until the entire system was installed.

Figure 3. Progression of replacement from wood tie deck to concrete ballasted deck on Bridge 208.

After the approach spans on one end were fitted with their new ballast boxes, we proceeded with the truss system, which had a different design. We removed the existing floor beams and stringers from the truss and then installed new floor beams and stringers and a thinner section of a prestressed ballast box. The new floor beams and stringers required that we use approximately 500,000 pounds of new steel in the two trusses. The floor system was preassembled prior to each day's use, as much as possible, to minimize track time required. All new steel was painted at fabrication. The track was taken out of service, normally on Mondays and Wednesdays, for deck replacement. Tuesdays and Thursdays were used to prepare for the next day's work. The bridge crews regular work week was four ten hour days.

We provided for a temporary floor beam and diaphragm system to accommodate the elevation difference of the new floor beam to the pair of old stringers for each day's work.

The first day on the truss system had to accommodate a cantilevering of the new floor beam at the existing deck plate girder location to the truss. This was the most difficult day in the process, requiring a 20 hour window of time. We removed the eight vertical end stiffeners of the existing deck plate girder, sandblasted and primed the old steel with an inorganic zinc primer, replaced the old filler plates with a new cap plate and installed a new floor beam. The truss was prepared for its new floor beam by sand blasting and painting the existing top cord with a zinc primer, installing the new floor beam, cross bracing, traction struts, stringers, and prestressed concrete slabs. The Nelson Studs, in this case, were factory installed by the steel fabricator. The steps of pouring the pyrament concrete was done, as stated above, for the approach spans. This sequence was repeated every other day until the trusses were completed. The approach spans on the other end of the bridge were completed, as stated above.

After the installation of the new floor system and ballast boxes, the jointed rail was replaced with welded rail, ballast was dumped across the entire bridge and the track was raised an additional eight inches. The walkway system was then added to one side of the bridge, completing the rehabilitation of Bridge 208.

The bridge was completed with an expenditure of $1.3 million. We feel that the following goals were accomplished:

- brought the bridge up to a Cooper's E80 loading
- provided member redundancy
- provided a reduction of truss loading
- extended the bridge life.

We feel the rehabilitation of the bridge was completed economically, for the goals that were achieved, and we look for many years of additional service from this bridge. We also believe that we have two or more bridges, of similar design, that would benefit from the same rehabilitation.

COMPUTERIZED REMOTE CONTROLLED WEIGHING ON C&NW

By: W. G. GeMeiner*

Historical Perspective

In 1983, the Chicago and North Western Transportation Company (CNW) had a coupled-in-motion weighing system in western Iowa that was unreliable, and had begun to raise the ire of the local shippers. The scale weighed individual axles, a design concept that required a great deal of site maintenance; mostly geared towards eliminating the effect of coupler interaction. CNW efforts to solve this weighing problem inadvertently resulted in an advancement of weighing technology that may be useful to other companies.

It might be said that the Railroad Industry looks at weighing as a "necessary evil." The delays associated with switching a car to a scale track for weighing sometimes seriously affects transit time. Once cars arrived at the scale, either the train crew sat around waiting for the clerk, who does the weighing, or vice versa. All these delays and their associated costs had a negative impact on our competitiveness with other carriers and transportation modes.

To summarize CNW's situation in 1983, we had an unreliable scale at a terminal where a large number of shippers required weights before their cars could be shipped. Weighing delays were costing both CNW and our customers a great deal of money. Shippers' insistence that this problem be resolved eventually reached the highest level in our company, resulting in support of the Scale Departments' plans to install a 70 foot, uncoupled-in-motion scale. Having received this support, the Scale Department was determined that this electronic scale would be reliable. Possible tactics were discussed with our weighing equipment supplier; and we came up with the concept of designing a diagnostics system that could be accessed remotely, using a modem and a personal computer. The implementation of this remote diagnostics package was the springboard that propelled the development of CNW's centralized remote weighing system. This ability to use terminal emulation over a telephone line to check diagnostics had provided us with the means to control the entire weighing system.

Figure 1. Uncoupled in-motion scale in Winona, Minnesota.

*Manager of Weights and Measures, Chicago and North Western Transportation Co.

Weighing Program Goals

When the Railroads' Administration Dept. became aware of the capabilities of this weighing package in early 1985, it wasn't long until the remote weighing concept was being used as a "tool" that helped facilitate the consolidation of CNW's clerical functions. Traditionally, and per union specification, the actual weighing, or at least generation of the scale ticket, is a clerical function. Our remote weighing capability allowed clerical forces to be consolidated in Yard Control Centers (YCC) at three locations across our System. As you can imagine, development and implementation of this kind of technology is not "pain free." As with all keyboard-controlled functions, if you put garbage in . . . you get garbage out. If the wrong car number or tare weight is entered, corrections are going to be necessary at some point down the line, resulting in more lost time. From the beginning then, one of the long range goals of this project was to increase the accuracy of the weight data, by reducing keystroke errors. More about that later.

In 1987, the CNW railroad conceived a master consolidation plan that envisioned centralized management of yard-related activities. In essence, all the "paperwork functions" were moved into YCCs in Boone, IA; St. Paul, MN; and Milwaukee, WI. A weighing desk was established that had the ability to control multiple scale locations. One clerk can easily handle the weighing chores for six or more weighing locations. Once the cars were weighed, he still had to take the weight data and re-key it into our mainframe car billing program. Another of our weighing program goals, therefore, was to integrate weight information with other railroad computer applications.

Weighing Locations and Types of Scales

There are currently 16 CNW weighing installations under remote control, some of which are more than 500 miles from a YCC. Our 1991 Capital Budget has money earmarked for the upgrade of four additional sites. It should be understood that CNW has applied this technology to lever system-style scales, as well as electronic weighing systems. Ten of our installations are static scale sites; 3 are uncoupled-in-motion; and 3 are coupled-in-motion. Several of the lever system-static scales are in excess of 50 years old.

There are three common elements to all scales; (1) a steel weighbridge upon which the running rail is secured; (2) a sensing element (either mechanical lever system or load cells) that transmits a change in balance condition; and (3) a weight indicator, usually either a mechanical balance beam or an electronic indicator.

New System Configuration

Basic scale configuration necessary to facilitate remote weighing consists of:

1. Weighbridge and sensing element (when a lever system is used, a load cell is installed between the levers and balance beam)
2. Instrumentation with remote-control electronics
3. Modem
4. Personal computer
5. Printer

Procedure for Weighing Cars

1. The switching crew moves a group of cars requiring weighing onto the scale track, stopping short of the weigh rails.
2. The switch foreman enters the scale house and calls Yard Control Center (YCC) on the telephone, advising that he has X number of cars to weigh.
3. The clerk at the YCC calls the scale via a personal computer, enters a password to gain access to the system. The scale is switched from STANDBY mode to WEIGH mode, a procedure which re-sets the scale (zeroing it), and runs a self-diagnostics check for various system parameters.

Figure 2. 3000 lb. tension load cell installed in steelyard road.

4. The clerk now instructs the switchman to place the first car onto the scale. While this is happening, the switchman relates car number, tare weight, and load limit information to the clerk, who keys it in.

5. The upper left corner of the clerk's PC screen has a live weight indication. While the weight is incrementing upwards, "MOTION" is displayed under the weight, and the PRINT is disabled. When weight stabilizes to within 3 graduations (typically), the clerk uses the PC's keyboard to send a command to the scale system to store the weight of the car. A printout is generated simultaneously.

6. If the car is too long to fit on the scale in a single draft, the clerk advises switchman to place the first half of car on weighrails. After weight stabilizes, he presses a key that stores the first draft. The bottom center of the PC screen displays HALF-WEIGHT ACCUMULATED XXXXXX LBS. The clerk instructs the second half of car to be placed on scale. When second half is weighed, the printout indicates 2 DRAFT behind the weight.

7. Each time a car is weighed, the PC subtracts the entered TARE weight from the GROSS weight provided by the scale. This net weight is compared against the entered LOAD LIMIT. If the net weight exceeds the load limit, a HEAVY indication is printed after the weight.

8. When all cars have been weighed, the car information is reviewed for correctness. If everything appears normal, the weights are transferred onto a RAM card that is capable of storing approximately 1000 car weights. This car weight information can be accessed later, should a question arise.

Additional Benefits

Interaction with CNW Mainframe Computer

Optionally, a main frame computer is used for interaction with the scale and for further integration of weight data into billing system. We have recently begun using a "cut and paste" software program that mechanizes the process of entering car number and tare weight information into the weighing system prior to weighing. A short time before weighing, the clerk goes to a personal computer screen that requests the yard location, track number, and N/S or E/W orientation for those cars that will be weighed next. The "cut and paste" software will direct the inquiry to our main frame Yard System and retrieve the car numbers. It will then match the car numbers with tare weight and load limit information from the AAR UMLER Listing. This car information is then "pasted" into the default directory of the scale control P.C. When the YCC receives a call from the switch crew, advising that they are ready to weigh, the clerk calls the scale and enters his password. Upon receipt of a valid password, the car information is automatically inserted into the entry screen, saving clerical time and eliminating keystroke errors. After the weighing has been completed, the "cut and paste" software will update several mainframe programs, including our Yard System and Autobill. An exception report is generated for such things as bad car numbers, "no bill," or overloaded cars.

Remote Diagnostics

From a maintenance point of view, the remote diagnostics has been invaluable. The standard message we receive about scale malfunctions is simply . . . "The scale does not work." Previously, there was no way of knowing if the scale was not operating properly or whether the clerk simply didn't know how to operate the weighing system. Now, CNW scale inspectors have laptop computers with internal modems that enable them to connect with a "malfunctioning" scale to check on it's operation. This can be done from home, a motel room at night, or anywhere there is a telephone line jack available. This feature has eliminated many unnecessary trips to outlying locations.

Overall Weighing System Design Concerns

Scale House Modifications

It is important to provide a protected, ambient environment for the scale electronics. A number of the scale houses were marginal, based on their age. These were completely rebuilt. In each case, the scale house is insulated, with a 100 Amp electrical service. Thermostatically-controlled heating and air conditioning was installed. A number of the installations have an alarm system to advise when temperature is not within the desired range of 65-75 degrees F. Two phone lines are installed, one for the modem, and one for voice communication.

Surge Protection, Grounding

Any device attached to railroad tracks is likely to experience lightning-induced electrical surges. There is no such thing as "foolproof" or "guaranteed" lightning protection; and CNW, like many companies, has experienced more than its share of lightning-caused damage. In 1988, a CNW Quality Team recommended that each site be evaluated, based on a variety of factors, prior to determing the extent of protection for that location. Extensive surge protection of incoming power is used at all locations. A high quality, combination modem/A.C. protector is installed downstream of a constant voltage transformer. The load cell(s) are protected using a specialized, in-line protector. The entire installation is brought to a common ground, including approach and exit rails. After grounding is complete, and occasionally thereafter, the grounding grid is tested by our C&S Dept., to insure that our standard of a maximum 5 ohms to ground is still being met. Sometimes locations with sandy soils are difficult to bring within our ground-potential standards. CNW has had good success using a bentonite slurry encasement of the ground rods to accentuate moisture retention, which has in every case improved the ground potential dramatically.

Scale Instrumentation, Including Modem(s)

The digital indicator meets all the requirements of the National Type Evaluation Program (NTEP), and is housed in a durable, water resistant enclosure. This enclosure is a steel cabinet measuring 24″ × 18″ × 12″, and is bolted to the wall. An industrial remote display on the front panel displays the weight. There are a series of 24 pin I/O connectors on the side panel to allow connection of the modem, as well as provision for temperature/intrusion alarms, and a local keyboard. There is a re-set key on lower front panel that allows for a "system-reset" of the electronics. The re-set key can be used to locally re-zero the device.

As the remote weighing system was developed, it became increasingly clear that "noisy" telephone lines were a major impediment to the overall reliability of the system. Spurious characters generated by noise on the line caused many problems with the software control program, and in numerous instances "locked up" the whole system. Realizing that line quality will vary based on many factors, we tried using the new generation of modems that have built in error checking and correction. These new modems, which use the MNP error-control protocol, are now installed on all of CNW's weighing systems, and have eliminated the problems associated with marginal line quality.

Figure 3. Remote weighing electronics in Roseport, Minnesota scale house.

Training and Documentation

As soon as the equipment has been installed, it is important that all affected persons receive adequate training. A simple, sequential guideline is posted at the scalehouse for the switchmen's benefit. The operational features of the scale are explained briefly at the YCC for the benefit of the clerical forces. When the remote capability was introduced to each YCC, I used a laptop computer connected to an LCD screen which, when mounted on an overhead projector, displayed the scale control screens in a large size format on the wall. We sample weighed several cars and there was sufficient opportunity to ask questions.

Likewise, it is important to train the scale inspectors and C&S personnel who have to maintain the equipment. Design concepts are briefly discussed, and a good half day is spent going over troubleshooting techniques.

When specifications are written for a custom designed system such as CNW's, it is important to have well written, organized documentation. The better electronics package you purchase, the better your documentation should be. If this sounds odd, just think about it. You buy a high quality, sophisticated electronics package. You train all your maintenance personnel in the first month or so of operation. The equipment purrs like a kitten for 18 months, whereupon it fails. By this time, chances are the technician has forgotten 75% of what he learned at the training seminar. Your man is going to rely on the instrumentation documentation, so it had better be good.

Results to Date

By the end of 1991, all primary CNW weighing locations will be controlled from one of three YCCs. In the past 12 months, more than 36,000 railroad cars were weighed by remote control. Now that there is an established base of qualified weighing system operators at each YCC, calls about scale malfunctions are becoming less frequent. CNW scale inspectors and C&S personnel are familiar enough with the operation and design of the scale electronics that when a scale does fail, the problem can usually be diagnosed and the repairs done "in house." Several locations are utilizing the "cut and paste" software, automating both car information input and the further keying of weight data into our car billing and yard systems. We anticipate that all remote locations will interact with our mainframe computer before the end of 1991. Thank you for your attention today.

ERRATA FOR ARTICLE ON "TRACK SURFACING WITH CONVENTIONAL TAMPING AND STONE INSPECTION"

AREA Bulletin 728, Volume 91, December 1990

Page 359, Exhibit 10, reverse labeling on rail profile roughness curves so top curve on graph is titled "tamped track" and bottom curve is titled "stone injected track."

PUBLISHED AS INFORMATION

COMMITTEE 5—TRACK

Chairman: J. D. Baker

CANADIAN NATIONAL'S EXPERIENCE WITH ELASTIC FASTENERS

By: N. W. Peters*

Introduction

Elastic fasteners have been used in Europe for a good number of years with excellent results. These fastening systems are used both in main track and in turnouts on concrete or on wooden ties. North American railways have not had the years of experience with these fastening systems that the Europeans have had. However, this paper will give a short overview of CN's experience with these fastening systems from the prospective of a railway that is acknowledged as being one of the foremost in North America in the use and expertise of both concrete ties and elastic fastening systems.

The CN Experience:

CN Rail's first experiences with elastic fasteners is very much tied in with its use of concrete ties. As CN experimented with various types of concrete ties in the early 1960's so did it experiment with various varieties of elastic fastening systems trying to come up with a suitable combination.

In 1964, CN installed British designed F23 concrete ties along with an elastic fastening system (also made in Britain) on its Napadogan Subdivision near Chipman, New Brunswick. By 1971, it was felt that this combination could stand up to the Canadian conditions. In fact, these ties and fasteners are still in track today. However, the ties are showing signs of distress, as they were manufactured from non-air entrained concrete and are spalling due to freeze thaw action.

Although CN experimented with several elastic fastening systems in initial service tests, it standardized only one type of elastic fastener. This was due to this particular fastener's economy, satisfactory long term holding power, ease of installation and removal, and reuseability. At the time CN standardized this type of clip (in the early 1970's), it was the only elastic fastener tested that possessed these characteristics.

In general, CN has been satisfied with its choice of elastic clip system. It has performed well with consistently good results. However, this does not mean that occasional problems were not encountered along the way. Some of these problems are outlined below.

Loose Clips

From approximately 1978 to 1982 CN experienced problems on its Ashcroft Subdivision with loose clips. The problem was that clips would not remain in the shoulders after installation. Within weeks after installation the clips were found lying beside the tie. The cause of this was attributed to a combination of factors. The first was worn pads and insulators on the field side of rail allowing the rail to move laterally and the clips on the gauge side to lose toe load. This problem was observed primarily on curves.

The second contributing factor was the relative softness of the malleable iron shoulders. Wear from repeated insertion and removal of the clips caused the formation of a sloped groove in the top of the malleable iron shoulders, which in turn caused the clips to back out and down the slope of the groove. This problem was rectified by using more wear resistant pads and insulators. Slight modifications to the design of the clips helped alleviate the problem. At the same time, CN revised its specification for the shoulders from malleable iron to ductile iron, which is harder and more wear resistant.

*Production Planning Engineer, CN Rail

Frozen Clips

In 1982, CN again experienced problems on its Ashcroft Subdivision with the clips freezing in the shoulders of the concrete ties. This "freezing" of the clips in the shoulders was caused by a combination of factors, all attributed to an accumulation of dirty ballast over the clips and shoulders.

Very fine dusts from the ballast combined with water caused cementing of the clips inside the shoulders. Upon laboratory examination, rust was found on the interface of the clip and malleable iron shoulders. Oxidation had caused the mating surfaces to expand and fuse to each other, causing the clips to jam. This rusting was attributed to the fine dust retaining moisture so that the clip and shoulder interface were always damp.

This freezing of the clips to the shoulders caused extreme difficulty in removing the clips during rail transposing and renewal. In fact, in some cases, in an attempt to remove the clips, the shoulders or the concrete around the shoulders were damaged, or the ties were split.

The problem was rectified by removing the ballast from the clips and shoulders that had been left by the original installation program. With the reduction of the dust, the cementing and rusting disappeared. In addition, to cope with the pre-existing damage, a "frozen clip" extractor was designed and supplied to the personnel affected.

Quench Cracking:

In addition to the problems outlined above, CN also experienced problems with embrittlement of the clips. These were clips that were installed on CN's Rivers Subdivision in 1976. The original clips used by CN were made in England and were relatively high in Silicon and low in Chromium. When manufacture commenced in Canada, the Canadian mill supplied a different formation of steel, relatively high in Chromium and low in Silicon. Clips require a tempered martensitic structure and depending on the chemistry, different quench and temper characteristics are required for each steel. Not knowing the characteristics of the Canadian steel, the supplier applied the same quench and temper parameters to it as were used in their English plants, resulting in an unexpected epidemic of quench cracks.

This defect resulted in the clips failing in track, some during installation and others afterward, with pieces breaking off without warning and becoming projectiles. This was clearly a safety hazard which resulted in approximately 100,000 clips being removed from track and returned to the manufacturer. The manufacturer put them through the quench and temper process again, this time to appropriate parameters. Subsequently, the manufacturer also performed magnetic particle inspection (MPI) on the clips to ensure no clips with quench cracks got back in track. Clips with cracks were scrapped, and clips indicated nothing under MPI were painted red (to indicate inspection) and returned to CN.

Fatigue Strength

A more recently developed type of clip was cause for concern as its rated toe load was, in CN's opinion, stressing the clip too close to the yield strength of the steel. In fact, the clip was stressed to 80 percent of its fatigue limit. When tested at CN's Technical Research Center, CN's concerns were to avoid potential problems for concrete ties where such shoulders are standard. CN changed the shoulder design to derate the clips from a 2900 lb. toe load to a toe load of approximately 2200 lbs. The clip itself, however, was not derated. This clip is a lower profile clip and is used on all of CN's concrete tie turnouts, as well as on CN's new "60D" concrete tie for tangent track, which uses a 10 mm rubber pad.

Longitudinal Restraint:

The elastic fasteners used by CN have an average toe load of 2,100 to 2,200 pounds. The clips themselves have a working range in which they are most effective. However, knowing the toe load does not automatically give the longitudinal restraint. The well known formula for determining the longitudinal restraint of the rails is given by $F = UN$. The coefficient of friction "U" depends on many things. The first is the type of surface the rail rests on. If the rail rests on rubber pads, it will have a different coefficient of friction "U" than if it rests on an EVA pad or on a steel tie plate.

The coefficient of friction will also vary depending if the rail is new or has been in track for some time. The amount of rust on both the rail and tie plate has a significant impact on the value of "U." Under warm weather conditions CN has found values of "U" ranging from as low as 0.30 to as high as 1.0. The longitudinal restraint on any one rail from one tie will vary from 1,260 pounds to 4,400 pounds. If frost and ice form between the rail and pad or pad and tie, and around the insulators, some very low values of restraint are possible.

It has been found that the value of restraint is very much dependent on the type of tie pad used and the material composition of the pad. In addition, the surface of the pad also has a bearing on the restraint (i.e. smooth, dimpled, ribbed, etc.) found in the system.

Application in Turnouts

CN first used elastic fasteners in turnouts in 1979. These so called "super turnouts" featured 136 lb. high strength rail, MJ clips, samson switch points, gauge plates at the point area and frog area, long raised guard rails, integral frog base plates, and elastic fasteners attached to tie plates secured by lag screws to hardwood ties. These components are all standard on CN's 136 lb. turnouts and are the features currently being sought by many U.S. Railroads for their turnouts.

The use of elastic fasteners in these turnouts has resulted in a much more secure turnout. The time taken to replace frogs or other rails is much reduced by the ease in which these fasteners are removed and reapplied. Tie life has been increased on wooden ties as respiking after component replacement is not required. Maintenance of these turnouts also decreased with the use of elastic fasteners as the problems associated with high spikes and wide gauge were eliminated.

Conclusion:

Any new system, when first introduced, can produce its share of surprises. Despite the occasional problems mentioned above, CN believes that the elastic fastening system it has chosen has served it well since its inception. The use of this fastening system has reduced maintenance on both wooden (mainly turnouts) and concrete tie areas.

It is important to note that in no case was the design of the clip a source of the problems experienced, but rather a material or manufacturing defect which was always corrected.

COMMITTEE 5 — TRACK

Chairman: J. D. Baker

GAUGE PLATES IN TURNOUTS

Subcommittee Chairman: D. N. Witt, Jr.

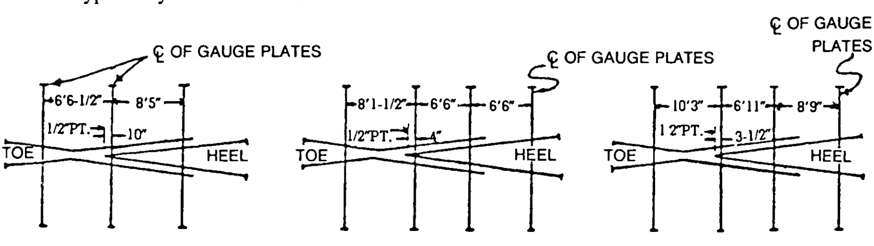
It is generally acknowledged that most of the major problems in turnouts where frequent wear and maintenance occurs is due to deviations in gauge and cross-level. Cross-level can be corrected by replacing timber and proper surfacing, while gauge is improved by replacing timber, which can deteriorate quickly under high speed traffic and heavy axle loads.

In order to better hold gauge on heavy tonnage track, some railroads have installed extra gauge plates throughout the turnout. In addition, extra gauge plates have been installed ahead of the point of switch to help hold the stock rail in locations where there is considerable trailing traffic through the turnout side. In the switch heel area, special plates have been designed and installed to assist in maintaining line and gauge. This is done on two roads that have heavily used universal cross-overs in centralized train control territory, where fast trains are often passing slower trains. Gauge plates have also been designed for use on the turnout rails between the switch heel and the frog. They are used where heavy unit trains often take the turnouts.

Several railroads have gauge plates in the frog area. These tie the frog to the guard rails. They are especially effective when used with the longer guard rails which are shown on AREA Plan 504-89. When the flare on the heel of the frog is opposite the flare on the guard rail, the wheels strike both at once on a trailing move. This aligns the truck immediately and avoids the double action which occurs when the flares are not opposite. The frog gauge plates are secured to the ties by spikes or lag screws. They are secured to the rails by a solid or direct fixation fastener. This depends on the particular railroad's standards.

The number of plates through the frog also depend on the various railroad's standards. The number varies from two to four depending on the frog number. The locations under the frog also vary by railroad.

A typical layout is shown below.



#10 TURNOUT (3-GAUGE PLATES) | #15 TURNOUT (4-GAUGE PLATES) | #20 TURNOUT (4-GAUGE PLATES)

The use of extra gauge plates throughout the turnout will save in the maintenance of turnout components. With the high traffic density on most main line territories today, getting track time to do maintenance is a problem. Therefore, high quality and lasting work must be done the first time.

FATIGUE BEHAVIOR OF RAIL STEELS IN A 33 KIP WHEEL LOAD EXPERIMENT AT FAST

By: P. Clayton*

Abstract

A number of different rail steels have been tested at FAST in the High Tonnage Loop using 100 ton capacity cars. Fatigue data on the rate of formation of shells and detail fractures and crack growth of detail fractures were obtained.

Under the test conditions employed, the crack propagation of detail fractures between 10 and 28% head area can be modeled by a linear function of MGT. The average growth rate for this size range is between 1.6 and 2% head area per MGT.

The tendency of rail steels to form shells has been related to a parameter termed the Shell Index. This incorporates the volume fraction of oxide non-metallic inclusions, the tendency of those inclusions to form stringers, and rail hardness. The shell rate can be reduced by lowering the oxide content, reducing stringer formation, and increasing hardness. All three factors have to be considered in predicting rail steel behavior.

Introduction

The development of the steel rail has resulted from the need to balance increasing service demands with improved rail steel quality at an economic cost. This issue is as important today as it has ever been as the railroad industry strives to maintain competitiveness in the transportation business.

The desire to minimize overall rail costs by the optimum utilization of rails requires that a better understanding of the service behavior of rails be generated. This will enable the predictive capability of existing rail deterioration models, which are being increasingly used in the scheduling of track renewals, to be improved.

Experiments carried out at FAST between 1985 and 1987 were designed to contribute to this effort with respect to two aspects of fatigue. The influence of rail steel metallurgy and non-metallic inclusions on the initiation of shells was determined and fatigue crack growth rates of some detail fractures (transverse defects initiated from shells) were measured.

There are a number of papers which refer to the adverse effect of inclusions on the initiation of shells. In particular, the work carried out in Australia[1,2] has identified oxide inclusions as a significant factor. This finding has been largely supported by work carried out in the United States[3-5].

Sugino et al[6] attempted to establish a parameter with which to separate acceptable from unacceptable inclusion levels using field experience with different rail steels. Their analysis was based on a count of oxide stringers. A stringer occurs when a single long inclusion is generated by the clustering of several small inclusions in the longitudinal, or rolling, direction. The Australian work, by comparison, focuses on the cross sectional dimensions of the inclusions as the critical element. In more general terms, Worth et al[7] have put forward the view that the overall volume fraction of inclusions needs to be controlled to reduce rail fatigue problems.

Two issues deserve consideration. Although intuitively it seems reasonable to suppose that the greater the inclusion volume fraction the greater the possibility of shell initiation, there is no documented evidence to either support or contradict this view. It is hypothetically possible that a large volume fraction of oxides very finely dispersed could be less deleterious than a lower volume fraction with more stringers.

Secondly, there is a danger that the notion "Fewer inclusions is good, very clean steels better, and absolutely clean steels should be the goal" will become part of conventional wisdom. Some rail manufacturers have, in recent years, achieved a dramatic reduction in oxide volume fractions through improved production practices. The performance of these modern rails need to be evaluated in order to prepare realistic specifications.

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In the present experiments an attempt was made to find a relationship between the shell defect rate and metallurgical quality, expressed in terms of oxide volume fraction, oxide stringer content and hardness. Such a relationship could provide the incentive to define the fatigue performance of rail in terms of a combination of factors rather than seeking a single isolated cause for service behavior. Information of this type is also required for the further development of PHOENIX[8], a computer model of the fatigue behavior of rail steel.

The second topic dealt with in this paper concerns the growth rate of detail fractures. This defect is expected to become the dominant one in continuously welded track[9] and is often considered to cause the end of the useful life of a rail. It is, therefore, given considerable attention in the detection of rail defects by ultrasonic examination. The intervals at which track should be inspected to minimize the number of in-service rail breaks from detail fractures is largely a function of the rate at which the transverse crack grows from a detectable size to one at which complete fracture is imminent.

In the FAST experiments, crack growth measurements were made on different rail steels in both 5 and 6 degree curves. One incentive to acquire these data involves the development of a detail fracture growth model at the Transportation Systems Center[10]. Until the current experiments were carried out there were no data available with which to correlate the predictions of the model for curved track.

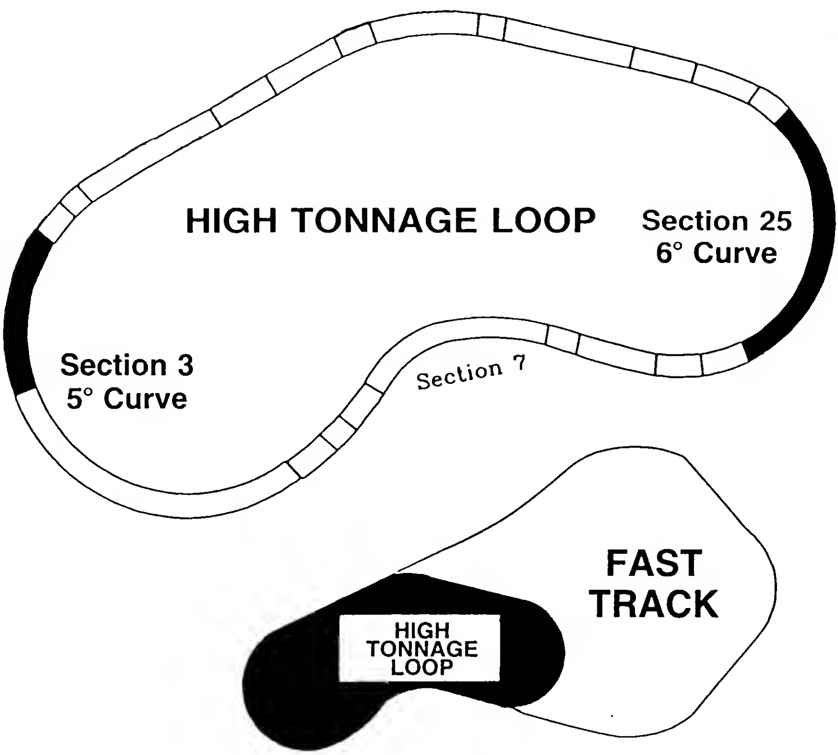

Figure 1
Fast High Tonnage Loop

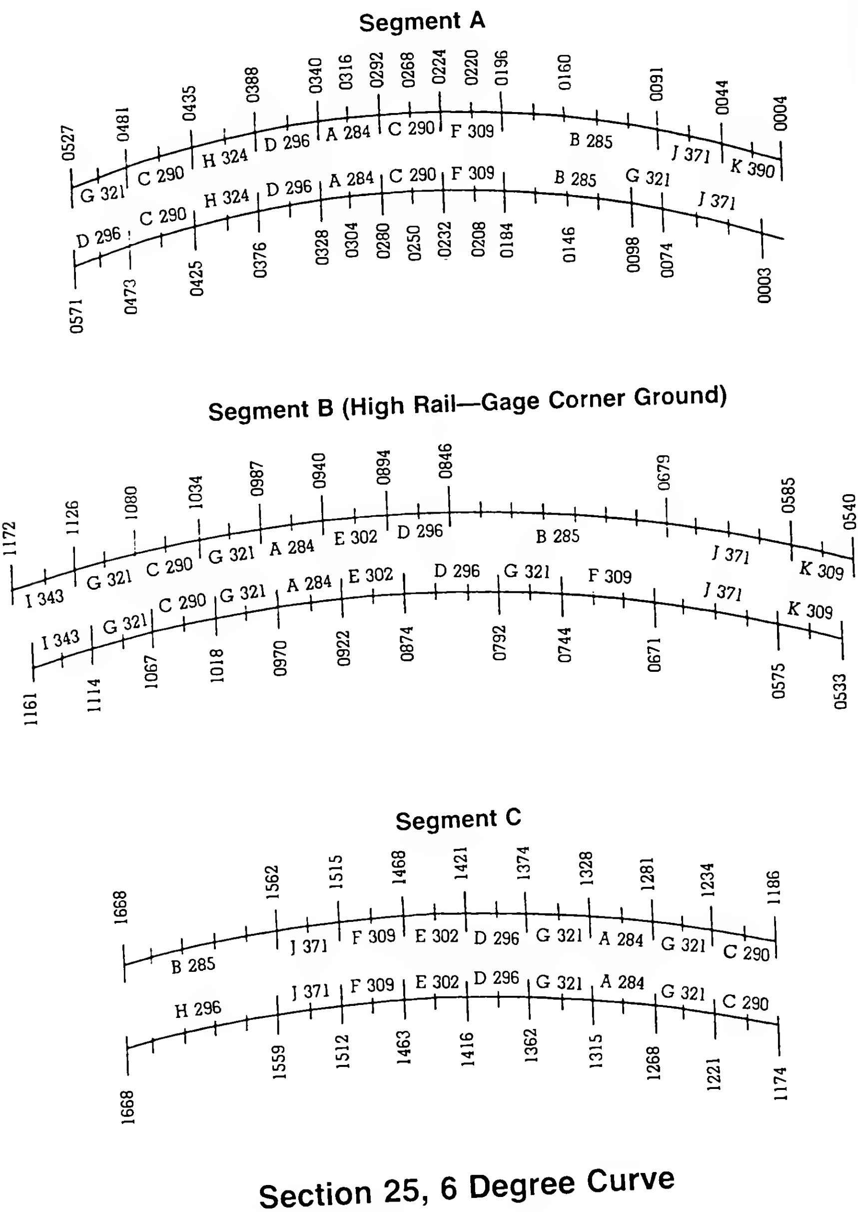

Figure 2a
Rail Steel Layout and Tie Numbers for Section 25

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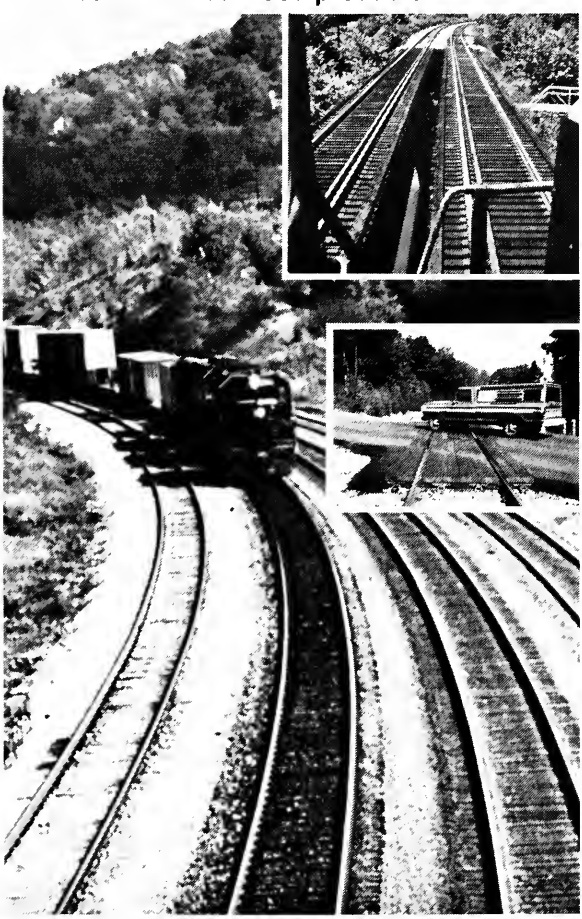

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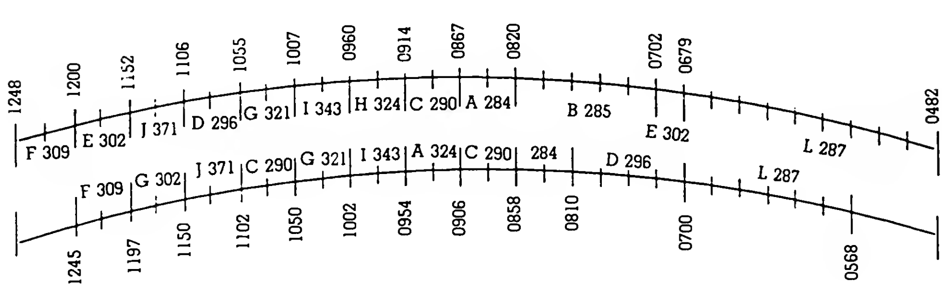

Section 3, 5 Degree Curve

Figure 2b
Rail Steel Layout and Tie Numbers for Section 03

Experimental

The experiments were undertaken in the FAST High Tonnage Loop, Figure 1. The test rails were distributed in four segments. A, B, and C were located in the six degree curve of Section 25 and D in the five degree curve of Section 3. The arrangement of the rails, Figure 2, represents a compromise between the desire to have an identical pattern in each segment and the availability of different steels.

The full 150 MGT of the experiment was conducted with the outer rail in a well lubricated condition. The variations in the lubrication level in the four segments did not affect the fatigue performance of the rail[5]. The only interruption to continuous lubrication occurred during the 30 dry down laps carried out every 3 MGT prior to ultrasonic inspection of the loop.

The track was carefully maintained and at no time were there any exceptions to FRA class 4 track standards. There were no significant differences in the track support conditions in the four test segments with both curves being on wood ties.

The train consisted of between two and four locomotives pulling between 75 and 85 loaded hopper cars of 100 ton capacity. The train speed was close to 40 mph throughout the four test segments. For the first 120.8 MGT the train operated only in the counterclockwise direction. Subsequently, the dry down laps were run in the opposite direction to provide distinct growth ring markings at known MGT levels on the detail fractures.

The high rails of segment B were ground on the gage corner in an attempt to reduce the incidence of fatigue. A full analysis of the data reveals[5], however, that the influence was negligible.

The chemical compositions of the rail steels used are given in Table I. Table II provides hardness and inclusion data. As can be seen, not all of the rail steels were fully characterized.

The hardness measurements were made on transverse sections taken from the rails after they had been removed from the track. At least four measurements were made for each steel using a pattern of indentations which covered the rail head beneath the deformed surface layer. To ensure the accuracy of these measurements the Brinell hardness tester was calibrated before and after taking the readings. Throughout this paper, a rail steel is referred to by the code letter given in Table I and its hardness.

Samples were taken from selected rail steels, in the orientation shown in Figure 3, for non-metallic inclusion determination. The 10 × 10 × 20 mm blocks were taken at the approximate location where shells are encountered, following Sugino et al[6]. The horizontal plane surface investigated is 12.7 mm below the running surface of a new rail profile with the centerline 19 mm in from the side of the rail.

Steel	C	Mn	Si	S	P	Cr	V
A	0.81	0.91	0.22	0.0002	0.014	0.03	0.00
B	0.75	0.85	0.17	0.0170	0.022	0.02	0.00
C	0.80	0.87	0.22	0.0050	0.017	0.02	0.00
D	0.75	0.91	0.36	0.0140	0.007	0.17	0.00
E	0.75	1.14	0.24	0.0150	0.012	0.19	0.00
F	0.80	1.12	0.40	0.0190	0.016	0.15	0.00
G	0.80	1.13	0.23	0.0190	0.018	0.19	0.00
H	0.79	0.93	0.44	0.0030	0.015	0.09	0.03
I	0.78	0.79	0.50	0.0060	0.024	0.41	0.06
J	0.85	0.91	0.22	0.0008	0.014	0.03	0.00
K	0.77	0.81	0.52	0.0050	0.023	0.42	0.06

Table I. Chemical Composition of Rail Steels

Steel	Brinell Hardness	Oxide Volume Fraction (%)	Stringer Length (μm)	Shell Index (−)
A	284	0.041	420	8.5
			380	
B	285	0.089	11700	4.4
C	290	0.004	980	10.3
			1060	
			100	
D	296	0.094	1030	6.8
F	309	0.051	100	9.8
G	321	0.033	1960	7.4
J	371	0.041	420	9.1
			380	

Table II. Hardness, Inclusions and Shell Index

The volume fraction of oxide inclusions was measured in accordance with ASTM E 542-83. A 20×20 grid containing 400 points with a spacing of 0.1 inches at a magnification of 400X was used. This magnification and grid size provided an optimum relative size between the inclusions and the grid. A minimum of 30 fields were counted for each specimen.

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Oxide stringer measurements were made following the approach of Sugino et al[6]. The specimen was viewed at a magnification of 100X in an optical microscope. Oxide stringers are defined as clusters of alumina, 100 micrometers or more in overall length, made up of individual globular inclusions separated by less than 100 micrometers. The total oxide stringer length in the whole of the 200 square mm surface was measured.

A number of the rails containing shells and detail fractures were examined in the laboratory. The approximate size of a detail fracture at any given MGT was determined from the marker rings as indicated in Figure 4. The crack area was divided by 4.86 for a 136 pound rail and 4.42 for a 132 pound rail to determine crack size in terms of percentage head area.

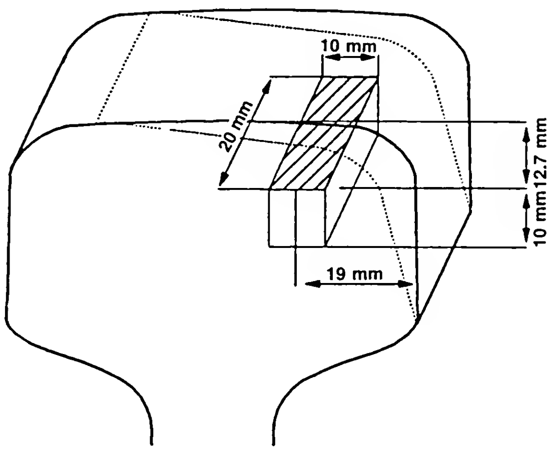

Figure 3
Location of Non-Metallic Inclusion Measurements

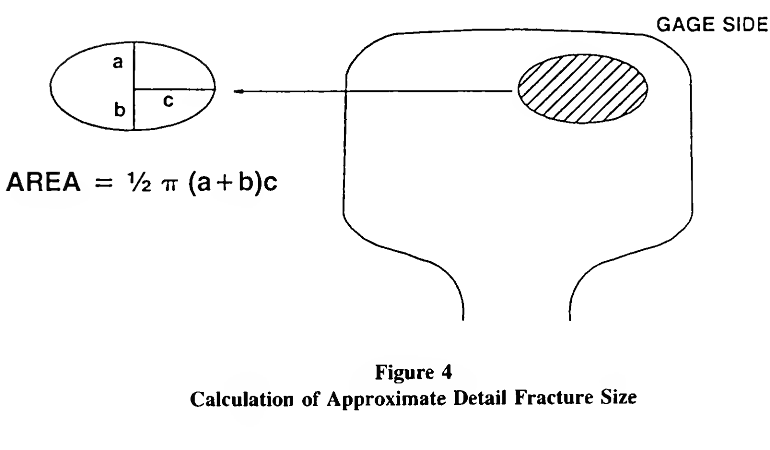

Figure 4
Calculation of Approximate Detail Fracture Size

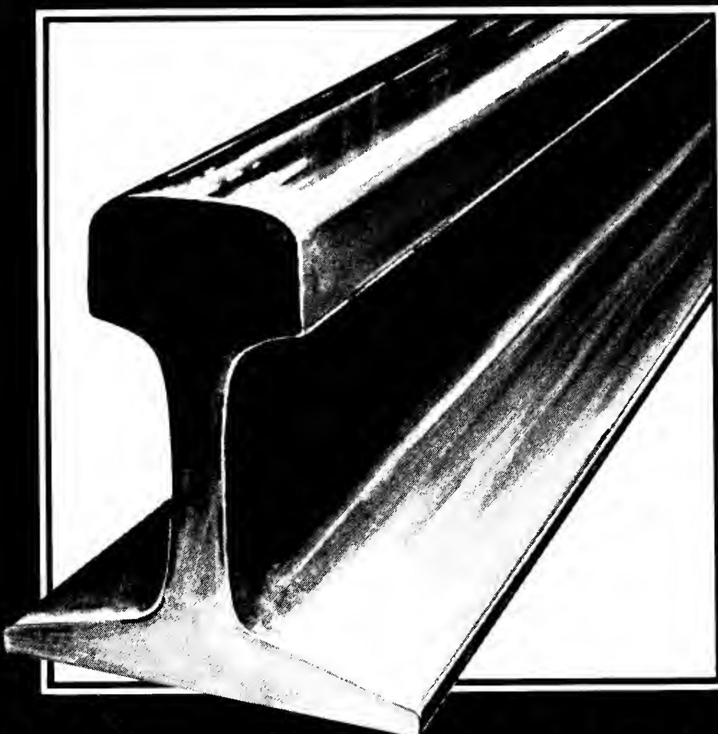

Figure 5
Detail Fracture from Bi-Planar Shell

Figure 6
Central Step Feature of Shell

Results

The shells and detail fractures produced in the experiment were very similar to those observed by many other workers in the past, with the only difference being in the case of the shells produced in the ground rail in segment B where the shells developed on two planes rather than one, Figure 5.

All the shells examined in the laboratory exhibited the characteristic step-like feature associated with oxide stringers, Figure 6. This provides further confirmatory evidence that the initiation of a shell defect is almost certainly connected with the presence of a suitable oxide inclusion.

The locations of the shells with respect to the as-rolled rail transverse profile are given in Table III. The shells formed 0.30-0.64" (7.6-16.3 mm) below the original rail surface and 0.23-0.64" (5.8-16.3 mm) in from the gage face. Assuming a normal distribution, the initial location with respect to the unworn profile is given by a mean +/− two standard deviations of 0.48 +/− 0.19" (12.2 +/− 4.8 mm) below the surface and 0.41 +/− 0.21 (10.4 +/− 5.3 mm) in from the gage face.

Defect	Distance From Unworn Profile	
	Vert.	Horiz.
03-0658	0.64	0.64
03-0841	0.54	0.46
03-0857	0.54	0.51
25-0279	0.57	0.42
25-0292	0.46	0.33
25-0293	0.59	0.45
25-0307	0.43	0.37
25-0330	0.54	0.46
25-0499	0.52	0.41
25-0724	0.47	0.41
25-0890	0.35	0.39
25-1308	0.51	0.41
25-1352	0.30	0.25
25-1356	0.36	0.27
25-1359	0.34	0.23
25-1385	0.46	0.41
25-1654	0.55	0.63

Table III. Shell Initiation Locations


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Rail Steel		Number of Shells								
		0-90 MGT				90-150 MGT				
		25A	25B	25C	03	25A	25B	25C	03	Total
A	284	1	4	0	11	7	2	5	2	32
B	285	43	143	9	19	*	*	19	1	234
C	290	0	0	0	0	0	0	0	0	0
D	296	0	11	11	0	0	3	11	4	40
E	302	0	0	0	0	3	0	0	0	3
F	309	0	0	0	0	0	0	0	0	0
G	321	10	2	0	0	2	1	10	0	25
H	324	0	0	0	0	0	0	0	0	0
I	343	0	0	0	0	0	0	0	0	0
J	371	—	0	—	0	—	0	—	0	0
K	390	0	—	—	—	0	—	—	—	0
L	294	—	—	—	4	—	—	—	9	13
					Total	66	166	65	50	347

* Rails removed soon after 90 MGT.
— Steel not present at any time.

Table IV. Summary of Shell Defects

Table IV summarizes the shell history at 90 and 150 MGT and includes both those shells which formed detail fractures and those which did not. The data are presented on the basis of rail metallurgy irrespective of position in the loop. A total of 347 shells were recorded, a far greater number than observed in any previous FAST experiment.

The incidence of detail fracture formation from shells was not a constant but depended on rail metallurgy, Table V. None of the many shells which grew to greater than 40 mm in length produced a detail fracture. Those which did initiate transverse defects were between 2 and 40 mm in length.

The number of starting rails for each rail metallurgy was not the same and not all of the rails lasted the full 150 MGT of the experiment. Of those that had to be prematurely removed, most were replaced because they were corrugated and this applied particularly to the B 285 rails. It is necessary, therefore, to normalize the shell data to account for these variations.

Table VI gives the shell defect rate for each rail metallurgy in terms of the number of shells produced per rail-MGT. The latter term requires some explanation. If a given rail metallurgy had ten rails, all of which lasted the full 150 MGT, then the rail-MGT would be 1500. If five of the rails had to be taken out after only 100 MGT then the value of the rail-MGT term would be reduced to 1250.

Rail		DF's	Shells	DF/Shell Ratio
A	284	19	32	0.59
B	285	6	234	0.03
D	296	5	40	0.13
E	302	2	3	0.67
G	321	12	25	0.48
L	294	7	13	0.54

Table V. Ratio of Detail Fractures to Shells

Rail Steel		Shells Per Rail—MGT
A	284	0.024
B	285	0.102
C	290	0.000
D	296	0.035
E	302	0.002
F	309	0.000
G	321	0.023
H	324	0.000
I	343	0.000
J	371	0.000
K	390	0.000
L	294	0.010

Table VI. Shell Average Defect Rates

Figure 7 shows a typical example of a detail fracture in a rail which was broken open after the experiment had been completed. It is evident that running the 30 dry down laps in the clockwise direction between 120.8 and 150 MGT provided excellent markings on the fatigue crack every 3 MGT.

Of the 51 detail fractures produced during the experiment, 12 had marker rings. Crack size as a function of cumulative MGT is shown in Figure 8 for one of the defects. The relationship was very similar for all those defects for which there were sufficient data to construct such a plot.

Analysis and Discussion

A major problem in testing rail in curved track is the possible influence of position in curve effects on the results. A full analysis of the data has shown[5] that this was not significant in this case. Neither were there any statistical differences in the fatigue behavior of any individual rail metallurgy in the four

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Figure 7
Marker Rings on Detail Fracture 25-1308

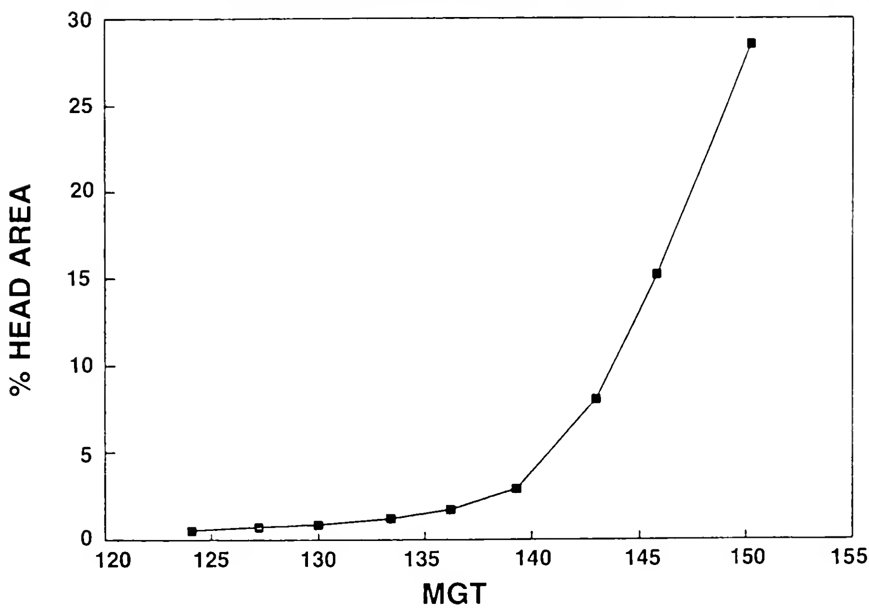


Figure 8
Crack Growth Versus Cumulative MGT for Detail Fracture 03-0576

different test segments. It is, therefore, possible to treat each metallurgy as a single group and analyze the data irrespective of position in the loop. This is the approach taken in this paper.

The shell defect data provide several examples of the influence of hardness, oxide volume fraction, and oxide stringers. However, it is also apparent that none of the three is clearly dominant. It seems appropriate, therefore, to seek a composite term which includes each of the three individual terms. As far as can be ascertained, this strategy has not been followed previously.

The parameter which best describes the limited data from the current experiment has been termed the Shell Index and can be expressed as:

$$\text{Shell Index} = \text{Ln}\left[\frac{\text{Oxide Volume Fraction} \times \text{Stringer Length}}{\text{Hardness}^2}\right]$$

where the oxide volume fraction is expressed as a percentage, the stringer length is the total length of oxide stringers in a 200 mm^2 section, as defined by Sugino et al[6], and hardness is measured with a Brinell machine.

The shell defect rate is plotted against the Shell Index in Figure 9. For the seven characterized steels, this plot separates those steels which did not form any shells from those which did. Furthermore, there is a reasonably good linear relation for those steels which exhibited defects.

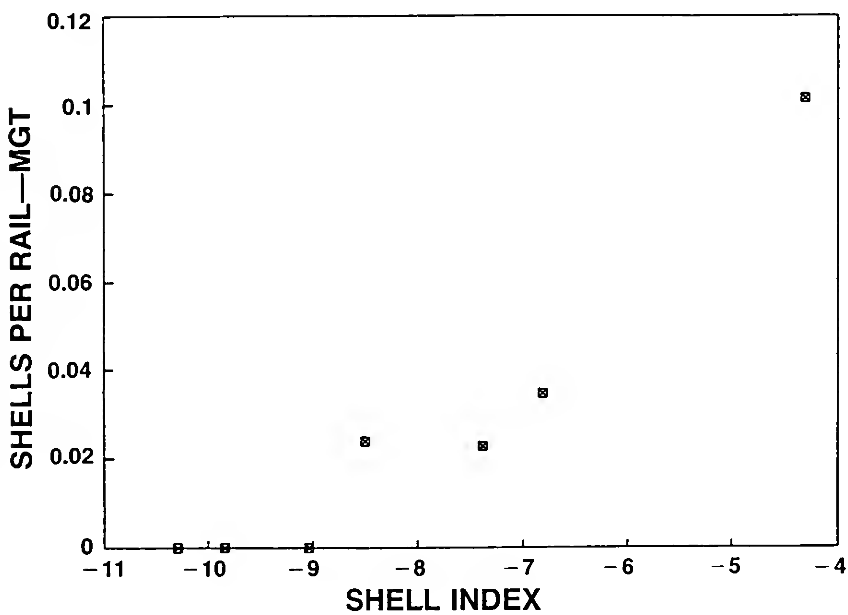
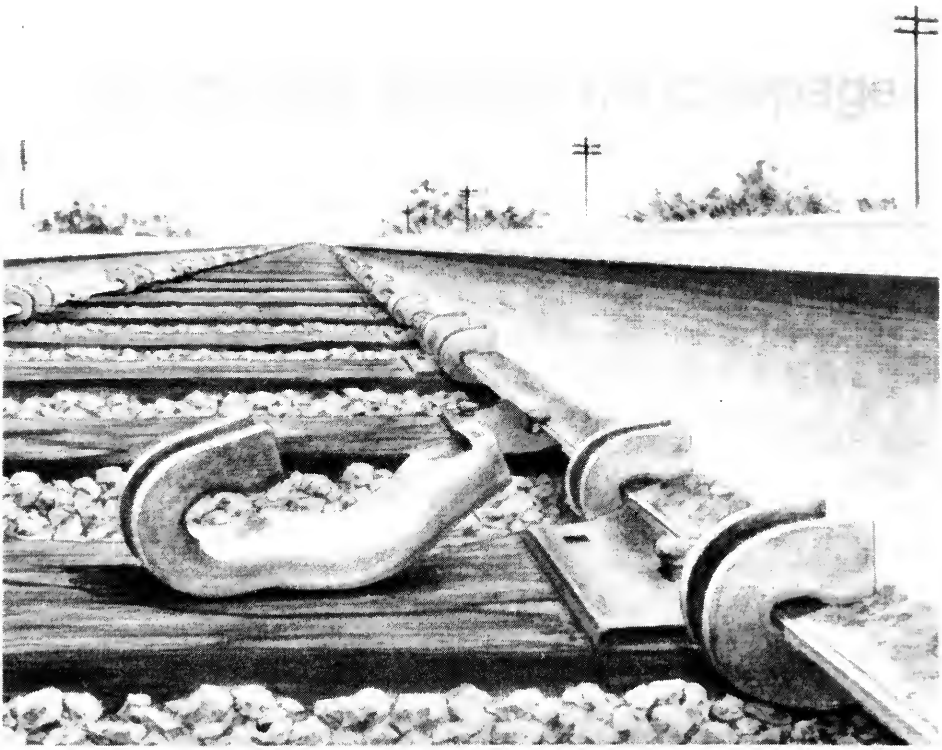


Figure 9
Shell Defect Rate as a Function of the Shell Index



It would be premature in the extreme to suggest that this analysis provides conclusive evidence that the Shell Index, in its present state of development, is a panacea for predicting the shell propensity of any rail steel. There are a number of good reasons for being cautious in even applying it at this stage:

a) In most cases, only a single sample of rail was analyzed for inclusion levels.

b) In the one case where three samples were taken, oxide volume fraction and oxide stringer length show a ten to one variation.

c) Only 150 MGT of traffic was accumulated.

On the other hand, enough encouragement stems from the results to justify a more systematic investigation of a metallurgical parameter which will enable the prediction of the fatigue behavior of a rail steel to be made. There is the distinct possibility that such a parameter could be incorporated into rail specifications. It is worth noting that ORE is currently conducting an investigation to determine the most suitable limits to place on inclusion levels in a new UIC rail specification. In light of the present results, it would seem that the ORE approach is somewhat oversimplified in that it ignores any possibility of the interaction of hardness and cleanliness.

There are two further aspects of the results of the experiment which deserve some mention. The first concerns the size of those shells which turned into detail fractures and the ratio of detail fractures to shells for each of the rail metallurgies, Table V.

Keer et al[11] have predicted that if a shell does not turn down into a detail fracture early on in its growth, it becomes increasingly unlikely to do so. The results of the current experiment are in agreement with this theoretical analysis because no shell greater than 40 mm produced a detail fracture.

The data in Tables II and V suggest that there might be a connection between the tendency for a shell to produce a detail fracture and the oxide volume fraction. The two steels which exhibited noticeably lower numbers of detail fractures with respect to shells were steels B and D. These two steels also had, by far, the highest oxide volume fractions. This indicates that it is unlikely that the turn down of a shell into a detail fracture is dependent on the presence of an oxide. Rather, it is interesting to speculate that the tendency to turn down is a function of the shell crack growth rate with this being influenced by the oxide content. There are, as yet, no data to substantiate this hypothesis because shell growth has not been monitored in any systematic way.

Crack growth measurements in this experiment were focused on the rate at which detail fractures propagated. Data were obtained for 4 of the 6 metallurgies that developed detail fractures. Five of the 12 defects were already in existence at the time reversed running was introduced at 120.8 MGT and three were already larger than 1% head area.

The crack growth plots were very similar for all the defects irrespective of location or metallurgy. The latter observation would have been expected from existing laboratory crack growth data.[12]

The consistency of the crack growth data can be illustrated by the plot in Figure 10 in which all the individual growth plots have been superimposed. To normalize the data a crack size of 1% head area has been taken as the starting point of growth. Figure 10 also indicates that the growth of cracks greater than 10% head area could well be represented by a straight line.

Figure 11 presents all the appropriate data points plotted in a single graph in which the best fit linear regression line has a slope of 1.6. If each individual defect is plotted similarly, the average slope is 2.0. These data suggest, then, that the detail fractures in this experiment grew on average somewhere between 1.6 and 2% head area per MGT for crack sizes of 10 to 28%.

The concept of an essentially linear crack growth model for cracks greater than 10% is consistent with the previous crack growth data generated at FAST[10]. These were for tangent track and showed that the crack growth from 10 to about 50% was essentially linear, with a rate of 1.6% head area per MGT.

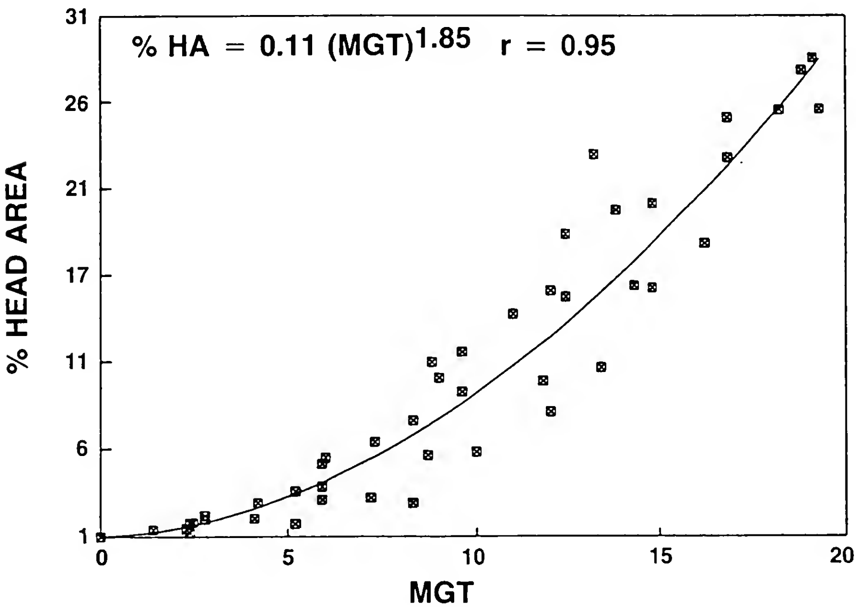


Figure 10
Normalized Crack Growth Based on all the Detail Fracture Data

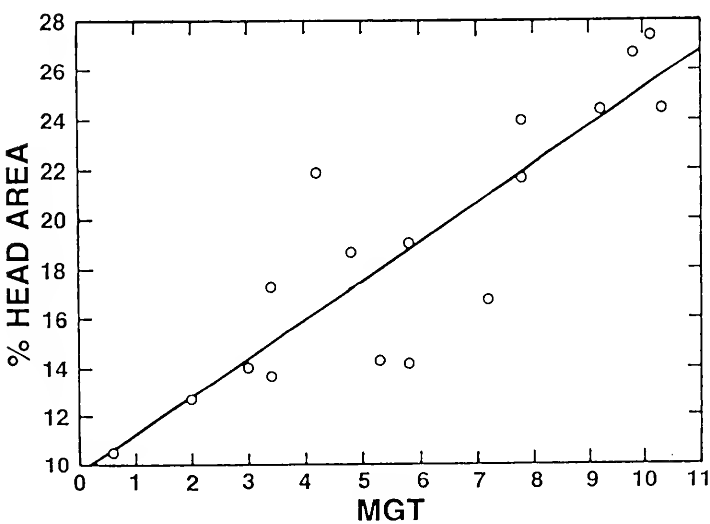


Figure 11
Normalized Crack Growth for all Detail Fractures Larger Than 10%

The work reported in this paper has produced some very interesting and potentially useful information about the shell formation tendency of different rail steels and detail fracture propagation rates. The concept of a shell index now requires further data to support its development. The incentive is that in the future, rail steels could be specified on the basis of fatigue behavior. Although the current experiment at FAST involving 39 kip wheel loads should provide further results for this purpose, it is likely that the amount of data required will necessitate obtaining results from revenue service with the help of several railroads.

Conclusions

1) Shells originated at approximately 0.5" below the surface of the unworn rail and 0.4" in from the gage face. All shells examined had a central step feature which is associated with inclusions.
2) The occurrence of shells in the rail steels tested has been related to a Shell Index which incorporates oxide volume fraction, a measure of oxide stringers and hardness. The indications are that shell formation can be suppressed by increasing rail hardness, reducing the volume fraction of oxides, reducing the number of oxide stringers or some combination of these actions.
3) The range of shell sizes which initiated detail fractures was 2-40 mm. None of the many shells longer than 40 mm resulted in a detail fracture.
4) The rate of detail fracture growth was very consistent for the defects measured in both 5 and 6° curves. The average growth from 1-28% head area involved 19 MGT of traffic. Growth from 10% could be approximated by a linear relation in which the average growth rate was 1.6 to 2% head area per MGT.

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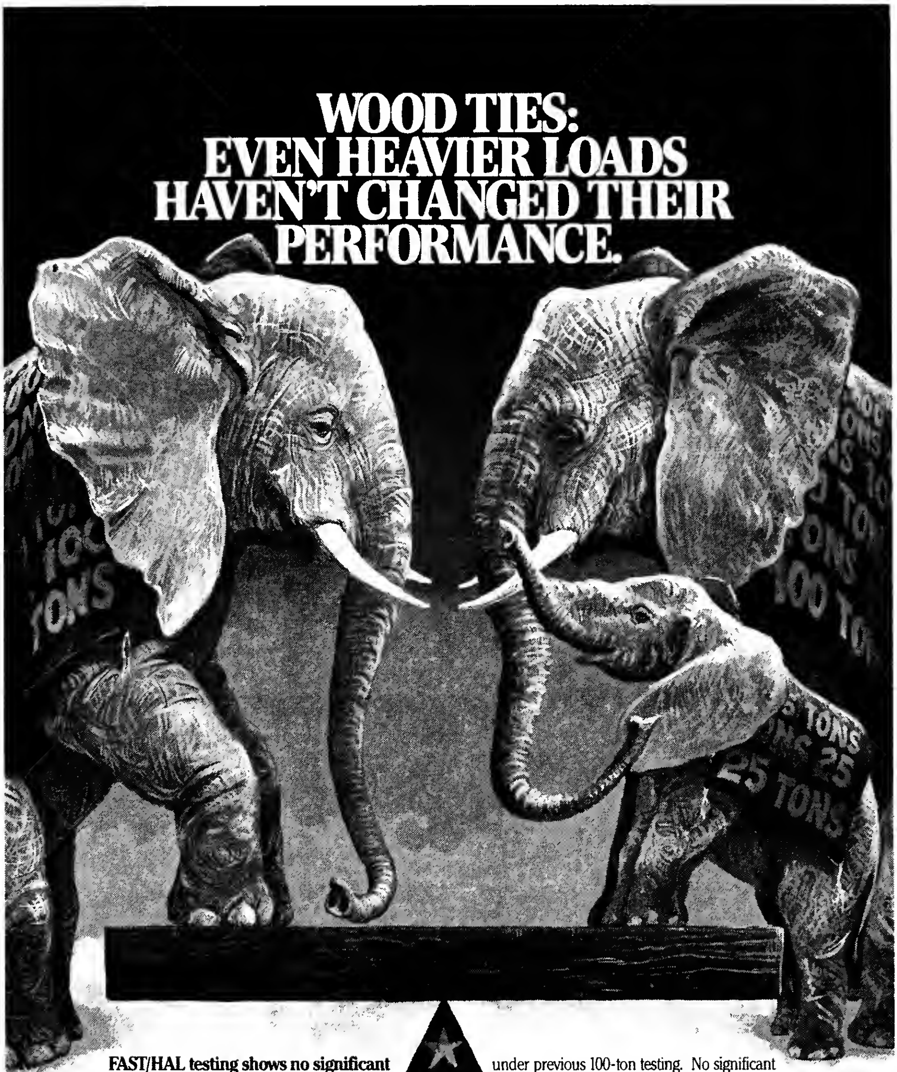
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MEMOIR

ALTON B. MERRITT, JR.

Alton Barton Merritt, Jr. died in Jacksonville, Florida on January 2, 1991.

Mr. Merritt was born January 29, 1932 in Winston-Salem, North Carolina. He received a B.S. Degree, with honors, from North Carolina State University in June, 1954. He served as a First Lt. in the U.S. Army, 1955-57. Following a brief service with Seaboard Air Line Railroad, he returned to N.C. State University as an Instructor while pursuing a M.S. Degree in Civil Engineering. In 1960, he rejoined the SAL RR, where he served as Assistant Division Engineer and Office Engineer, Maintenance of Way.

Following the SAL-ACL Merger, in his subsequent work with Seaboard Coast Line, he served as a Maintenance of Way Staff Officer, Budget Officer, and later, as a Senior Assistant Engineer, Design and Construction. In the latter capacity, he was the principal engineer responsible for the design and construction management of SCL's Rice Yard, Waycross, Georgia, a major new classification and equipment maintenance facility. Later, he was responsible for the design and implementation of major improvements in the Welding Facility at Nashville, Tennessee.

Following formation of CSX Corporation, Mr. Merritt was Engineer of Track for Seaboard System RR, a CSX unit, and later served as director of Planning for CSX Rail Transport. At his death he was Director of Engineering Services for CSX Rail Transport.

Mr. Merritt was a resourceful and adaptable engineer as is reflected in his career in Maintenance of Way, Budgeting, Design and Construction, Planning, and Engineering Services. He made substantial contributions in each of these areas and shared his knowledge freely with others in the industry through his work with AREA.

Mr. Merritt became a member of AREA in 1936. He served on Committee 4—Rail from 1964 until his death this year. He was Secretary to the Committee from 1970 to 1978, and again from 1981 to 1982. He was a Subcommittee Chairman in 1986-87. In these years he contributed, in a major way, to the refinement of the Rail Specification and the advancement of the work of the Committee. He also served as a Member of Committee 32—Systems Engineerng during its early years.

Mr. Merritt was a Fellow of the American Society of Civil Engineers, as well as Professional Engineer of Virginia, North Carolina, South Carolina, Georgia, Florida and Alabama.

He is survived by his wife, Patricia C. Merritt, and a son, Richard B. Merritt, a Trainmaster with CSXT, New Orleans, Louisiana.

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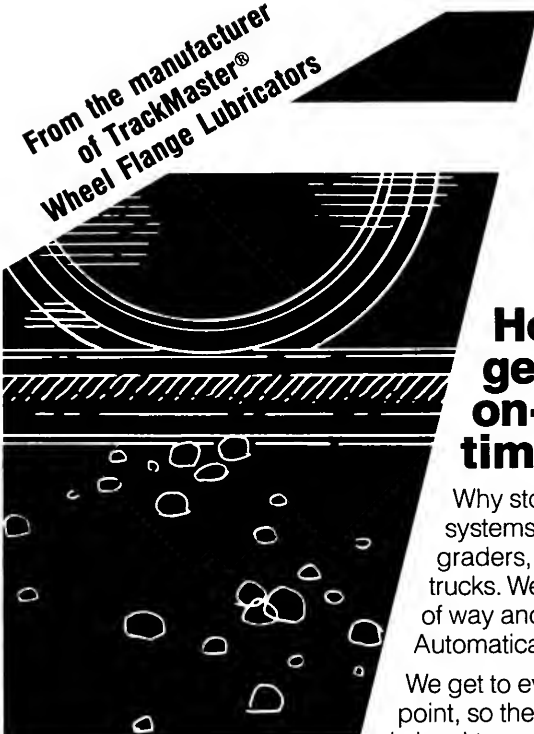

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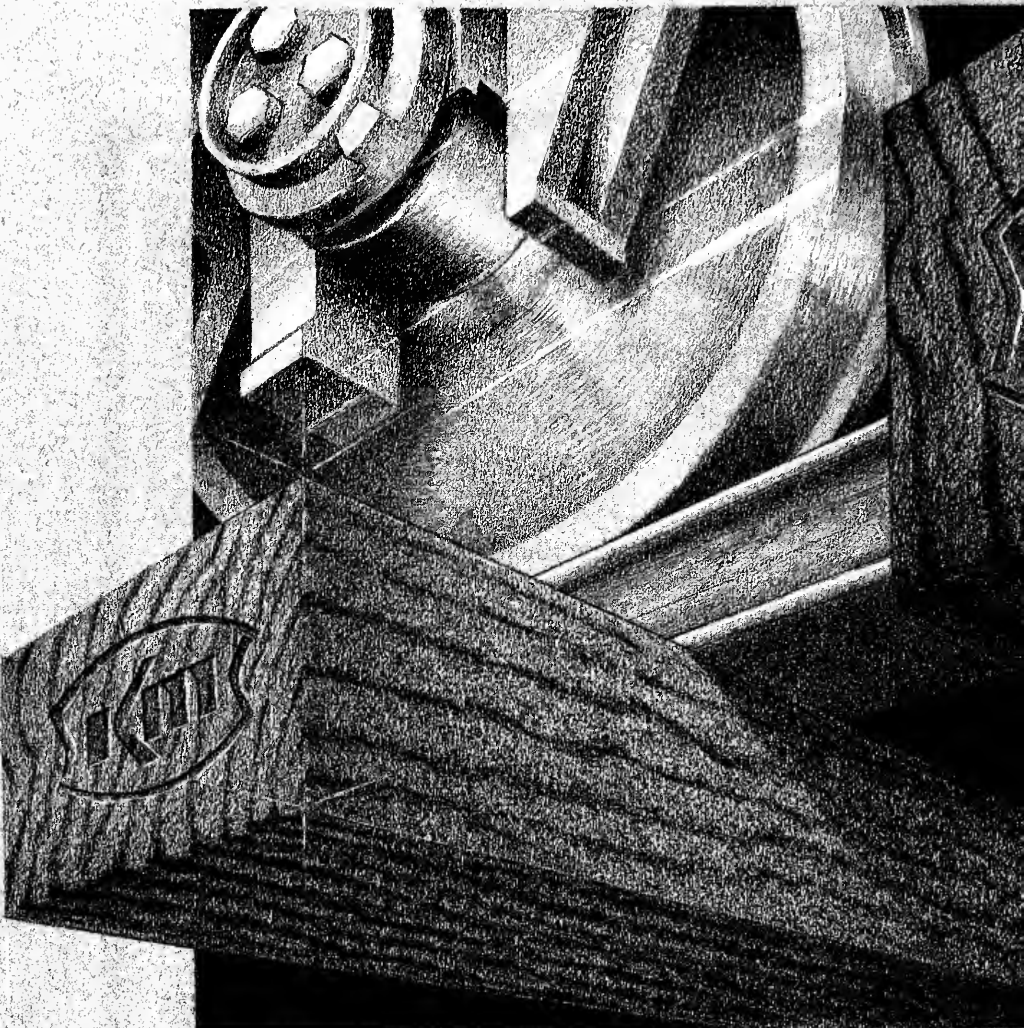

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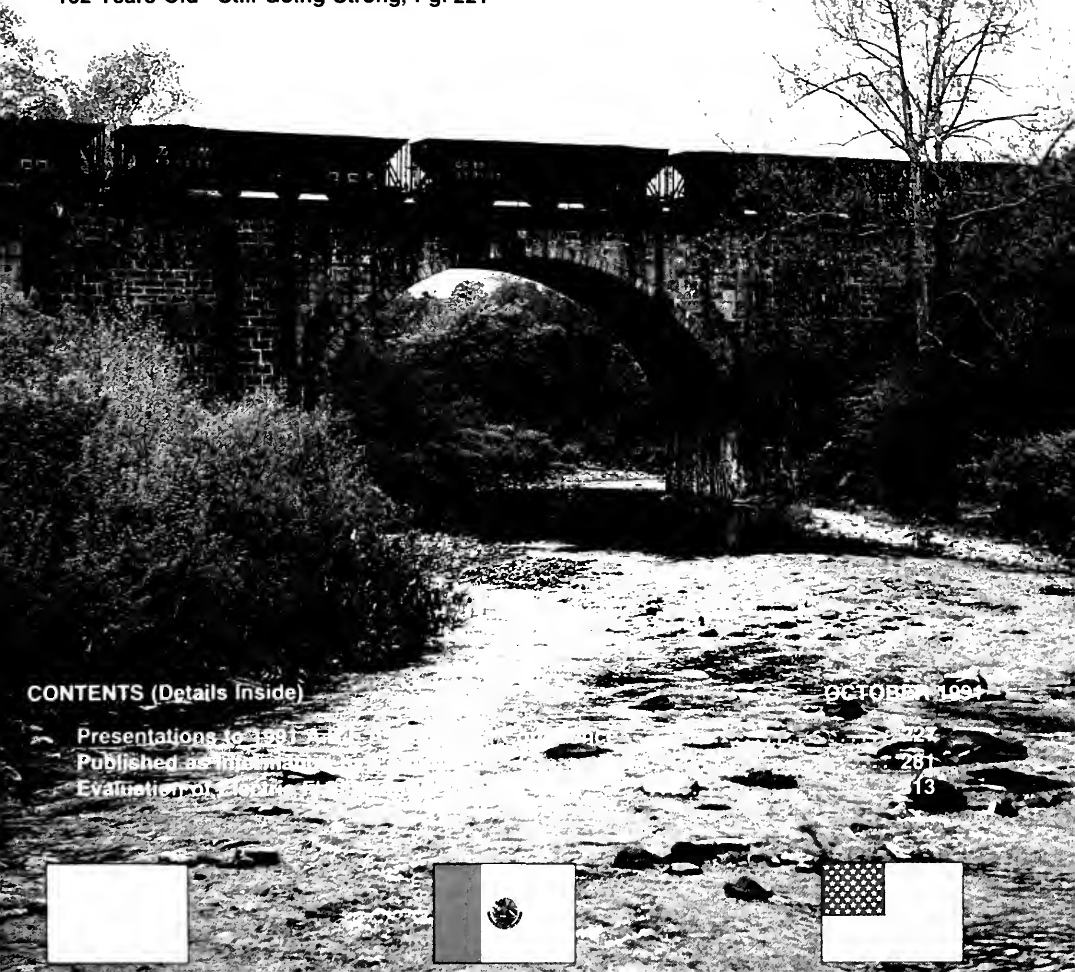

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American Railway Engineering Association

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Stefanie Streever, Editor

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Front Cover: Eastbound CSX coal train crosses 162-year old Carrollton Viaduct in Baltimore, Maryland April 28, 1991.

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162 Years Old and Still Going Strong

The oldest railroad bridge on the North American railroad network was built in 1829 to carry the original mainline of the Baltimore and Ohio railroad (now CSX) west from Baltimore, Maryland over a stream known as Gwynns Falls. The bridge, called the Carrollton Viaduct, lies about one mile west of the old Pratt Street Station in Baltimore, now the home of the Baltimore and Ohio Railroad Museum.

While this double-track structure no longer carries the mainline west from Baltimore, it still serves an important function for unit coal trains coming into the port of Baltimore. The bridge is a single 80-foot span stone arch and has not been strengthened or received significant repairs since it was originally constructed.

Construction commenced on this bridge in December, 1828, and it was completed in late 1829. The track consisted of 5/8 inch thick by 2-1/2 inch wide flat iron strips fastened to wood beams supported by wooden crossties. The first train operated over the bridge on January 1, 1830 and regular scheduled service was inaugurated on May 24, 1830. These trains were pulled by horses, as it was not until August 1830 that the famous locomotive "Tom Thumb" was tested.

Regular locomotive haulage of trains over the bridge (with the 7,000 pound locomotive "York") did not begin until June, 1831. The photo above and the one on the front cover show an inbound coal train crossing the bridge. While the scenery appears pastoral, the bridge is actually deep inside urban Baltimore.

It is interesting to note that there was some worry when the 13,000 pound locomotive "Atlantic" was put into service in September 1832 as to whether the bridge would be safe under such an additional load. As engineering advanced, of course, it became obvious that the bridge was actually much stronger, and as can be seen in the photo above taken on April 28, 1991 from the south side of the bridge, strings of 263,000 pound cars are routinely carried.

Photo 1: Overall view of by-pass project with Gold Hill Depot in background, at left.

Tunnel Bypass Restores Line Out of Service for 53 Years

While the AREA does not normally cover tourist railroads, it is significant that in some cases these lines have resurrected historically important railroad engineering achievements and restored them to use. One example is the restoration of the Georgetown Loop between Georgetown and Silver Plume, Colorado where the line loops over itself on a high bridge and traverses several horseshoe curves to gain altitude where the canyon floor rises at a steeper grade than permissible for railway construction. Another example is the 301-foot high Kinzua viaduct near Mount Jewett, Pennsylvania.

In Nevada, the most difficult stretch (between Gold Hill and Virginia City) of the old Virginia and Truckee railroad line from Carson City to Virginia City, opened in 1870. Although it was abandoned in 1938, Virginia and Truckee restored this line on June 5, 1991. We congratulate Virginia and Truckee president Bob Gray on restoring this railway engineering achievement to operation.

To reopen the line, it was necessary to reopen two tunnels and cross a state highway. Also, the three-mile right of way had been sold into 60 individual parcels which had to be repurchased before construction could be complete. The 122-year old Gold Hill Depot, though built entirely of timber, was still standing and restorable.

The biggest engineering problem was the first tunnel out of Gold Hill, which was deemed to be too deteriorated to restore. The decision was made to build a bypass of the tunnel by swinging around the outside of the spur of the mountain through which the tunnel cut. Because the original horseshoe curve just beyond the Gold Hill Depot was 19 degrees, it was decided to use this curvature for the by-pass.

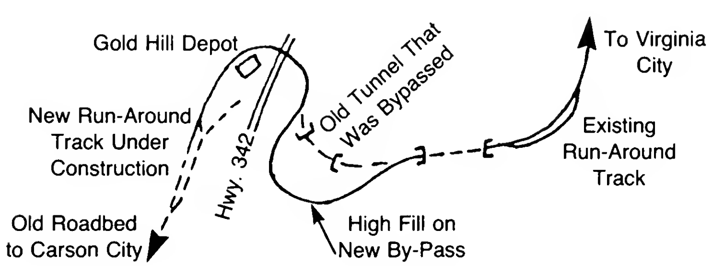

Photo 2: New 75-foot fill on tunnel by-pass.

Even this sharp curvature required the construction of a 75-foot high fill to get back to the original alignment on the other end of the tunnel—an enormous undertaking for a small tourist line.

Photo 1 shows the overall by-pass project, with the Gold Hill Depot downgrade on the left beyond the horseshoe curve and the high fill on the right. Photo 2 shows a close up of the fill at the Virginia City end of the tunnel, and photo 3 shows the other end of the bypass at the Gold Hill end of the tunnel. The view from the bypass looking towards the horseshoe curve and the Gold Hill Depot is shown on Photo 4. Photo 5 shows the Gold Hill Depot area, looking towards the end of track beyond the depot, with the restored crossing of the state highway in the foreground. The crossing was built to present-day standards with cantilever flashing light signals for the safety of highway traffic. A new vertical alignment for the highway was necessary to conform to the superelevation of the tracks, since the previous grade of the highway at this point had a slope steeper than that caused by the track's superelevation.

Photo 3: End of by-pass at Gold Hill end of tunnel.


Photo 4: Looking towards Gold Hill Depot from by-pass.

A run-around track is under construction beyond the depot as well as additional trackage. There is the possibility of extending the line restoration somewhat further towards Carson City, and the old grade can be seen beyond the end of track. The new runaround track was scheduled to go into operation about September 1, 1991.

Photo 5: Gold Hill Depot with present end of track beyond.

ECONOMIC ASSESSMENT OF INCREASED AXLE LOADS BASED ON HEAVY AXLE LOAD TESTS AT THE AAR TRANSPORTATION TEST CENTER—PUEBLO

M. B. Hargrove*

The history of freight railroad technology shows a pattern of increasing vehicle size with increasing axle loads as developments in materials and engineering knowledge have made their use technically feasible and economically desirable. The possibility that technology has changed sufficiently to allow increased economic efficiency in the rail transportation of bulk commodities by increasing axle loads above 32.5 tons was publicly raised by Australian representatives at the 1985 Heavy Haul Conference in Vancouver [1]. The conclusions of the Australian paper led to renewed interest in and support for studies of this issue by U.S. roads.

Unfortunately, all of the estimates of the economics of heavy axle loads (>33 tons) generated prior to the conducting of the FAST-HAL tests at the Transportation Test Center (TTC) relied heavily on models of track deterioration calibrated from data observed under traffic consisting of lighter axle loads (<33 tons) since the limited revenue operations of >33 ton axle load equipment in North America had not created sufficient data to allow the calibration of deterioration models. The FAST-HAL tests at TTC were designed to develop data on the relative deterioration rates of track components under 33 ton and >33 ton (39 ton) axle loads, and the results of 160 Million Gross Tons (MGT) of 39 ton axle load traffic were documented in the Phase I tests [2].

The FAST-HAL *Ad Hoc* Economic Review Committee, whose membership is shown in the Appendix, has reviewed evidence of the impact of Heavy Axle Load (HAL) traffic on the economics of rail bulk commodity (coal) transportation. This review has included data from the FAST-HAL tests at TTC, from test sites on individual railroads and from laboratory tests. In some cases, where data from controlled tests was not available, expert opinion was used. Three activities have been undertaken: first, a life-cycle cost methodology was developed and calibrated, second, estimates were made for four "generic" operating scenarios of the relative economics of providing coal transportation in conventional design cars of 263,000 lb. (33-ton axle loads), 286,000 lb. (36-ton axle loads), and 315,000 lb. (39-ton axle loads) Gross Vehicle Weight (GVW) (The 286,000 lb. car configuration analyzed was a 263,000 lb. car loaded to 286,000 lb.). The details of the car designs evaluated are shown in Exhibit 1. Third, two case studies were conducted using the Committee's methodology to evaluate actual operations on two railroads. This allowed the Committee's estimates to be compared to these railroads' actual experience with 263,000 lb. equipment and to the estimates of the effects of HAL traffic prepared independently by the two participating carriers.

To fully understand the Committee's methodology and findings it is necessary to first consider the relationships between car size (axle loads) and costs. For coal and many bulk commodities the shipper is substantially indifferent to the number of cars involved in the movement. His only concern is to move a given large quantity of commodity between two points. Thus the value of the service (revenue potential) is not effected by car size. Increased car size (axle loads) are of value only to the extent that they reduce the cost of providing this service on a net ton mile basis.

Operating Costs

Crew Costs—Crew costs are almost invariant with train size and weight; therefore, the crew cost per net ton mile is minimized by maximizing the net load per train. The limits on train size for most North American bulk train services is set either by maximum allowable drawbar force or by maximum allowable train length due to yard track and passing siding lengths. Car size (axle load) can effect crew cost per net ton mile in both situations although the effect is larger in the length limited situation.

Maximum drawbar forces for a given route are largely proportional to trailing tons behind the locomotives. Individual roads use different limits, typically 350,000 to 375,000 pounds, which result

*Director, Engineering Economics Division, Research & Test Department, Association of American Railroads

Exhibit 1
Coal Equipment Evaluated

All conventional design, four axle, steel gondolas.

Base car (263)—Modeled on existing common design
Gross weight—263,000 pounds
Length—53′1″
Tare—59,700 pounds
Net/Tare ratio—3.41

"Fully loaded" car (286)—Base car max loaded, 36″ wheels
Gross weight—286,000 pounds
Length—53′1″
Tare—59,700 pounds
Net/Tare ratio—3.79

315,000 pound car (315)—Heavy car on 38″ wheels
Gross weight—315,000 pounds
Length—53′1″
Tare—68,000 pounds
Net/Tare ratio—3.63

Individual car designs will differ from committee assumptions in all weight classes.

in trains of 9000 to 12,000 trailing tons with head end power only. Since the drawbar forces respond to total trailing weight, if the use of increased axle loads can improve the net-to-tare weight ratio, then the net load in a given weight train is increased. After extensive review of existing car designs and discussions with car builders, the Committee used a net-to-tare of 3.63 for the "315K car" compared to 3.41 for the "263K car,"—an increase of 6.5%. The "fully loaded" 286K car has a net-to-tare of 3.79, even better than the 315K car.

For length limited services it appears that cars with adequate capacity for "315K Gross Weight" bulk service can be designed within the length constraint of 53.08 feet between pulling faces imposed by existing rotary dumpers. Thus the net load per foot of length is increased from 1.91 net tons per foot for "263K Gross Weight" cars to 2.33 for "315K Gross Weight" equipment, an increase of 22.0%. Some individuals have commented that a shorter "263K" car could be designed under the same clearance limits used for the "315K" car thus eliminating this advantage of the "315K" car, but this design does not exist at this time.

Fuel Costs—In bulk service, the primary determinate of fuel consumption per net ton mile on a given route is the gross train weight per net ton. Holding other factors constant, the higher the net-to-tare ratio, the less the fuel consumption per net ton mile. The Train Energy Model (TEM) was used to simulate the operation of trains of 263K, 286K, and 315K Gross Weight equipment over a variety of routes for both drawbar and length limited services to get precise estimates of fuel requirements.

Locomotive Costs—Ownership and Maintenance—Locomotive requirements are proportional to the trailing tons for a specific bulk service over a given route. As in the case of fuel, locomotive costs per net ton mile are favorably effected by increases in the net-to-tare ratio of the equipment. TEM simulations are used to determine the locomotive requirements for a specific move.

Car Costs—Ownership and Maintenance—The relative capital cost per ton of capacity of "263K cars" versus "315K cars" is an important issue in the economics of heavy axle load equipment. As in the case of net-to-tare ratio, the examination of the limited series of "315K Gross Weight cars" built to date

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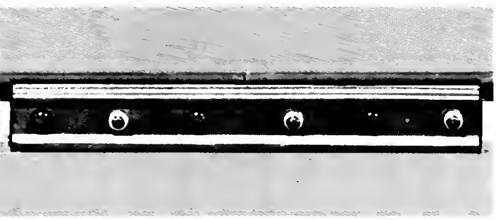

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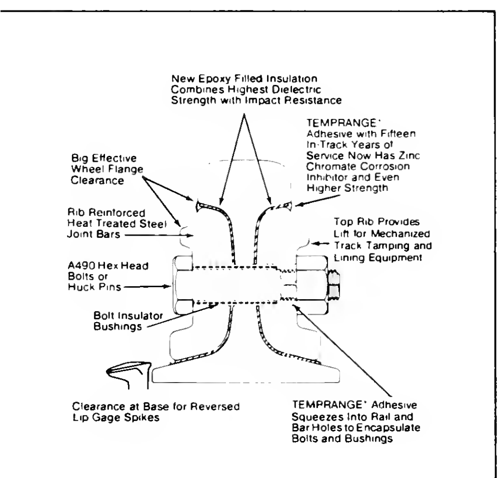

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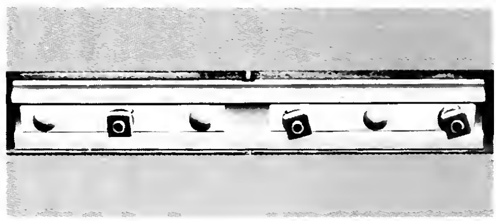

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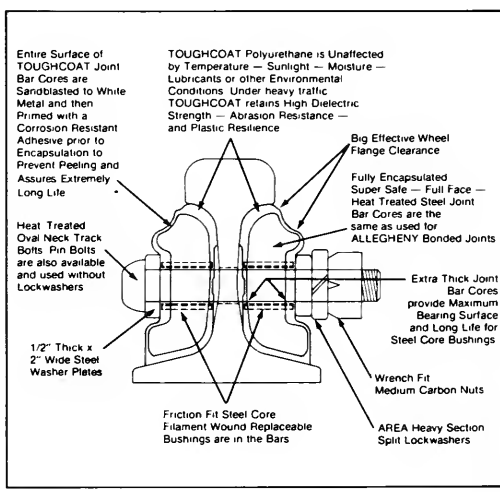

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SUITE 990 • TWO GATEWAY CENTER • PITTSBURGH, PA 15222 compared to equivalent designs in "263K Gross Weight" configurations does not lead to a clear answer, but the Committee has estimated a modest reduction in car capital cost.

In the area of car maintenance, the AAR maintains a car maintenance data base for research purposes. This data base, along with data on wheel wear from FAST and the repair unit cost from the Car Repair Billing System repair cost master, were used to estimate the car maintenance costs per net ton mile.

Certainly, under these assumptions the "315K Gross Weight car" shows only a modest advantage in equipment costs. Since the "286K Gross Weight" car is a 263K design with increased lading, it shows substantial improvements. Of course the equipment ownership cost per net ton mile of service depends on the annual utilization of the equipment, with equipment ownership cost being higher for lower utilization services.

Track Maintenance Costs

In each of the previous categories of direct operating expense, the "315K" car has shown modest reductions in net ton mile cost compared to the "263K" car. The negative impacts of increased axle loads occur in the area of track maintenance. The principal function of the FAST-HAL tests is to quantify the degree of acceleration in track degradation that occurs in the major track components under 38.5 versus 32.5 ton axle loads. One of the major findings of FAST-HAL is that the track structure is not catastrophically deteriorated by 38.5 ton axle loads; therefore, the question is the relative economics of heavy axle loads, not the technical feasibility. The relative impact of heavy axle loads varies among the major track components. Each must be considered separately.

Rail—Modern rail maintenance procedures, lubrication, can reduce the wear rates to a point where the rail will fatigue before it reaches gage face wear limits. The wear rates in the well lubricated regime at FAST-HAL are low enough to allow wear lives well above 1000 MGT even in 6 degree curves. The ability of railroads to maintain an effective level of lubrication equal to that achieved at FAST has been questioned by our industry committee. Following investigations of wear data from existing revenue service field sites, the effective levels of lubrication were adjusted downward in our wear model predictions, so that rail typically is predicted to reach gage face wear limits in curves of greater than 2 degrees. Grinding of the rail head can retard the onset of fatigue damage with increased grinding required as axle load and gross tonnage increase. These higher grinding rates result in reaching head height wear limits before the fatigue defects reach a critical level requiring rail replacement; thus, the predicted mode of failure for rail in tangent and low degree curves is head height loss. Only in the case of the older standard rail (pre-1983) is the grinding of rail not expected to be effective in eliminating rail fatigue as the principal reason for rail removal.

Ties—The FAST-HAL tests have shown that the ties, both wood and concrete, are not deteriorated at a significantly higher rate; therefore, the tie cost per net ton is approximately equal. There is some concern about wood tie life in higher degrees of curvature especially if standard cut spike fasteners are used. Some upward adjustment in tie cost was made for severe curves.

Ballast & Subgrade—The ballast materials at FAST-HAL have required more frequent surfacing, particularly the more marginal materials. The estimated increase in surfacing and deterioration of the ballast gradation (ultimately ballast life) results in higher ballast costs per net ton mile under heavy axle loads. This effect may be greater under conditions of soft subgrade, but this cannot be verified until the additional testing at FAST is conducted. The subgrade pressures are higher under heavy axle loads, and although the firm subgrade at FAST has not shown significantly higher deterioration rates, subgrades in general were estimated to need a small increase in maintenance per net ton mile.

Turnouts—The turnouts at FAST have shown a much higher deterioration rate under heavy axle loads. This has been reflected in higher routine maintenance requirements and in a shorter life for the

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major components of the turnout. A higher quality of turnout has been installed for test at FAST, and the early results indicate that the extra investment is highly justified by the increased life and reduced routine maintenance requirements.

Other factors—The higher routine maintenance requirements for 33 versus 39 ton axle loads have been factored into these analysis by carefully examining the routine maintenance records at FAST and factoring out those activities which were either directly related to the conducting of tests or were for maintaining components not typically present in mainline track. The differential requirements in the remaining routine maintenance activities were used to adjust the typical routine maintenance costs of Class I roads.

The potential impacts on bridge maintenance costs have not been incorporated into the "generic" analysis. These will increase the track maintenance cost penalty associated with heavy axle load cars, although the degree of penalty will be route specific. Depending on the type of bridge and its existing condition, a bridge may be adequate for heavier axle loads and experience no accelerated deterioration. It may require immediate major renovation at a high cost, or an intermediate position requiring accelerated, but not immediate attention. Bridge costs were estimated for the case studies, and in these cases the incremental bridge costs did not outweigh the other elements in the analysis.

Illustrative Examples

The following two cases illustrate the relative importance of the various cost elements effected by changing axle loads as estimated by the Committee's methodology. They are based on coal movements over "generic" Eastern and Western routes.

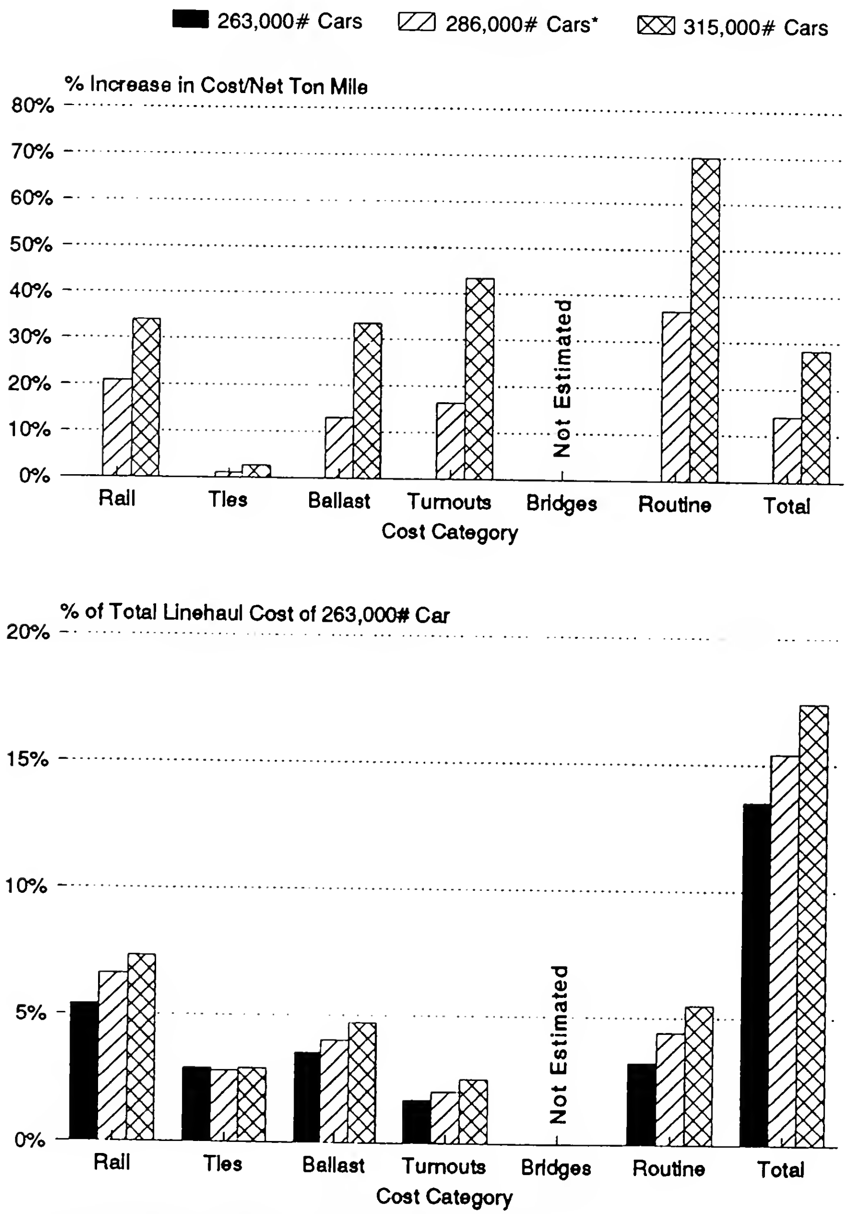
Exhibits 2 and 3 show the relative track maintenance costs per net ton mile for 33, 36, and 39 ton axle load cars when the service is limited by train length for the Eastern and Western services respectively. In both cases, the rail and turnout maintenance costs are substantially increased by heavier axle loads.

Exhibits 4 and 5 integrate these track maintenance costs in with other direct operating costs of providing the service in the length limited Eastern and Western services respectively. The significant decrease in crew cost per net ton mile swings the total cost in favor of heavy axle loads in these length limited cases.

Exhibits 6 and 7 summarize the findings of the four "generic" routes for both the length-limited and the weight-limited operating scenarios for the 286,000 lb. and the 315,000 lb. GVW cars respectively. The results vary widely, but in most cases the heavier cars provide a reduction in direct transportation costs. The higher net-to-tare ratio of the 286,000 lb. car modelled results in typcially greater savings than the 315,000 lb. car as modelled; this should be viewed as an artifact on the specific equipment studied and should not be viewed as a basic finding of the study.

EXHIBIT 2

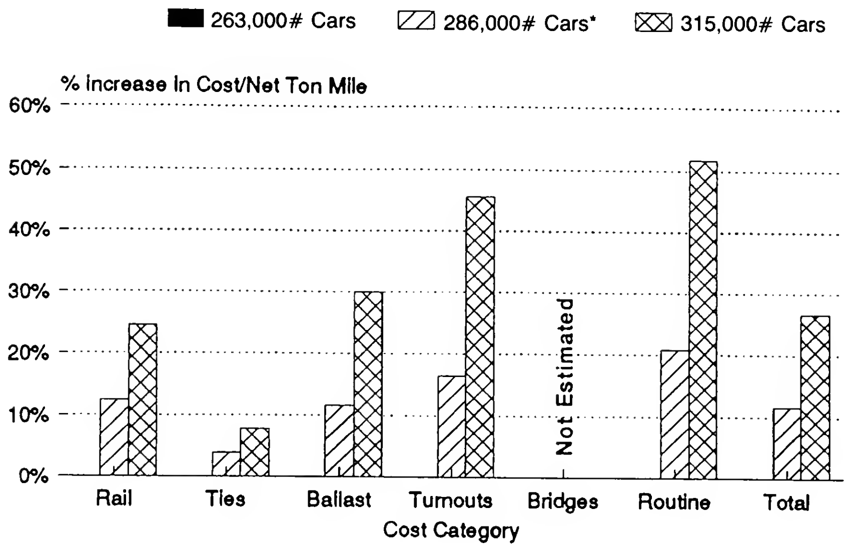
HAL Track Maintenance Cost Comparisons
vs 263,000# Cars
Generic Eastern Route, Length Limited

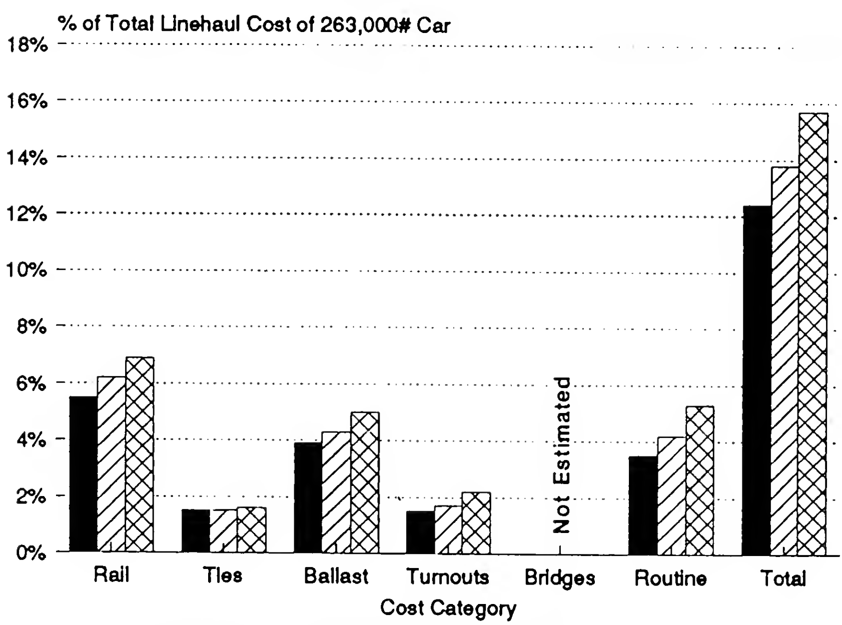


* Intermediate projection, not measured directly at FAST

EXHIBIT 3

HAL Track Maintenance Cost Comparisons
vs 263,000# Cars
Generic Western Route, Length Limited

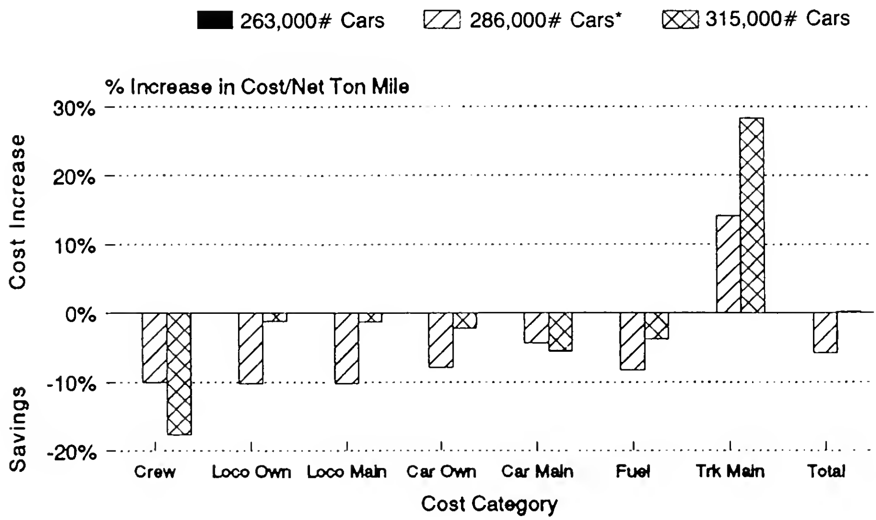




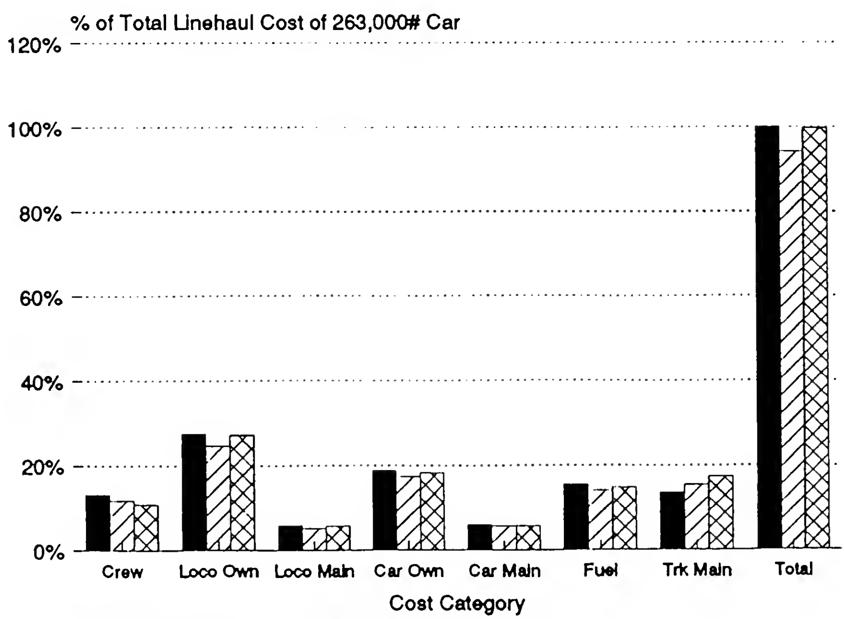
* Intermediate projection, not measured directly at FAST

Exhibit 4

Linehaul Cost Comparisons
vs 263,000# Cars
Generic Eastern Route, Length Limited



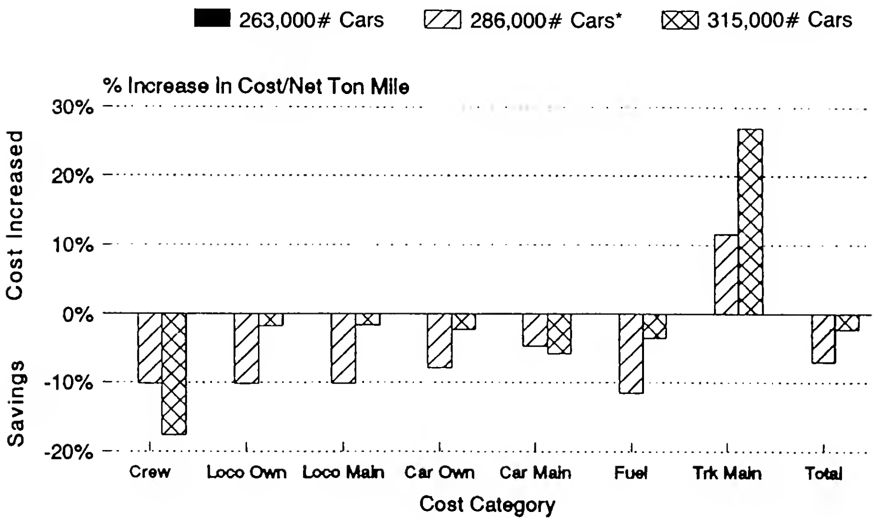
Excludes Bridge Costs



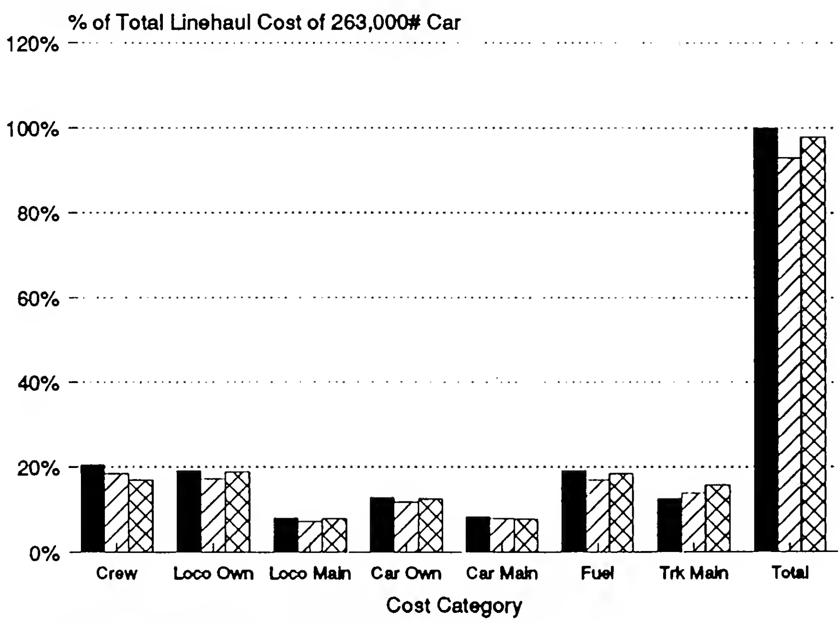
* Intermediate projection, not measured directly at FAST

Exhibit 5

Linehaul Cost Comparisons
vs 263,000# Cars
Generic Western Route, Length Limited



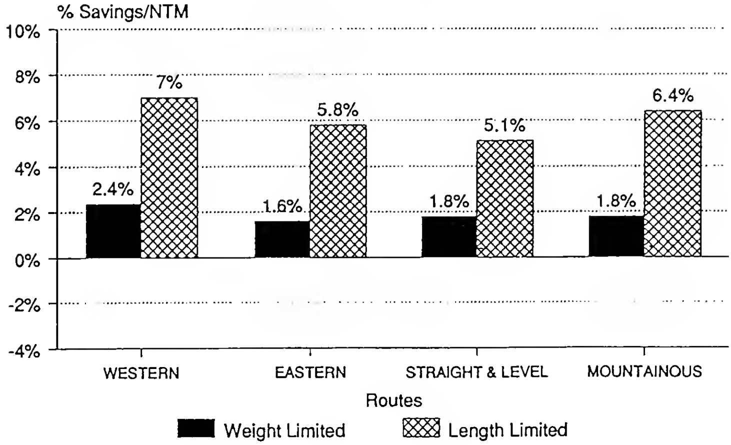
Excludes Bridge Costs



* Intermediate projection, not measured directly at FAST

EXHIBIT 6

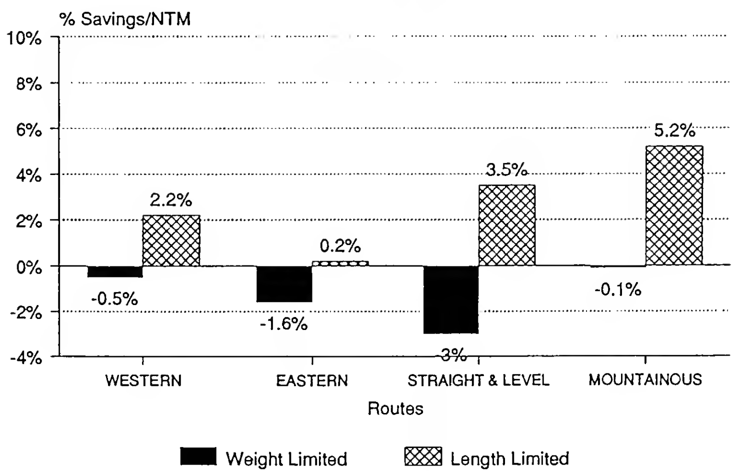
HAL Analysis—286,000# Cars
% Savings From 263,000# Base Case



Excludes Bridge Costs

Exhibit 7

HAL Analysis—315,000# Cars
% Savings From 263,000# Base Case



Excludes Bridge Costs

Conclusions

The Committee offers the following conclusions concerning the technical and economic viability of utilizing heavy axle load equipment in the provision of coal service over typical good quality, well maintained main line track:

(1) Although track is deteriorated at an accelerated rate by HAL equipment, the deterioration of track components is not catastrophic. Thus, the operation of HAL equipment is a question of economics, and not one of technical feasibility.

(2) There are sufficient potential "bottom line" cost savings associated with increased axle loads under favorable conditions to justify detailed examination of HAL alternatives. Results of the analysis of the "generic" scenarios indicated that total cost savings (including the impact on track costs) of as much as 5%-7% per net ton mile could be obtained under *specific* HAL operations, as compared to the 263,000 lb. car "base case." These scenarios, however, did not include any consideration of bridge upgrading or replacement cost.

(3) Economic results are highly route and service specific. Thus, individual railroads should analyze their particular service alternatives.

(4) The benefits of increased axle loads results principally from increased net train loads due to increased net-to-tare ratios and net load per foot of train length, reduced equipment capital costs due to greater capacity per capital dollar, and reduced car/locomotive maintenance and other mileage-related costs. There are wide variations among car designs of the same GVW (axle load). Therefore, specific equipment alternatives must be investigated.

(5) The Committee's methodology, supported by the AAR cost models available to AAR member railroads, is capable of performing the necessary analysis.

Beyond these general conclusions, the Committee offers the following economic cautions:

(1) Bridge impacts must be carefully analyzed. These costs are highly site and service specific as they depend on the design and maintenance state of the individual bridges on the route(s) under consideration.

(2) The analysis must consider the entire infrastructure, including signals, sidings, subgrade conditions, facilities, etc.

(3) If axle loads are increased, track budget requirements can also be expected to increase, both absolutely and as a percent of total operating costs. Track component standards, maintenance standards, and inspection and maintenance procedures may need to be revised in order to achieve the lowest infrastructure cost under the higher axle loadings.

(4) The transition to HAL operations must be well planned and actively managed, both in terms of the integration of functional requirements (i.e. engineering, equipment, operational and commercial) and the allocation of adequate resources, if the potential benefits are to be achieved.

(5) Axle loadings (gross car weight) should be considered as one of several variables which can be used to "optimize" the utilization of assets and other resources (locomotives, track capacity, crews, cars, etc.). The emphasis should be on finding the optimum axle load for the particular service, and not simply on maximizing axle loads.

Today, several questions related to HAL service remain unanswered. Clearly, further research into alternatives in track components, maintenance policies and procedures, and equipment designs is needed in order to decrease the negative effects of increased axle loads. That said, it is believed that now is the time to begin to investigate, on a route and service specific basis, the potential of HAL service for the rail transportation of coal and other commodities as well.

REFERENCES

[1] Marich, S. and Maass, U., "Higher Axle Loads Are Feasible—Economics and Technology Agree," *Proceedings of the Third International Heavy Haul Conference,* Vancouver, BC, Canada, Oct., 1986, pp. 18-31.

[2] Reiff, R. P., *et al, Proceedings of the 1990 Heavy Haul Workshop,* Pueblo, CO, Oct., 1990.

Appendix. The FAST/HAL Economic Committee

Name	Title	Railroad
R. E. Cox	Assistant Vice President, Distribution Services	Southern Pacific Transportation
Samuel T. Adenbaum	Director, Cost Inf. Systems-Costing	Conrail
Mike Franke	Vice President, Maintenance	Santa Fe
William T. McCarthy	Director, Maintenance Planning	Burlington Northern
Jim McClellan	Director, Corporate Development	Norfolk Southern
Stan McLaughlin	Vice President, Engineering	Union Pacific
Gary Mitton	Chief of Operations Services	Canadian National
Ron Newman	Director, Applied Technology	Burlington Northern
Craig Piennett	Director, Cost & Profit Planning	Union Pacific
Hillary Rawert	Asst. Vice President Cost & Market Research	Kansas City Southern
Michael D. Roney	Manager, Track Technology	Canadian Pacific
Larry Shughart	Manager, Operations Research	CSX Transportation
David Staplin	Asst. to Vice President Eng., Planning & Analysis	CSX Transportation
Ed R. Trask	System Engineer, Planning and Analysis	Canadian National

TESTS OF INNOVATIVE MAINLINE TURNOUTS ON UNION PACIFIC

By: J. R. Beran* and W. C. Thompson**

Union Pacific has a five-year $300 million expansion project to improve the transportation of Wyoming coal to points east.

What brought this flurry of construction about was passage of the Clean Air Act by Congress in November, 1990. This Act requires coal burning power plants to reduce sulfur emissions by burning a higher percentage of low sulfur coal, which is abundant in the Powder River Basin of eastern Wyoming. Shortly after President Bush signed the legislation into law, demand for low sulfur coal by southeastern and southern power utilities increased dramatically. The increased demand presented a unique challenge in meeting our customer's needs. This issue arose due to the fact that a good portion of the main corridor for moving this coal (see Photo 1), in the North Platte Subdivision, Council Bluffs Subdivision and the Marysville Subdivision, were already operating near capacity. Tonnage for the North Platte-Gibbon portion of this corridor was already approaching 200 MGT annually. To increase capacity, we will install CTC through much of this corridor and install a double track or additional sidings in areas where it is economically justifiable.

Our venture into the Powder River Basin began in May, 1983, when the Chicago and Northwestern constructed a corridor from Joyce, Wyoming, on our North Platte Subdivision, to Shawnee Jct., Wyoming, which is on the south end of a joint BN/C&NW track leading into Bill, Wyoming. This project was comprised of 106 miles of C&NW track reconstruction and new connector track. At the same time, the Union Pacific upgraded the North Platte Subdivision.

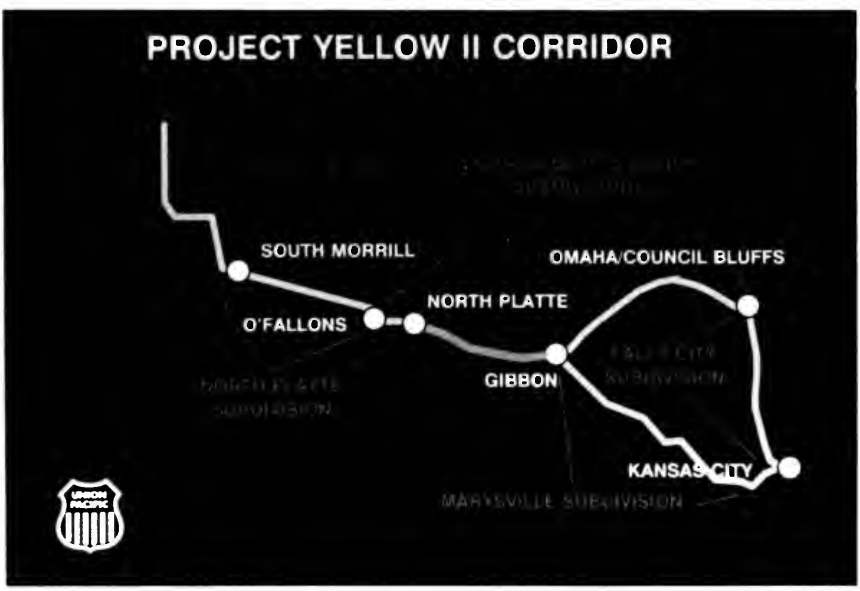


Photo 1. Main coal traffic corridors.

*Chief Engineer Design, Union Pacific Railroad

**Director Engineering Methods and Research, Union Pacific Railroad

Original traffic predictions would have put 10 coal trains per day in 1991 on the North Platte Subdivision. Traffic projections estimate 34 trains per day for 1991 and a steady increase during this decade is expected. The line capacity to meet this increased demand is just not there.

Projects to improve capacity include, but are not limited to, 15 miles of track in Union Pacific's Bailey Yard at North Platte, 14 new or extended sidings, construction of 15 miles of double main track and installation of 111 miles of CTC which will be controlled out of Union Pacific's Harriman Dispatching Center. A general summary of projects from 1991 to 1994 for the four subdivisions are shown in Exhibit 1.

Exhibit 1. General summary of the 4 subdivision projects, 1991 to 1994.

NORTH PLATTE SUBDIVISION

COAL CORRIDOR PROJECTS

1991 PLANNED CONSTRUCTION

- 5 SIDING PROJECTS (8.0 MILES)
- 2 MULTIPLE TRACK PROJECTS (8.9 MILES)
- 25 MILES OF CTC

1991-1994 SUMMARY
OF PROPOSED PROJECTS (1991 INCL.)

- 16.4 MILES OF SIDING EXTENSION PROJECTS
- 19 MILES OF DOUBLE TRACK
- 25 MILES OF CTC

MARYSVILLE SUBDIVISION

COAL CORRIDOR PROJECTS

1991 PLANNED CONSTRUCTION

- 3 MULTIPLE TRACK PROJECTS (11.6 MILES)
- 15 MILES OF CTC

1991-1994 SUMMARY
OF PROPOSED PROJECTS (1991 INCL.)

- 69 MILES OF MULTIPLE TRACK
- 60 MILES OF CTC

Exhibit 1 (cont.)

COUNCIL BLUFFS/SIDNEY SUBDIVISIONS

COAL CORRIDOR PROJECTS

1991 PLANNED CONSTRUCTION
- 72 MILES OF CTC

1991-1994 SUMMARY
OF PROPOSED PROJECTS (1991 INCL.)
- 5.0 MILES OF SIDING PROJECTS
- 38 MILES OF MULTIPLE TRACK
- 157 MILES OF CTC

FALLS CITY SUBDIVISION

COAL CORRIDOR PROJECTS

1991 PLANNED CONSTRUCTION
- 7 SIDING PROJECTS (6 MILES)
- 12 MILES OF CTC
- COUNCIL BLUFFS SUB. CONNECTION

1991-1994 SUMMARY
OF PROPOSED PROJECTS (1991 INCL.)
NO NEW ADDITIONAL PROJECTS
PROPOSED AFTER 1991

This, of course, is a great opportunity to experiment with some innovative track components and construction techniques. Bill Thompson will fill you in on what we are doing with switches in conjunction with CTC work on the Council Bluffs subdivision and perhaps a year from now we can report on results. I will also update you on other planned experiments or trial installations, such as asphalt reinforced subgrades and concrete tie installation methods. Bill Thompson, our Director Methods and Research, will now present the details of the turnout test.

As part of Union Pacific's need to improve the performance of its trackwork in the heavy haul environment, particularly between North Platte and Gibbon, Nebraska, considerable work is being done to develop a premium track system. In 1989, a decision was made to install, as part of the 1990 and 1991 Council Bluffs Subdivision CTC work, a test of the best available mainline turnout technology.

Premium Turnout Functional Specification

1. Highest overall quality.
2. Ease of assembly.
3. Ease of installation.
4. Long term survivability and durability under extreme load, tonnage and traffic conditions.

Why the Test?

1. Its consistence with UPRR's goals, especially in terms of the customer and improved quality.
2. Quick Results

   This main line corridor handles some of the heaviest tonnage in the world, almost 200 MGT annually. A major benefit of a test in this location will be accelerated results. We expect fast failures, in months rather than years.

3. Reduce Life Cycle Costs

   Turnouts used in this corridor require a tremendous amount of time and money for maintenance, component changeout and eventual replacement.

4. Reduced Track Time

   Operating and customer delivery commitments continue to reduce the available time to install and maintain track.

5. Vendor Opportunity

   The test will provide a tremendous opportunity for both existing suppliers of track components and suppliers new to UPRR to prove the quality of their design and products.

   Vendors participating in this project include:
   - A.B.C. Rail Corporation
   - Balfour Beatty
   - Cogifer, Inc.
   - Pandrol, Inc.
   - Sherman-Abetong
   - Vape
   - Voest-Alpine
   - Yamato-Sumitomo

6. Potential Exists for Increased Axle Loading

Conclusions From the FAST/HAL Turnout Tests

- The standard turnout built with standard components (which performed adequately during the 33-ton test regime) will perform poorly under concentrated HAL traffic.
- Turnouts built with premium components will last longer with less maintenance.

7. Demand for Improvement.

   Encourages technology improvement within the industry.

8. Cost of Quality

   The test will contribute to the UPRR Quality Program with prevention costs (research) offsetting failure costs (excess maintenance). Some of this research may also benefit other railroads.

The following is a summary of each of the seven (7) types of turnouts to be installed in the test between North Platte and Gibbon, Nebraska (near Grand Island). All turnouts are being installed in double track with minimum 20-ft. track centers. If the existing track centers are less than 20-ft., then track is being shifted.

U.P.R.R. Universal Crossover

STATION: Brady, Nebraska M.P. 261
MANUFACTURER/COUNTRY: Balfour-Beatty/British
GEOMETRY: Tangential (Spiral)
TIE: Azobe 7″ x 9″ Untreated
TIE FASTENER: Coach Screw (UIC 864-1)
RAIL: Head Hardened—360 BHN British Steel
RAIL FASTENER: Pandrol E-2055
SWITCH POINT: Asymmetrical 56-ft.
STOCK RAIL: Undercut H.H.
STOCK RAIL SUPPORT: Base Spring Clip
HEEL BLOCK: Cast Fully Bolted
FROG: Movable Point, Welded
GUARD RAIL: None
BALLAST TYPE: Granite, Wyoming, 2,515 lb/yd^3
DATE INSTALLED: 8/90

U.P.R.R. Universal Crossover

STATION: Vroman, Nebraska M.P. 254
MANUFACTURER/COUNTRY: Voest-Alpine/Austrian
GEOMETRY: Tangential 680 M Radius
TIE: Azobe 6″ x 10″ Treated
TIE FASTENER: Coach Screw (UIC 864-1)
RAIL: Head Hardened—360 BHN Rodange
RAIL FASTENER: Pandrol E-2055
SWITCH POINT: Asymmetrical 65-ft. with Clamp Lock
STOCK RAIL: Undercut Head Hardened
STOCK RAIL SUPPORT: Base Clip/Spring Steel and Pin
HEEL BLOCK: None - Flex Point Only
FROG: Movable Point with Clamp Lock, Sliding
GUARD RAIL: None
BALLAST TYPE: Granite, Wyoming, 2,515 lb/yd^3
DATE INSTALLED: 6/90

U.P.R.R. Universal Crossover

STATION: Willow Island, Nebraska M.P. 244
MANUFACTURER/COUNTRY: ABC/U.S.A.
GEOMETRY: AREA No. 20 (Standard UPRR) - Control
TIE: Douglas Fir - Softwood 7″ x 9″
TIE FASTENER: Cut Spike
RAIL: Head Hardened - 360 BHN
RAIL FASTENER: Cut Spike/True Temper Anchors
SWITCH POINT: Full Depth 39-ft.
STOCK RAIL: Sampson Undercut Head Hardened
STOCK RAIL SUPPORT: Bolted Adjustable Brace
HEEL BLOCK: Cast Bolted Floating
FROG: RBM/ABC

GUARD RAIL: Hook Flange—Bethlehem
BALLAST TYPE: Granite, Wyoming, 2,515 lb/yd^3
DATE INSTALLED: 2/91

U.P.R.R. Universal Crossover

STATION: West Odessa, Nebraska M.P. 200
MANUFACTURER/COUNTRY: Sherman-Abetong/Cogifer U.S./Swedish
GEOMETRY: AREA No. 20
TIE: Concrete
TIE FASTENER: Vape
RAIL: Head Hardened—360 BHN
RAIL FASTENER: Pandrol E-2055
SWITCH POINT: Full Depth Head Hardened 58-ft.
STOCK RAIL: Sampson Undercut H.H.
STOCK RAIL SUPPORT: Pandrol Adjustable
HEEL BLOCK: Cast Bolted Floating
FROG: RBM/ABC
GUARD RAIL: Bolted Adjustable
BALLAST TYPE: Granite, Wyoming, 2,515 lb/yd^3
DATE TO BE INSTALLED: 4/91

U.P.R.R. Universal Crossover

STATION: Simonds, Nebraska M.P. 208
MANUFACTURER/COUNTRY: ABC/U.S.A.
GEOMETRY: AREA No. 20
TIE: Oak—Hardwood 7″ x 9″
TIE FASTENER: Cut Spikes
RAIL: Head Hardened—360 BHN
RAIL FASTENER: Cut Spike/True Temper Anchors
SWITCH POINT: Full Depth 39-ft.
STOCK RAIL: Sampson Undercut Head Hardened
STOCK RAIL SUPPORT: Pandrol Adjustable Brace
HEEL BLOCK: Cast Floating
FROG: To be determined
GUARD RAIL: To be determined
BALLAST TYPE: Granite, Wyoming, 2,515 lb/yd^3
DATE TO BE INSTALLED: 6/91
NOTE: This is a change from original plan to use a French design turnout.

U.P.R.R. Universal Crossover

STATION: Darr, Nebraska M.P. 233
MANUFACTURER/COUNTRY: ABC/U.S.A.
GEOMETRY: Tangential No. 20
TIE: Oak—Hardwood 7″ x 9″ Treated
TIE FASTENER: Coach Screw 15/16″
RAIL: Head Hardened—360 BHN
RAIL FASTENER: Pandrol E-2055
SWITCH POINT: Full Depth Long-Welded 64-ft.
STOCK RAIL: Sampson Undercut Head Hardened
STOCK RAIL SUPPORT: Bolted Adjustable Brace
HEEL BLOCK: Cast Bolted Floating
FROG: Railbound H.S.L.A./ABC

GUARD RAIL: Bolted Adjustable Guard Bar
BALLAST TYPE: Granite, Wyoming, 2,515 lb/yd^3
DATE TO BE INSTALLED: 8/91

U.P.R.R. Universal Crossover

STATION: East Lexington, Nebraska M.P. 221
MANUFACTURER/COUNTRY: Yamato-Sumitomo/Japanese
GEOMETRY: Tangential
TIE: Oak Hardwood—7″ x 9″ Treated
TIE FASTENER: Coach Screw
RAIL: Head Hardened—360 BHN
RAIL FASTENER: Pandrol E-2055
SWITCH POINT: Symmetrical Fully Heat Treated 50′
STOCK RAIL: Undercut H.H.
STOCK RAIL SUPPORT: Hook in Pandrol Shoulder
HEEL BLOCK: Cast Bolted Block
FROG: Movable Point, Vertical Weld
GUARD RAIL: None
BALLAST TYPE: Granite, Wyoming, 2,515 lb/yd^3
DATE TO BE INSTALLED: 10/91

Premium Turnout—Lessons Learned

1. Warranty
2. Track work vendor must adapt product for use with UPRR standard drive switch machine.
3. Provide assembly, installation, and maintenance support through training, video and technical assistance.
4. Include specialty tools.
5. A quality control and problem resolution program within the vendor organization saves time.
6. Prints must be in English, with U.S. dimensions, curve information, tie layout, insulated joint locations, description of material provided by railroad, show past revisions and describe warranty and return policy.
7. Point to frog distance is approximately the same as UPRR No. 20.
8. Tangential geometry with entry angle specified.
9. Hardness of all running surface 360 BHN. Some variation exists in how this is interpreted by a vendor and in the best available technology.
10. Premium rail fasteners.
11. Preassembled and match marked
12. Premium ties, minimum 7″ x 9″.
13. Premium tie fasteners.
14. Premium long life and long length frogs.
15. Switch lubrication techniques and information.

Measures

To help us get a good handle (develop an effective measure) on what is going on we have or are developing the following:

1. Project and installation cost tracking.
2. Train tonnage, numbers and direction.
3. Maintenance cost and time tracking for both track and signal.
4. Turnout inspection and maintenance record.

Conclusion

This paper has highlighted several examples of trackwork improvements and tests on the Union Pacific. The work will help Union Pacific improve the quality of service provided to our customers and help us reach our company goals. This test will also benefit our customers, suppliers and the Union Pacific and the railroad industry.

We must recognize everyone involved including Curt Holman, Manager Engineering Methods and Research, who has steadfastly supported this project, as well as all employees that have and continue to contribute to it. These include Stan Hanquist, Tom Belka, Pat Lee, Herald Louis, Joe Cardenas, Marcus Begley, El Shew and Al Kraft.

On behalf of Union Pacific, Jim Beran and myself, thank you for the opportunity to review this project and test.

RAILROADS AND DEREGULATION: A STUDY IN SUCCESS

By: Edward J. Philbin*

Last night, my wife asked if I still considered myself an engineer. I said I did and showed her the pocket slide rule I used in college. And I told her a favorite story of mine, about the noted electrical engineer, Charles Steinmetz. The anecdote illustrates the value of our engineering training and experience no matter what our individual fields are now.

Steinmetz, the "electrical wizard," worked for General Electric and made great contributions to electrical theory and practice by inventing over 200 electrical devices. After he retired, GE hired him back as a consultant when a machine malfunctioned. None of the GE people could figure out what was wrong.

Steinmetz came to work, walked around the machine, bent down, stood up, looked here and there, tested various parts, then reached inside his pocket for a piece of chalk.

He went up to the machine and marked an "X" at a particular spot. The GE people then moved in and started taking the machine apart. They were absolutely amazed to find that the defect lay precisely where Steinmetz had made his chalk mark.

Several days later, GE got a bill from Steinmetz for 10 thousand dollars. Shocked at the amount, they asked Steinmetz to itemize it.

This is the itemization he sent them: "For making one chalk mark on machinery, one dollar. For knowing where to put the mark, nine thousand nine-hundred and ninety-nine dollars."

I'll begin with a brief description of the Interstate Commerce Commission because I know that this is a diverse audience. I'll also share some impressions I have developed during my year at the ICC, and I'll focus on where I think the industry is headed and some of the challenges coming our way.

The commission is a much smaller agency today than it was 10 years ago. We have about 625 employees and a budget of approximately 44 million dollars. In addition to headquarters operations in Washington, the commission has three regional offices—including the central region's main office here in Chicago—and 19 smaller field offices. Staff in these offices largely help people comply with our regulations and resolve complaints.

The commission is composed of five members nominated by the President and confirmed by the Senate. The newest commissioner, Gail McDonald, came on board last September. As chairman, I am responsible for administering the agency.

The commission's organizational structure has changed somewhat since I arrived. Two offices, the former Bureau of Accounts and the former Office of Transportation Analysis, have been combined into the new Office of Economics for the sake of efficiency. To increase our responsiveness to the public and to Congress, we created an Office of External Affairs, which handles industry liaison, and an Office of Congressional and Legislative Affairs.

The commission is, in general, responsible for the economic regulation of interstate land transportation. Today, the ICC maintains jurisdiction over railroads, trucking companies, one coal slurry pipeline, one anhydrous ammonia pipeline, household goods movers, and freight forwarders of household goods.

Deregulation which began in 1980 has created the opportunity and the incentive for the nation's railroads and motor carriers to innovate and become more efficient. The gains from deregulation are the result of freedom. Freedom to manage. Freedom to compete. Freedom to innovate. Freedom to believe in the future. Freedom for business managers to think for themselves, to choose their markets, to design their service offerings, to be inventive. All without heavy-handed, if well-intentioned, governmental intervention.

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*Chairman, Interstate Commerce Commission

The movement toward less regulation in the transportation industry and increased reliance on the marketplace is saving the nation billions of dollars each year. We can argue over the precise magnitude of these savings. But I don't think anyone can challenge the fact that railroad and motor carrier deregulation has had a positive impact on carriers, shippers, consumers, and the economy in general.

In fact, just two weeks ago, Gilbert E. Carmichael, the head of the Federal Railroad Administration, testified before Congress that, in addition to railroads being safer, more fuel efficient, and less polluting than other transportation modes, *they are in the best operating condition in railroad history!*

Last year was another record year for railroad earnings. Net operating income for the nation's largest railroads rose almost 15 percent, to $2.6 billion dollars, for the year ending September 1990.

The nation's largest railroads moved over a trillion ton-miles of traffic for the second year in a row, intermodal volume was up for the ninth straight year, and the number of carloadings increased to over 17.4 million. Improved earnings have enabled the industry to invest over 100 billion dollars into track and equipment, and this has resulted in dramatically improved safety, service, and productivity.

Rail construction—a rare bird a decade ago—continues apace. The ICC is currently involved in approximately 20 railroad construction cases, and is now in the process of preparing environmental documents for four of those cases.

Cost reductions, efficiency gains, and increased productivity have enabled railroads to offer better service at lower prices. A recent commission study found that the railroads' inflation-adjusted rate level has fallen 22 percent between 1980 and 1988, at the same time that rail carriers were dramatically improving their financial health. In addition, improvements in delivery time have led to significant savings for shippers due to lower costs associated with reduced inventories.

Today is the birthday of Rudolph Diesel, the German engineer who invented the engine that bears his name. The diesel engine revolutionized the railroad industry through the efficiency it brought to locomotive power.

In my opinion, the Staggers Rail Act—the landmark railroad deregulatory legislation passed by Congress in 1980—was no less revolutionary in the incentives, efficiencies, and managerial freedoms it brought to rail operations. The law brought about a sea change in the conduct of the railroad business.

If I were speaking to you 12 years ago about the nation's rail system, I would have identified a spectrum of troubles: bankrupt railroads, deteriorating track beds, a flight of capital investment, artificial inefficiencies imposed by government and an ICC constrained by law. Battered by financial catastrophes of historic proportion—including the Penn Central Rail bankruptcy and oil shortages—the railroad system in the late 1970s was near collapse.

At that time, outdated regulations were suffocating the industry, stifling innovation, and strangling competition. During the 1970s, the number of *new* regulations published increased from 20,000 to 90,000 pages per year! Railroad rates of return, where they existed at all, were too low to maintain existing service. As it always does, the private sector and the general public paid the price. Fearing transportation disruptions, delivery uncertainties, and higher prices, industries stockpiled inventories.

But the Staggers Act changed all that. Railroads may now more easily abandon money-losing track, enjoy greater operational and ratemaking freedoms, increasingly resolve disputes through negotiation rather than through lengthy and costly federal processes.

As part of its congressional mandate to promote the growth and viability of the nation's rail system, it has been the ICC's policy to encourage the entrance of new local, or "short line," and regional carriers to maintain service on lines that are either marginally or totally unprofitable when operated by larger, "trunk" lines.

We believe that new market entrants are often especially suited to meet regional or local needs. Through the development of new marketing and managerial approaches, they can increase operational flexibility, efficiency, and profitability. This new vitality can make a significant difference in the rail service provided to shippers, and practically guarantees them the benefits of lower costs, more varied service offerings, and increased transportation choices.

Critics of deregulation point to bankruptcies and business failures as evidence that deregulation is unsuccessful. Since the passage of *Staggers* there have been, of course, a few rail bankruptcies as the least efficient carriers drop out. This is, unfortunately, a normal consequence of a dynamic competitive market that Congress must have anticipated.

However, we have seen new, more efficient market entrants emerge, and existing carriers consolidate or trim back operations to enhance their competitive standing. Throughout this process, most of the operations of bankrupt carriers have been purchased or replaced by other carriers and service to shippers has usually continued.

Another criticism is the impact deregulation has had on rail labor. For example, in the creation of new short line or regional railroads, labor problems have plagued the process. Labor protection for affected employees is legally *required* in a line sale between two existing railroads. However, the application of labor-protective conditions is at the discretion of the ICC when a line sale is made between an existing carrier and a new short line carrier. Recent ICC decisions addressing the proper functioning of labor-protective conditions establish a means for facilitating the process of short line development.

The development of new rail lines is a sign that the rail system is coping with, and adjusting to, the changing competitive environment. In transportation, as in all free markets, change is the one "constant" in business operations. This change is healthy and will continue as the industry—with the aid of our interpretation of the law—strives to respond quickly by shifting resources as fluctuating economic conditions dictate.

In our approach to all of the cases before us, we are mindful of Patrick Henry's words that "freedom is as necessary to the health and vigor of commerce, as it is to the health and vigor of citizenship."

While deregulation has been championed primarily because it has brought about increased competition and lower rates, it has done far more than that. It has also spurred *service reliability.* As a result, many shippers have reevaluated their logistics networks.

Improved reliability, for example, has been the genesis of one of the most innovative trends in the manufacturing sector. Economies are now being realized through the reduction of inventories—particularly in the auto industry—by "just-in-time" inventory control. By this technique, costs are reduced when components are shipped to assembly centers as needed, instead of costs being incurred while components sit idly stockpiled awaiting drawdown.

Transportation deregulation in the 1980s also created new leverage for savvy and innovative shippers. Shippers are now able to capitalize on railroad transportation contracts with guaranteed rate and service provisions that permit shippers to do more than just reduce transportation costs. Rate and service contracts allow shippers to formulate overall logistics and distribution strategies and to design their transportation plans to complement those strategies.

Some railroad security analysts are optimistic about the industry's ability to operate during the current economic downturn without any severe, adverse consequences.

Earnings may not be substantially depressed by recession since major sources of rail traffic, like coal, grain, and food products are now less likely to mimic the economic cycle. Factors on the horizon that bear watching include ongoing labor negotiations and the pace of the continued spinoff of marginal branch lines.

In closing, I wish to reiterate that the last decade witnessed positive, sweeping regulatory reform. And the marketplace is working as a result. While some are proposing reregulation, that is exactly what we should not do.

President Bush's regulatory guidelines state that regulations must be necessary, economically sensible, understandable, responsive to public concern, and cost beneficial. In short, "if it ain't broke, don't fix it." And I don't think the marketplace is "broke."

During my confirmation as chairman, I candidly told the senators that I intended to base my decisions on the letter and spirit of the law. I've done that and, since the substantive law is deregulatory and pro-competitive, practically all of the approximately 900 decisions I've made since joining the ICC have been pro-market and deregulatory. And I will continue to base my decisions on the current law.

Our future challenge is to work together to enhance market opportunities and to keep abreast of the ever-changing environment, especially legislative initiatives, regulatory changes, industry trends, engineering and technological developments, and current events. To paraphrase Henry Ford, "You must never stop thinking business. You must think of it by day and dream of it by night."

It is appropriate that we now depend upon transportation managers, not government, to forecast and swiftly respond to the multitude of forces affecting the free marketplace upon which our national economic future depends.

These managers should remember the technique used by the coalition generals in the Persian Gulf War. They anticipated certain obstacles to obtaining their goal, they prepared themselves to meet those challenges, then made full use of the "tools" they had at hand with the freedom they were given to use them as they saw fit. The result will go down in military history.

I appreciate this opportunity to speak to you and hope that your meeting is successful.

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REHABILITATION OF TRACK AND BRIDGES ON MOUNTAINOUS LINE TO PORT OF LAZARO CARDENAS

By: Ing. Hector Barraza M. del C.*

Lazaro Cardenas Port Description and Development

The steel industry boom of the last two decades has paved the way for the development of the port Lazaro Cardenas in the state of Michoacan. It is one of the most important ports on the Mexican Pacific coast and is near the city of Lazaro Cardenas, which is located on the west coast of Mexico at a distance of 322 km from Acapulco, Gro. and 704 km from Mexico City. The port is connected by railroad to the cities of Morelia, Mich., Iraputo, Gto; Toluca, Mex. and Mexico City, and through these to the main cities, ports, and northern and southern borders of the country. The city itself lies on the bank of the Balsas River which is in the Pacific coast seismic zone close to large iron mines. The need for rail transportation in this port have significantly changed during the last 10 years, being closely related to steel production at "Sicartsa" (a metallurgy plant), the fertilizer plant "Fertimex," the grain importing company "Conasupo" and most recently to automobile parts imported from Japan.

City and Port of Lazaro Cardenas.

*Civil Engineer, National Railways of Mexico

Rail Transportation Needs

The Lazaro Cardenas yard has become one of the busiest in the Mexican Railroad Network since it serves the main industrial port of the Mexican Pacific Coast. In recent years this yard has witnessed an increasing work task due to the evergrowing demand for rail transportation. This activity has caused a saturation of the facilities and serious operational problems all along the route serving the port.

The annual growth of freight railroad traffic in this area from 1985 to 1988 has been 11.2%. In 1985 it was observed that the outbound freight exceeded the inbound freight by approximately 100%, particularly as a result of surpluses in iron ore and coke. From 1986 on the traffic flow has been primarily directed to Lazaro Cardenas, the most important being unit trains with coal for the steel industry.

When the Fertimex plant started its operation in 1987 a new stage in the freight traffic was initiated to such an extent that the fertilizer shipments increased in one year by 122%. During the first semester in 1989 a new freight increase was observed when the second stage of the Sicartsa plant was started along with an additional increase of the fertilizer shipments. These shipments included 402,000 tons of steel plates and structural profiles that were sent to the City of Monterrey, and 1,203,000 tons per year of iron ore that were received from the Manzanillo mines. In 1989 the Fertimex plant operated at 74% of its capacity. This meant a production of 2,295,000 tons per year out of which 845,000 tons were conveyed by trains, representing a 212% increase in relation to 1987 tonnage.

At the end of 1988, the railways of Mexico began handling unit container trains with imported auto parts from Lazaro Cardenas to the Nissan plant at the City of Cuernavaca. I would like to point out that multimodal transport has the well-known-economical advantages of providing door-to-door and port-to-port service.

Freight Traffic for the Port of Lazaro Cardenas.

The above mentioned figures indicate that the transportation demand to and from the port is based mainly on raw materials, particularly for the steel industry. In 1988 the railways transported only 30% of Sicartsa's production and roughly 100% of inbound materials. The present programs project that railroad participation will increase from 30% to 70%, and everything seems to indicate that the requirements for rail transportation in the future will be determined primarily by Sicartsa, Fertimex and Conasupo. On the other hand the movement of manufactured goods, now being handled mostly by road, could gradually be taken over by the railways, provided there is good quality and efficient service.

The forecast of railroad freight for the port of Lazaro Cardenas from 1988 to the year 2010 can be summed up as follows:

Movement and Forecast of Railroad Freight for the Port of Lazaro Cardenas
(thousands of metric tons)

Year	Outbound	Inbound	Total
1988	2094	2226	4320
1989	3155	4545	7700
1990	3987	4513	8500
1991	4339	4583	8922
1992	4556	4812	9368
1993	4783	5053	9836
1994	5023	5305	10328
2000	8268	5582	13850
2010	13247	9353	22600

Observed Condition of the Track and Structures Up to 1988

The port of Lazaro Cardenas is served by three alternate rail routes as follows: Irapuato-Penjamo-Ajuno-Corondiro-Lazaro Cardenas, Celaya-Acambaro-Ajuno-Lazaro Cardenas or by the Mexico City-Toluca-Morelia-Lazaro Cardenas line. Up to 1988, the physical condition of the track on all the routes except for the Ajuno-Corondiro section was satisfactory and supported the regular traffic of trains with 3000 H.P. locomotives and 100 ton cars. The Ajuno-Corondiro section is located in the utmost mountainous zone where poor conditions of the track and the low capacity of the bridges prevented an adequate operation throughout the whole route. This included the necessity to avoid usage of high capacity locomotives and also heavily loaded cars.

The Ajuno-Caltzontzin section is 52 km long with up to 18° curves and 2.5% grades. The track was built with 100 lb/yd rail rolled in 1967 and has a defect density of more than 80 per 100 kilometers, including many surface defects. The wooden crossties were in bad condition and at the end of their service life. The ballast made of crushed stone was scarce by 40% and highly contaminated with dust, oil and sand. The roadbed was in fair condition.

The Caltzontzin-Corondiro stretch built in the 40's has curvatures of up to 12° and a 2.0% grade. It was built with 112 lb/yd rail rolled in 1938, and has bolted joints. It has nearly 50 rail defects per 100 kilometers, as well as severe wear in curves and flattening of the rail head in tangents. The wooden crossties, ballast and roadbed were in a similar condition as the Ajuno-Caltzontzin stretch. A series of metallic viaducts of important dimensions are located on this route, where the "Marques" and "Cobano" bridges are the most significant. The last part of the route leading to the port of Lazaro Cardenas from Corondiro, whose length is 194 kilometers, was recently built and inaugurated in 1982. The condition of the track is acceptable and the 115 lb/yd "RE" section continuously welded in 1972 doesn't show significant wear or defects. Most of the ties are two-block concrete and the rest are wooden ties with elastic fastenings. The bridges in this stretch were constructed to E-72 Cooper capacity, most of them being of prestressed concrete. Because of the orographic characteristics of the zone, it was necessary to bore through hard rock mountains to build 39 tunnels. Presently, due to some problems in cuts on this line, a stabilization program is being performed.

Rehabilitated and strengthened Marques bridge.

Rehabilitation Program for the Ajuno-Corondiro Stretch

As previously mentioned, up to 1988 the poor condition of the track in this stretch caused frequent derailments which made train operation unprofitable and quite difficult. The rehabilitation of this section became top priority because of the great traffic demand caused by the development of the port. Besides that, the low capacity of the viaducts, E-45, did not allow the operation of high tonnage unit trains. For this reason the track and structures department decided to rehabilitate the entire track and to strengthen the bridges, increasing their capacity to E-80.

Two types of track were selected for this job, depending mainly on curvature. For track with curvature between 0° and 4.5°, continuously welded 115 lb/yd. rail with a 302 Bhn hardness was installed. Monolithic postensioned concrete ties with French-type elastic fastening were used, and crushed stone ballast from 3/4" to 2-1/2" size, with a 12" depth, the standard section used on the Mexican railroad, was used. On tracks where the curvature is between 4.5° to 18°, continuous premium welded rail of 115 lb/yd and 360 Bhn hardness was installed on 7" x 9" x 8'-6" hardwood ties. These ties were specially prepared for a French-type elastic fastening. The ballast section provided was with the same characteristics as previously described. According to the Mexican experience, this type of track has given the best results for the numerous layouts with sharp curves.

The metallic viaducts were strengthened by means of steel plates in each of the structural elements to form box sections in all the truss members. Girders, stringers and floor beams were strengthened with the addition of plates to their flanges.

As a second stage to improve the whole route, the construction of a by-pass from Ajuno to Caltzontzin is underway. On the by-pass maximum curvature will be reduced from 18° to 9°, and the maximum grade from 2.5% to 1.0%. At the present time this project is at the beginning of its second stage, which includes the construction of embankments and the finishing of tunnels. The conclusion of this by-pass is scheduled for 1993.

Work Procedures and Methods Used on Tracks and Bridges

The rehabilitation work of this 157 kilometer track section was performed with personnel and equipment from the National Railways of Mexico. Semi-mechanized methods were used on three work fronts, each having 130 workers, one track crane to dismantle and lay rail, one bulldozer to spread the sub-ballast layer, 2 tie-exchanging machines and supplementary mechanical tools plus surfacing equipment. Work performance on each front was an average of 1,200 feet of rehabilitated track per eight hour shift. The welded rail and ties had been previously distributed.

Surfacing work in progress on rehabilitated line.

The rehabilitation of this section was completed in 16 months, beginning in August of 1989. The approximate cost of the rehabilitated track was 225,000 dollars per kilometer.

The strengthening of bridges was done by hiring specialized companies to work during the same time the track rehabilitation was being carried out. The investment in main bridges was 1.7 million dollars.

Instrumentation of the "Marques" Bridge

In order to evaluate the performance of the steel strengthening on the Marques bridge, structural instrumentation was used with help from the A.A.R. through a technical assistance contract. The A.A.R. provided the necessary measurement equipment and specialized technical personnel to carry out the tests.

The principal part of the bridge superstructure consists of a 3 hinge arch 465′ long and 368′ high. 120 strain gauges on 64 measurement channels were installed to cover all the main members of the truss. Two series of tests with heavy unit trains were programmed, including a consist with 3-3000 H.P. locomotives and gondolas loaded with 90 tons of coal. The train passed at different speeds varying from 6 miles per hour to 50 miles per hour. Braking of the train on the structure was also done to determine effects of horizontal forces in the arch members. The outcome of this instrumentation work was highly promising and we were able to verify a new safety factor of 3 for the strengthened structure for high tonnage unit trains. With the available equipment and with the training received from the

A.A.R. technicians, we have programmed the instrumentation of 3 major structures during this year utilizing our own specialized technical personnel.

Results and Conclusions

Through the above mentioned track and bridge rehabilitations we have been able to expedite traffic, obtaining as a result a fluent movement of high tonnage unit trains without operating problems, according to our schedules. This provides the port of Lazaro Cardenas with good railroad service and enables us to satisfy present as well as future anticipated needs.

VANCOUVER SKYMAP DEMONSTRATION PROJECT MAINTENANCE MANAGEMENT SYSTEM

By: C. J. Liew* and J. Huggett**

General

AutoCAD has been established by the engineering industry as a defacto standard for a majority of computerized drafting. In the last few years, there has been a significant shift from manual drafting to computerized drafting. The reason is strictly an economic one as production time for drawings; especially those used for multiple applications from procurement, installation, as-builts to maintenance; can be significantly reduced. Recently, the emerging trend in the industry is towards more computerized automation of standards for design and drafting productions.

As a result of some direct experience with the capabilities and applications of AutoCAD in the last few years, the SkyTrain Project Office has now adopted AutoCAD as their preferred choice for all design assignments and are preserving the option for implementing a computerized information system in the future to assist in the operation and maintenance of the overall SkyTrain facilities.

SkyMAP GIS Application

To this end, a prototype Geographic Information System (GIS) project, SkyMAP, was started in late 1989 to demonstrate the potential benefits which can be derived from a computerized information system which integrates design, as-built documentations and maintenance records. The SkyMAP is a customized application of the GeoSQL software developed by Generation 5 Canada Ltd. Permatrack Technologies Inc., of Vancouver, B.C. was commissioned by the SkyTrain Project Office to demonstrate this concept for the three kilometer extension from New Westminster to Scott Road Station in Surrey. The project has been completed and is available for full implementation.

The decision by B.C. Transit to adopt a GIS solution is a natural choice considering the rapid development of CAD and GIS applications in the last few years combined with overall improvements in the performance of personal computers. This trend towards lower costs of CAD and GIS technologies will be an incentive to companies that have to manage large inventories, resources and databases.

SkyMAP Life Cycle Planning

The concept of life cycle planning treats a facility as a continuous process of planning, design, construction and operation/maintenance, which the SkyMAP application has provided. The managed of SkyTrain, not unlike any major transit project, is influenced by many factors such as the management of design, as-built and maintenance records for consistencies and engineering integrity. On fast track projects, as in SkyTrain Phase One, emphasis is usually placed more on scheduling and cost control than other functions. During the early 1980's, most engineering firms on the SkyTrain project opted to produce most of the drawings manually as the use of CAD was limited by cost and availability of experienced operators. In the late 1980's this situation changed dramatically with improvements in the performance of personal computers and the wide acceptance of AutoCAD. Some engineering firms recognize that AutoCAD can produce good quality drawings more quickly and efficiently than drawings produced manually. This is especially true in the case of trackwork and guideway element design where components seldom change significantly between one project and another or even between similar projects constructed in different parts of the world.

As a result of these developments, B.C. Transit have now adopted AutoCAD as the preferred standard for all design assignments on their future extensions and SkyMAP as the management system to integrate all drawings and maintenance records. Continuing development of the SkyMAP software

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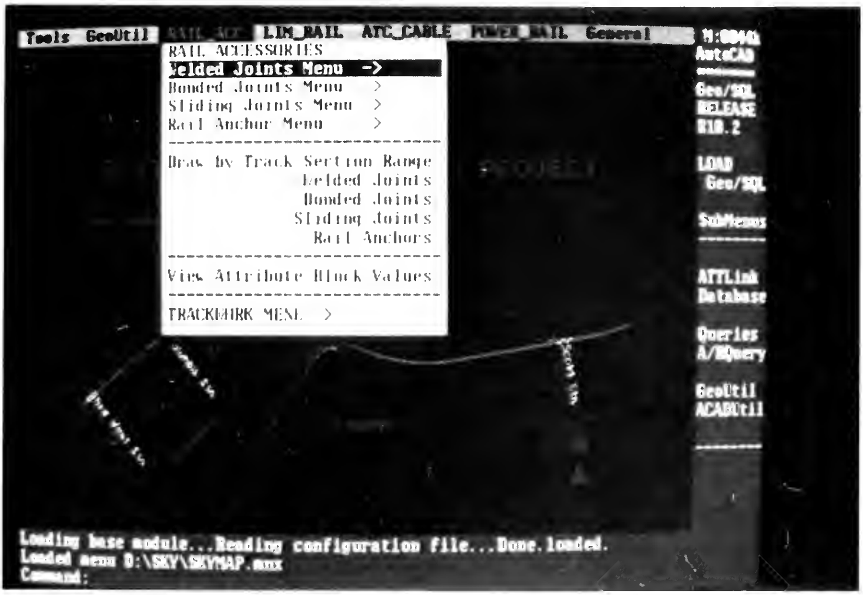
** Manager-Systems Engineering, SkyTrain Project Office, B.C. Transit

raises many possibilities from automation of trackchart preparation using design databases to updates of as-built drawings directly from survey records. B.C. Transit has continued to support this development. Permatrack Technologies continue to develop with Generation 5, the interface software to bridge the gaps between design, as-built and maintenance such that the overall system approach is similar and record management is transferrable.



Base Map showing Pop down menu for processing queries

Design Environment

The SkyMAP technology allows users to prepare layout drawings and review design conflicts from database records without producing drawings using conventional methods. The Geoview table allows "pseudo objects" to be extracted from the database and visually shown on a previously defined alignment once the start and end chainages of the alignment are given. In linear type projects, this is especially useful since in most cases the centerline of the alignment is first mathematized and coordinated. Other map elements are then referenced to the centerline and offsets to the centerline. By selective review, all design elements and potential conflicts can be resolved at the design phase directly on the spatial database without the high cost associated with drawing productions. The use of this feature for design and other applications can reduce the time required for drawing productions by leaving all final drafting to the end of the project when all conflicts have been finally resolved.

The Geoview table also allows the semi-automated preparation of trackcharts which are used to schematically show the rail chart, general information, alignment, profile and type of structure on a trackwork installation contract. Since the configuration of track charts can usually be standardized, all the basic data can be stored as textual records thereby reducing the amount of storage required for each drawing. Each of the trackcharts can be processed by selective extraction of the textual database and displayed as required. It is entirely possible that the trackcharts will be saved for plotting purposes only and, therefore will require a small amount of storage space on the hard disk if space becomes a problem.


RAIL
ROAD
CROSSING
YIELD
UNION PACIFIC
STOP
W
R
R
LOOK OUT FOR
THE CARS
YARD
LIMIT

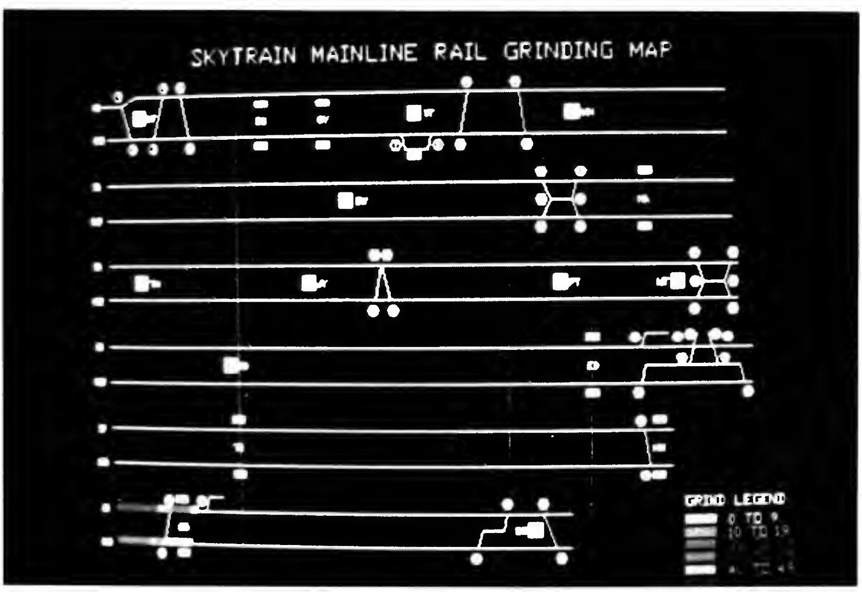
As-Built Environment

Retrieval of as-built records transferred from the SkyTrain construction group to maintenance has been cumbersome and were not easily accessible for maintenance purposes. Thick volumes of data turned over to maintenance were both difficult to store and retrieve not only because of the volume of information but also because the reference system for construction was based on chainages while the reference system for maintenance is based on discrete track sections approximately 25 meters in length. Track sections are used by the ATC (Automatic Train Control) software identification to allow vehicles to be physically identified by their position along the track so that they can be continuously monitored.

SkyMAP allows both as-built or maintenance records to be retrieved independently. This is especially important since most maintenance personnel are not familiar with or interested in the construction contracts except in order to retrieve warranty and critical construction information as the need arises.

The textual database prepared during design can be easily reproduced on forms for field inspections. As these records are updated on the databases, they can be automated to update the design drawings to show the as-built conditions. This will not only reduce the time required to prepare as-built drawings but also reduce the error in transferring as-built records from the field. To ensure maximum efficiency and minimum error, Total Station survey equipment combined with Electronic Field Book (EFB) data recording of the measured data should be used for survey of as-built information. An additional benefit of this method is the ability to automatically generate CAD/GIS drawings from the data, complete with symbol generation, attribute placement, line connection and layer separation.

Since the as-built records can also be extracted as "pseudo objects," they do not require object numbers. "Pseudo objects" are objects that are defined by their chainages along a unique spatial object. For example, rail welds are not specifically defined during design; but during construction when their locations are surveyed and referenced to the chainages along the track centerline. One of the advantages of using "psuedo objects" is that all attributes can be physically referenced from textual database records without the need for drawing these objects on the map.



Schematic Plan of Rail Grinding for Entire SkyTrain System

Operation/Maintenance Environment

The SkyTrain Operating Company (BCRTC) is responsible for operating and maintaining the SkyTrain system. Since its start of revenue service, maintenance crews have concentrated on several areas of work. The noise level on certain sections was initially higher than the acceptable range anticipated by the developer of the system. This has been overcome by regularly grinding the rails and other measures. The other maintenance task is the position of the Linear Induction Motor (LIM) rail relative to the top of rail elevation. The air gap between the LIM rail installed on the guideway and the LIM motor on the vehicle must be monitored and maintained to tolerance.

The rail grinding program requires the preparation of charts and reports on a regular basis. These charts and reports allow management to review and analyze the extent of the grinding program and its effectiveness in reducing the noise level on the guideway. This was previously done by extracting the data from work orders which specify the limits of the grinding, the rotation of the grinding stones and the type of grinder used. These grinding records were then manually accumulated over the reporting period and color coded on the Mainline Operations Map which schematically represents the entire alignment on one plot. The SkyMAP produces standard processes for routine tabulation of these rail grinding records, by time periods, grinder type or the latest grinding period. All input to the database is generated directly from the work orders provided by the Operating Company. The resulting graphics can then be visually displayed on the true plan alignment or the Mainline Operations Map using color to differentiate between the number of passes by total grinding, grinder type or latest grinding.

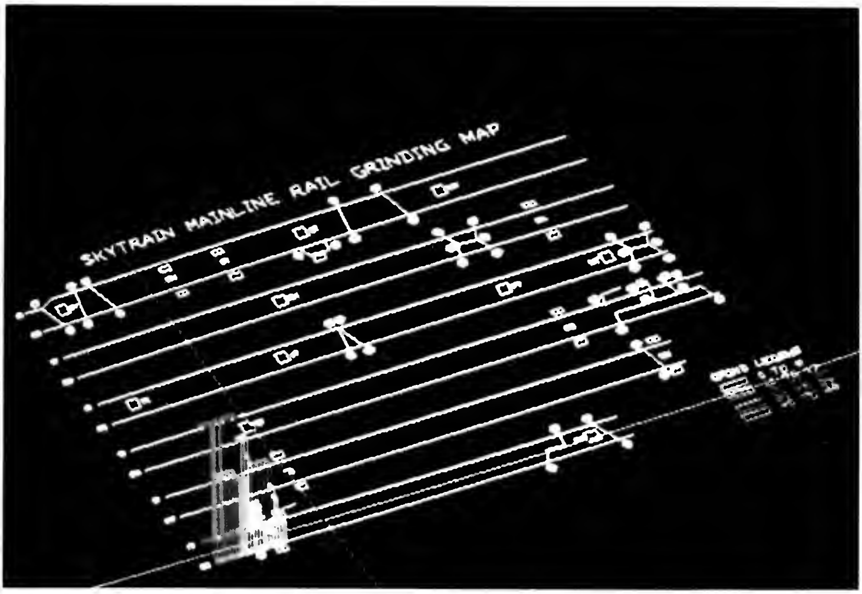
Noise measurements are currently provided on an analog tape plotted over time. With the use of control points along the guideway, the analog output provides a visual plot of the noise level as measured along the guideway. Since these records were measured on a constant time basis and the speed of the vehicle may vary, the plots were at best, a good indication of the problem areas. These plots were then subsequently used to establish the extent of the problem area and therefore the criteria for the next grinding program. Again the SkyMAP now produces standard processes for routine graphic displays of these noise measurement reports from data generated by either digital input or manual input provided by the Operating Company. Graphics can then be visually displayed on the true plan alignment or the Mainline Operations Map using color to differentiate between the range of noise level being measured.

Measurements of LIM rail deviations are regularly taken on test vehicles. The records produced on analog format were then manually recorded and plotted on the Mainline Operations Map. This process usually requires a long processing time as both the retrieval and plotting have to be manually extracted and color coded on the Mainline Operations Map. Deviations outside of the acceptable limits were then identified and work orders generated to correct these deficiencies. The SkyMAP produces standard processes for routine graphic displays of these LIM rail deviations from data generated by either digital input or manual input provided by the Operating Company. The graphic displays have been automated using color to differentiate between the ranges of the LIM rail deviations.

The benefits of the Operation/Maintenance of these routine displays can be significant since each of these standard processes can be done using the SkyMAP routines within minutes. In comparison, manual extraction and color coding of each item can sometimes take several days to produce.

SkyMAP Technical Issues and Solutions

Based on a review of the technical issues faced by the SkyTrain Project Office and the Operating Company, the project team set up some specific deliverables that were required as part of the Demonstration Project. The SkyMAP application is a management of the GeoSQL graphics interface between the spatial database and attribute database. Spatial database stores all map data in non-graphic format allowing selective display using AutoCAD as the graphics engine. Attribute database describes the properties or entity characteristics of objects in the spatial database and is stored in relational databases such as Rbase in which information is contained in tables.



3-D View of Rail Grinding shown on Schematic Map

Spatial Database

The spatial database stores all graphic entities, describes the physical location by coordinates and maintains entity relationships. It stores all map data using spatial objects such as points, lines or polygons by automatically defining unique object numbers which are maintained throughout the life of the object. The object number is used for retrieving, comparing and cross referencing objects with graphic and non-graphic data. Entities in the spatial database are grouped into subjects.

The spatial objects were initially prepared from a mathematized alignment of the track centerline using a COGO (Coordinated Geometry) program and imported directly into AutoCAD. Standard AutoCAD commands were then used to extend the spatial objects to include running rails, power rails and ATC (Automated Train Control) cables.

These spatial objects were then extracted and linked with the textual or attribute database using track section numbers as the unique identifier. Once this linkage is completed, all spatial objects can be retrieved independently or collectively and displayed on the screen. At the same time, queries can be made from the map elements on the screen by specifying either a geographic location, track section ranges or by database conditions. By this process, all the textual database can be displayed, analyzed and/or edited. To simplify the queries, standard processes were programmed into pop down menus using AutoLisp, to integrate the numerous components of the consolidated database such that intelligent reporting and analyses on a user-friendly system could be carried out efficiently. Users who were trained for a day on the use of the software application were able to perform simple to fairly complex tasks for analysis purposes. More advanced training will be required to effectively customize their own applications.

Spatial objects were prepared on individual layers for each specific item relating to alignment, rail grinding, noise, LIM rail deviations, trackwork, special trackwork, LIM rails, ATC cables, and power rails. These layers can be placed on conventional CAD maps, saved or edited as conventional CAD drawings if needed.

Each spatial object can be accessible individually or in combination. This not only allows easy manipulation of the databases, but also allows complex relationships to be developed between databases as required. For example, the effectiveness of a particular rail grinding program to reduce noise measurements on curves and/or tangents could be evaluated by displaying the appropriate layers of information and specifying the appropriate conditions.

In addition, standard processes for routine graphic displays of rail grinding reports, noise measurement reports and LIM (Linear Induction Motor) rail deviation generated by both digital input or manual input provided by the Operating Company can also be produced on either the true plan alignment or on the Mainline Operations Map. Graphics can be visually displayed on thematic maps using, for example, color to differentiate the number of passes of rail grinding, noise level fluctuations, deviations of the LIM from design specification, etc.

Engineering drawings prepared on AutoCAD can also be directly accessible from the query of the spatial objects. This set-up allows the user to retrieve accurate as-built records and engineering drawings and instructions that are vitally important for maintaining the system components to their design tolerances. The engineering drawings can either be stored on AutoManager or AutoVue, utilizing all the features of these CAD management software such as zooming, editing, plotting, etc.

Example of Attribute Database for Rail Welds

Attribute Database

The initial work required the design and implementation of a consolidated attribute database for the transfer of important construction records to maintenance for their routine uses. Tables were set up for each of these major subjects such as trackwork, LIM rail, ATC cable and power rail. Under each of these major subjects, tables were defined to describe textual information relating to each subject. For example, under the trackwork subject, tables were defined for running rail, rail accessories, rail fasteners, rail supports, switch machines and rail grinding. These tables were then linked to the spatial database either as "pseudo objects" or spatial objects. The benefit of using "pseudo objects" is the ability for the user to make changes effectively as a result of design conflicts or as-built conditions. Rail

accessories, for example, were linked to the spatial database as "pseudo objects" since during design and construction, their positions can change due to design or field conflicts. Other objects such as rail fasteners are grouped by track section numbers and extracted as spatial objects.

The design of each table has to incorporate a unique linkage field which in most cases is the track section number except for "pseudo objects" where the unique identifier is usually the track centerline, running rail or power rail.

The attribute database allows critical as-built records to be accessed from the map using standard processes or ad hoc inquiries. These records include stationing, type, structure, quantities, construction contract number, supply contract number, etc. From this table, other tables containing detailed information on the construction contract such as scope of work, contact person or warranty of the product, etc. can also be linked, allowing the user to query the database to obtain more detailed information.

Analysis and Maintenance Planning

The SkyMAP application was completed, tested and commissioned by the beginning of 1990, and was accepted by B.C. Transit for implementation.

The application has been designed for easy access by end users for analysis and maintenance planning. The establishment of relationships between component degradation and physical layout of the system such as geometry, grades, component types, etc. can now take place allowing actual maintenance requirements to be forecasted.

Although the frequency and scope of maintenance usually increases with time under normal wear and tear, B.C. Transit has considered that maintenance planning should be defined and monitored at the early stages of system operation. In fact, a significant amount of planning work can be done in the areas of resource planning, inspection and monitoring of critical work items. Too often, corrective work can become accepted as the norm for maintenance and in the long term, can be expensive, disruptive and time consuming. Preventative maintenance will require a sound database, which in the long term can increase the life of system components, thereby lowering the overall maintenance cost of the infrastructure. A good example faced by the SkyTrain engineers is in the areas of preventative rail grinding where regular grinding to remove surface defects and corrugations on the track can significantly improve the life of the rails, track structure and wheel wear while, at the same time, reduce the noise level. Another example is in special trackwork areas where regular spot grinding to remove burrs and corrugations can extend the life and serviceability of the track components. Replacement costs not only will be expensive, but can create major disruptions to train operations.

Conclusion

The success of the demonstration project has assisted B.C. Transit in developing their approach towards the overall life cycle planning from conceptual design to maintenance. This need is accentuated by the commitment to the overall transit programs for B.C. in the next few years ranging from feasibility studies of some corridors to construction in other corridors. As a start, B.C. Transit has produced an AutoCAD Design Standards for their consultants to follow with AutoCAD as the preferred choice for drawing productions. At the same time, they are also preserving the option to consolidate all the engineering and as-built records into one consolidated database using the SkyMAP application as guidance for their engineering and maintenance management system.

Future development will have to consider more automation of standardized proceses for the production of engineering and as-built drawings, compatibility of records between different disciplines, transfer of data within the life cycle planning of the entire SkyTrain system, direct interface of records between construction and maintenance and the use of an overall control system for the management of construction and maintenance activities. With the tools available at the Operating Company for accounting, reporting, generation of work orders, etc. and the continuing development of the SkyMAP application, the logical progression is to permit management to integrate all information to the benefit of the entire system operation.

PUBLISHED AS INFORMATION BY COMMITTEES

COMMITTEE 4—RAIL

Chairman: H. W. Newell III

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 1989 and 1990 By Weight and Section

In 1989

Weight	Section	N. American Tons Shipped	Non-N. American Tons Shipped	Total	% Total
100	RA	4,929	0	4,929	0.7
100	RE	705	0	705	0.1
115	RE	140,816	26,852	167,668	25.4
119	RE	1,739	0	1,739	0.3
122	CB	17	1,100	1,117	0.2
132	RE	115,985	47,814	163,799	24.8
133	RE	54,744	2,200	56,944	8.6
136*	RE	217,860	42,096	259,956	39.5
140	RE	1,682	0	1,682	0.3
OTHER	Includes Girder Rail	260	275	535	0.1
TOTAL		538,737	120,337	659,074	100

In 1990

Weight	Section	N. American Tons Shipped	Non-N. American Tons Shipped	Total	% Total
100	RA	1,661	0	1,661	0.3
100	RE	439	0	439	—
115	RE	104,184	3,075	107,259	19.7
119	RE	6,236	0	6,236	1.1
122	CB	0	0	0	—
132	RE	89,273	32,768	122,041	22.4
133	RE	37,186	36,000	73,186	13.4
136*	RE	153,807	78,790	232,597	42.8
140	RE	1,885	0	1,885	0.3
OTHER	Includes Girder Rail	0	290	290	—
TOTAL		394,671	150,923	545,594	100

*(Includes 136# with modified head profile)

NOTE: The report is from data furnished by North American Rail Producers covering rail shipped to railroads, transit agencies and contractors known to supply rails to railroads in North America. The non-North American rail data was obtained by soliciting 54 railroads and major transit agencies as to their purchases of non-North American rail. Of the 54 solicited, 49 responded including all class 1 railroads and all major transit agencies except for one.

COMMITTEE 12 — RAIL TRANSIT

Chairman: D. D. Dali

Report of Subcommittee C-2-87

REVIEW OF RAIL TRANSIT SYSTEMS

Subcommittee Chairman: R. C. Arnlund
By: R. G. Bogovich

INTRODUCTION

Committee 12 — Rail Transit was formed to study various aspects of the rail transit industry. The rail transit industry included properties with Intermediate Capacity Systems, Light Rail Systems, Commuter Rail Systems and Heavy Rail Systems. There are numerous rail transit systems throughout North America that have been in operation for many years. Many new rail transit systems are currently in the planning stage. In addition, a number of rail transit systems are being expanded and several new rail transit systems are under construction.

One of the objectives of Committee 12 is to promote the collection, assembly and distribution of technical data and issues particular to the rail transit industry. In pursuit of this objective, Committee 12 undertook a survey of rail transit properties to collect general baseline technical data. In addition, information about past and current problem areas which the various properties have experienced was solicited to establish technical subjects for further investigation by Committee 12.

DATA COLLECTION

Data collection consisted of the distribution of a questionnaire to known rail transit properties in North America. The initial distribution was followed up with direct contacts with personnel at the properties in order to maximize the number of return responses to the questionnaire. The baseline technical data has been summarized on the following tables. The information pertaining to specific problem areas is being reviewed by Committee 12 and will be addressed in subsequent articles.

SUMMARY

The information presented herewith concerning the rail transit systems is constantly changing and periodic up-dates will be provided the keep this information current. In addition, information concerning other existing and new rail transit systems will be added as this information becomes available.

Dissemination of this information to the membership is to familiarize all those interested in the variations that exist in rail transit systems with a brief but concise summary, and with as much specific information as was obtainable at this time.

Committee 12—Rail Transit
Questionnaire

AGENCY	TRANSIT CORRIDOR LENGTH	MAINLINE TRACK LENGTH: TUNNEL	MAINLINE TRACK LENGTH: AERIAL	MAINLINE TRACK LENGTH: AT-GRADE	NO. OF STATIONS: SUBWAY	NO. OF STATIONS: TOTAL	MAXIMUM DESIGN SPEED	MAXIMUM DESIGN CURVATURE: MAINLINE	MAXIMUM DESIGN CURVATURE: SECONDARY	MAXIMUM DESIGN SUPERELEVATION	SUPERELEVATION RUNOFF RATE
INTERMEDIATE CAPACITY SYSTEMS											
Toronto Transit Commission	4 mi.	-0-	1.4 mi	2.6 mi	-0-	6	50 mph	--------	30 m	6"	Depends on speed
Skytrain, Vancouver	24.7 km	2.5 km	16.3 km	6 km	3	17	57 mph	70 m (235' R)	30 m (100' R)	6"	Depends on speed
LIGHT RAIL SYSTEMS											
Bi-State Development Agency, St. Louis (Proposed)	18 mi.	2 mi	3 mi	32 mi	3	20	55 mph	125' R	125' R	3" Actual 3" unbalanced	1/2" in 31'
Calgary Transit	17.8 mi.	1.42 mi	.88 mi	15.40 mi	-0-	30	50 mph	250' R	80' R	4 1/4"	1"in 88'
Dallas Area Rapid Transit (Planned)	93 mi.	15 mi	31 mi	140 mi	6	96	70 mph	750' R	350' R	6"	-----------
Edmonton Transit	10.3 km E 2.4 km F	4.6km E 3.8km F	1 Bridge Future	16 km	4 E 2 F	8 E 2 F	80 km	180 m R	35 m R	100mm	30mm per second for the maximum speed in the curve
Greater Cleveland Regional Transit Authority	10.3 mi.	-0-	-0-	20.6 mi	-0-	27	40 mph	19 Deg.-30' (300')	48 Deg.-30' (120')	7" (3" Unbalanced)	1" in 75'
Los Angeles County Transp. Commission	22 mi.	1.6 mi	3.8 mi	36.6 mi	1	22	55 mph	82' Embedded Track; 300' R Open Track	82'	4"a + 3"u	Ls=1.17 EV
Mass Transit Administration, Baltimore (Proposed)	22 mi.	-0-	1.0 mi	21.0 mi	-0-	24	50 mph	300' R off street 100' R in street	100' R	6.0 "	1" in 31'/ Depends on Length of Spiral
Massachusetts Bay Transportation Authority	28 mi.	4.2 mi	1.0 mi	22.8 mi	11	64	50 mph	70' CR	45' CR	6"	--

Committee 12—Rail Transit
Questionnaire (cont.)

AGENCY	TRANSIT CORRIDOR LENGTH	MAINLINE TRACK LENGTH TUNNEL	AERIAL	AT-GRADE	NO. OF STATIONS SUBWAY	TOTAL	MAXIMUM DESIGN SPEED	MAXIMUM DESIGN CURVATURE MAINLINE	SECONDARY	MAXIMUM DESIGN SUPERELEVATION	SUPERELEVATION RUNOFF RATE
LIGHT RAIL SYSTEMS (Continued)											
Metropolitan Transit Authority of Harris County Houston (Proposed)	12.38 mi.	6.0 mi	5.6 mi	0.7 mi	10	17	50 mph	250' R	150' R	4.0 "	1" in 50 '
Metropolitan Transit Development Board, San Diego	20.4 mi.	-0-	-0-	20.4 mi	-0-	22	50 mph	25 m R	25 m R	2"	1" in 62'
N.F.T. Metro Systems, Inc.	6.4 mi.	10.4 mi	-0-	2.4 mi	8	14	50 mph	1000' R	75' R	5.5"	Depends on Length of Spiral
NJ Transit Bus Operations, Inc	4.17 mi.	1.25 mi	-0-	2.92 mi	4	11	40 mph	42.3' R Loop Track	-----	2.0 "	-------
Port Authority of Allegheny County	22.5 mi.	1.9 mi	1.4 mi	19.2 mi	3	13	55 mph	82' R	35.25' R	4"	Site Dependent
Regional Transit Authority New Orleans	15 mi.	-0-	-0-	15 mi	-0-	124 Stops	28 mph	15,000' R	----	2.0"	varying
Sacramento Regional Transit Dist.	18.3 mi.	-0-	.7 mi	17.6 mi	-0-	28	55 mph	82' R	90' R	6"	1" in 28.3'
Santa Clara County Transit District	20.0 mi.	354 ft	-0-	39 mi	-0-	30	55 mph	82' R	100' R	6.0"	Ls=1.10 UV Ls=1.17 EV Ls=30 E
Tidewater Transp. District Commission Proposed	17.7 mi.	-0-	1 mi	16.7 mi	-0-	13	50 mph	100' R	100'R	4.3"	1/2" in 31'
Toronto Transit Commission	60 mi.	-0-	-0-	60 mi	-0-	-0-	Mixed Traffic	40' R	37' R	-----	-------
Tri-Met	15 mi.	-0-	-0-	30 mi	-0-	40	55 mph	82' R	80' R	6"	5/8" in 31'

Committee 12—Rail Transit
Questionnaire (cont.)

AGENCY	TRANSIT CORRIDOR LENGTH	MAINLINE TRACK LENGTH: TUNNEL	AERIAL	AT-GRADE	NO. OF STATIONS: SUBWAY	TOTAL	MAXIMUM DESIGN SPEED	MAXIMUM DESIGN CURVATURE: MAINLINE	SECONDARY	MAXIMUM DESIGN SUPERELEVATION	SUPERELEVATION RUNOFF RATE
					COMMUTER RAIL SYSTEMS						
Long Island RR	115 mi.	6.4 mi	16.9 mi	681.6 mi	-0-	134	80 mph	12 Degrees 30'	12 Degrees 30'	6"	1/4" in 31'
Metro-North Commuter Railroad	268 mi.	3 mi	4 mi	261 mi	-0-	107	95 mph	7 Deg.-30'	17 Deg Loop	6"	3/8" in 31'; 1/4" in 31' Over 90 mph
Staten Island Rapid Transit	14.3 mi.	-0-	-0-	14.3 mi	-0-	22	40 mph	--	--	1"	1" in 40'
					HEAVY RAIL SYSTEMS						
Bay Area Rapid Transit	71 mi.	41.5 mi	48.1 mi	56 mi	14	34	80 mph	11.4 Dc	11.4 Dc	8 1/4"	3/4" in 31'
Chicago Transit Authority	97.9 mi.	23.1 mi	94.3 mi	131.8 mi	21	143	70 mph	85' by arc Def. Min. R	85' by arc Def. Min. R	5" actual plus 3" unbalanced	1" in 50'
Greater Cleveland Regional Transit Authority	38.4 mi.	.8 mi	-0-	37.6 mi	1	18	65 mph	630' R	300' R	7"	1" in 75'
Greater Cleveland Regional Transit Authority Future (Rail Bus)	19.2 mi.	.8 mi	-0-	37.6 mi	1	18	65 mph	9 Degrees-00' (630')	19 Degrees-30' (300')	7" (3" Unbalanced)	1" in 75'
Los Angeles County Transp. Commission (Proposed)	18 mi.	8.4 mi	-0-	-0-	5	5	75 mph	750' R	250' R	4"	1" in 29.25"
Mass Transit Administration Maryland	16 mi.	4 mi	4 mi	8 mi	6	12	70 mph	750' Min. R	500'/250' Min. R	4" Tunnel 6" Surface	1" in 50'

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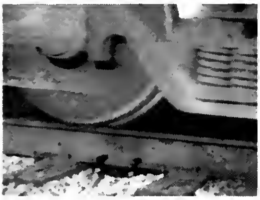
Committee 12—Rail Transit
Questionnaire (cont.)

AGENCY	TRANSIT CORRIDOR LENGTH	MAINLINE TRACK LENGTH			NO. OF STATIONS		MAXIMUM DESIGN SPEED	MAXIMUM DESIGN CURVATURE		MAXIMUM DESIGN SUPERELEVATION	SUPERELEVATION RUNOFF RATE
		TUNNEL	AERIAL	AT-GRADE	SUBWAY	TOTAL		MAINLINE	SECONDARY		
HEAVY RAIL SYSTEMS (Continued)											
Massachusetts Bay Transportation Authority	53 mi.	12.3 mi	1.0	41.0	25	60	60 mph	100' R	70' R	6"	-------
Metro-Dade Transit Agency	21 mi.	-0-	40 mi	2 mi	-0-	21	70 mph	1100' R	300' R	4"	1" in 50'
Metropolitan Atlanta Rapid Transit Authority	33.5 mi.	15.7 mi	16.0 mi	35.3 mi	9	29	70 mph	750' R	350' R	6"	1" in 69'
NJ TRANSIT Rail Operations	449.6 mi.	4.0 mi	-0-	297.0 mi	-0-	153	80 mph	--	12 30'	4"	1/2" in 31'
New York City Transit Authority	224 mi.	137 mi	70 mi	17 mi	279	469	45 mph	Design Max R = 850' Actual Max R = 146'	Design Max R = 235' Actual Max R = 112'	6.5"	1" in 40 '
Port Authority Trans-Hudson Corp.	14 mi.	8 mi	-0-	6 mi	10	13	40 mph tunnel 55 mph outside	115' R	90' R	4"	Varying
Port Authority Transit Corporation	14.5 mi.	5 mi	6 mi	19 mi	6	13	75 mph	.573V^2 R	-------	8"	Ls=1.17EcV
Toronto Transit Commission	38 mi.	31 mi	-0-	7 mi	60	60	50 mph	1000' R	250' R	4" plus 2 1/2" unbalanced	1 1/4" per second of travel Max.
Washington Metro Transit Authority	73 mi.	36 mi	7 mi	30 mi	40	66	75 mph	755' R Min.	250' R Min.	Tunnel 4" Surface 6"	100'

New Generation Lubricators



Electric Powered, 961 Intelligent Rail Lubricator™

Consistent grease delivery to the rail in all temperatures, with any grade of grease. 20 settings of output. Microprocessor controlled to hold settings. New wheel detector is located completely beneath base of rail and needs no adjustments. AC or battery powered DC with solar charging option.

Hydraulic Powered, 761 Hydraulube™ Lubricator

Uses power from passing train wheels without mechanical linkage. Patented M&S Powerblock™ attaches to rail without drilling or grinding. Converts wheel energy to smooth hydraulic pulse to drive system. Locate lubricator up to 25′ from rail. Adjustable, consistent output in any temperature.

M&S
Moore & Steele Corporation

Committee 12—Rail Transit
Questionnaire (cont.)

AGENCY	MAXIMUM DESIGN GRADIENT	GAGE: TANGENT	GAGE: CURVE	RAIL SECTIONS: PRESENT	RAIL SECTIONS: FUTURE	REQUIREMENTS FOR RAIL GUARDING	METHOD OF RAIL GUARDING	EMERGENCY GUARD RAIL REQUIREMENTS	ELECTRIC CURRENT SUPPLY
INTERMEDIATE CAPACITY SYSTEMS									
Toronto Transit Commission	------	4'-8 1/2" + 1/16, - 0	4'-8 1/2"	115 RE	115 RE	Crossovers only	----------	None	3rd & 4th Rail, 600 V DC
Skytrain, Vancouver	6%	4'-8 1/2" + 1/16, - 0	4'-8 1/2"	115 RE	115 RE	None	----------	Parapet walls to contain vehicle	3rd & 4th Rail, 600 V DC
LIGHT RAIL SYSTEMS									
Bi-State Development Agency, St. Louis (Proposed)	6%	4'-8 1/2"	Varies by individual Curves	N/A	132 RE	Inside Rail As Req'd. by Curve	Bolt on Planed Rail	None	Span Wire & Catenary 750 V DC
Calgary Transit	6%	1435 mm + 0 - 3	1441mm + 0 - 3	100 ARA-A Ri60	100 ARA-A Ri60	(Under Review)	Bolt on Planed Rail/ Fabricated Assembly with Wear Bar/ Girder Rail	Bridges, Elevated Structures, Track Radius Under 330', Approaching Tunnels with Center Wall	Catenary 600 V DC
Dallas Area Rapid Transit (Planned)	Subway 4% At-Grade 6%	4'-8 1/2" - 1/8 + 1/8	4'-8 1/2" - 1/8 + 1/8	--	115RE	Inside Rail-Track Radius Under 700'	Fabricated Assembly with Wear Bar Isolated from Running Rail	None	Catenary-1500 DC
Edmonton Transit	5.5%	1435mm + 0/- 3 mm	1435mm + 0/- 3mm	100 ARA-A	100 ARA-A	Inside Rail-Track Radius Under 200m	Inside Rail-Girder Guard Rail, Bolt-on Rolled Strap Guard	Bridges, Approaches to Abutments or Portals	Catenary 600 DC
Greater Cleveland Regional Transit Authority	6%	4'-8 1/4"	4'-8 1/2"	100 RB	100 RB	Inside Rail-Track Radius Under 1000'; Curves Over 5 3/4 Deg.	Bolt-on Planed Rail & Rail Spiked 15" inside both Running Rails	Bridges and Elevated Structures and at Station Locations	Span Wire, Catenary-600 DC
Los Angeles County Transp. Commission	4% Sus-tained; Short Lengths up to 6%	4'-8 1/2" + 1/8" - 1/8"	4'-8 3/4" + 1/8" - 1/8" 500' R - 250' R; < 250'R 4'-9"	115RE	115RE	Exceptionally Hazardous Situations	European 'U' Section	None	Catenary 600 V DC
Mass Transit Administration Baltimore (Proposed)	6%	4'-8 1/2"	4'-8 3/4" 200' R to 280' R	115RE	115RE	Inside Rail-Track Radius Under 800'; Inside/ Outside Rail-Track Radius Under 300'	Bolted Strap Guard Rail	Elevated Structures	Catenary-750 V DC

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Committee 12—Rail Transit
Questionnaire (cont.)

LIGHT RAIL SYSTEMS (Continued)

AGENCY	MAXIMUM DESIGN GRADIENT	GAGE TANGENT	GAGE CURVE	RAIL SECTIONS PRESENT	RAIL SECTIONS FUTURE	REQUIREMENTS FOR RAIL GUARDING	METHOD OF RAIL GUARDING	EMERGENCY GUARD RAIL REQUIREMENTS	ELECTRIC CURRENT SUPPLY
Massachusetts Bay Transportation Authority	6%	56 1/2" + 7/8 - 3/8	56 3/4" + 3/4 - 1/4	85 100 115 128 149	115 128 149	Inside Rail-Track Radius Under 1000'; Inside/Outside Rail-Track Radius Under 100'	Inside/Outside Rail-Girder Guard/Bolt-on Planed Rail	Bridges, Elevated Structures	Catenary-600 DC
Metropolitan Transit Authority of Harris County Houston (Proposed)	6 %	4'-8 1/2" +/- 1/4	4'-8 1/2" +/- 1/4	----	115 RE	Inside Rail under 550' R Both Rails under 15 degrees	Bolt-on Planed Rail	None	Third Rail & Overhead Catenary 600 V DC
Hetropolitan Transit Development Board, San Diego	4.3%	4'-8 1/2" +/- 1/8"	4'-8 1/2" +/- 1/8"	115RE 90 ARA-A	115RE	None	None	None	Span Wire, Catenary-600 DC
N.F.T. Metro Systems, Inc.	6%	4'-8 1/4" + 1/8 - 1/8	Varies to 4'-9 1/4" +/- 1/8"	115RE 128RE 7A	--	Inside/Outside Rail on Track Radius Under 75' (Yard)	Inside Rail Bolt On Planed Rail Yard	None	Catenary 650 DC
NJ Transit Bus Operations, Inc	5.5 %	4'-8 1/2"	4'-8 1/2"	115 RE	115 RE	Inside Rail under 900' R Both Rails under 300' R	Bolt-on Planed Rail	None	Overhead Span Wire 600 V DC
Port Authority of Allegheny County	10%	62-1/2" + 1/8 - 0	62-3/4" + 1/8 - 0	100 ASCE & 100 ARA-B 115 RE 128 & 149 RE	115 RE 128 RE 149 RE	Inside Rail under 900' R, both rails under 100'R	Girder Guard Rail Girder groove rail Bolt-on rolled Strap Guard and Bolt-on planed Rail	Approaching High Level Platforms & on Bridges	Span Wire, Catenary-650 DC
Regional Transit Authority New Orleans	----	St Charles 5'-2 1/2" +/- 1/8 Riverfront 4'-8 1/2"	St Charles 5"-2 3/4" +/- 1/8 Riverfront 4'-8 3/4"	115 RE 149 RE RI-59	115 RE 149 RE RI-59	Systemwide	Girder Guard Both Rails	None	Overhead Span Wire 600 V DC
Sacramento Regional Transit Dist.	7%	4'-8 1/2" +/- 1/8"	Varies to 4'-9", +1/2,-1/8"	115RE	115RE	Inside Rail-Track Radius Under 300'	Inside Rail-Bolt-on Planed Rail	Bridges; Elevated Structures	Span Wire, Catenary-750 DC
Santa Clara County Transit District	6.0%	4'-8 1/2" +/- 1/8"	Varies to 4'-9",	115 RE Ri59 132 RE	115 RE Ri59 132 RE	Inside Rail under 900' R on Mainline; under 300' R in Yard	Bolt-on Planed Rail with 132 RE Section	Bridges and Adjacent to Highway Structures & Tunnels	Overhead Catenary 750 V DC

Committee 12—Rail Transit
Questionnaire (cont.)

AGENCY	MAXIMUM DESIGN GRADIENT	GAGE TANGENT	GAGE CURVE	RAIL SECTIONS PRESENT	RAIL SECTIONS FUTURE	REQUIREMENTS FOR RAIL GUARDING	METHOD OF RAIL GUARDING	EMERGENCY GUARD RAIL REQUIREMENTS	ELECTRIC CURRENT SUPPLY
LIGHT RAIL SYSTEMS (Continued)									
Tidewater Transp. District Commission (Proposed)	4.3%	4' 8 1/2" +/- 1/8"	4' 8 1/2" +/- 1/8"	----	115RE	None	None	None	Span Wire, Catenary - 600V DC
Toronto Transit Commission	8 %	4'-10 7/8" + 1/16, - 0	4'-11" + 1/16, - 0	100 ARA-A, 149#, 128#, Ic	115 RE, New Section from TRADEARBED	Inside Rail under 1000'R Both Rails under 100'R	Girder Guard and Girder Groove Rail Both Rails	None	Overhead Span Wire 550 V DC
Tri-Met	7%	56 1/2" +/- 1/8"	56 1/2" +/- 1/8"	115RE RI59	115RE RI59	Inside Rail-Track Radius Under 500'	Inside Rail-Girder Groove Rail, Bolt-on Planed Rail; Outside Rail-Girder Groove Rail	Bridges, Adjacent to all major structure that may cause damage to a car or its passengers in case of derailment	Span Wire, Catenary-750 DC
COMMUTER RAIL SYSTEMS									
Long Island RR	1.5%	4'-8 1/2" + 1" - 1/2"	4'-8 1/2" + 1" - 1/2"; 4'-9" Over 8 Deg.	100lb PS 112lb RE 115lb RE 119lb RE 130lb PS	119lb RE	None	None	Bridges; Elevated Structures; Physical Obstructions 3' Above Top Rail	Third Rail 750 DC
Metro-North Commuter Railroad	1.37	4'-8 1/2" + 3/4" - 3/4"	4'-8 1/2" + 3/4" - 3/4"	119 127 131 132 140	119 127 131 132 140	Inside Rail-Curves Over 17 Deg. (G.C.T. Loop)	Brace & Chairs	Bridges, Elevated Structures, Track Radius Under 302.95' Protect Structures	Third Rail 700 DC; Catenary 60HZ 13KV AC
Staten Island Rapid Transit	--	4'-8 1/2" + 1/8" - 1/8"	4'-8 3/4" + 1/8" - 1/8"	100 RB	115 RE	Track Radius Under 500'	Inside Rail-Bolt-on Planed Rail	Bridges; Track Radius Under 500'; Curves Over 10 Degrees	Third Rail 600 DC
HEAVY RAIL SYSTEMS									
Bay Area Rapid Transit	4%	5'-6" + 1/2 - 1/4	5'-6" + 1/2 - 1/4	90 RAA 115 RE 119 RE	90 RAA 115 RE 119 RE	Inside Rail-Track R Under 950'	Restraining Rail Fasteners (Landis) with 90 RAA rail	Track Radius under 950' and Aerial Crossovers	Third Rail 1000 DC
Chicago Transit Authority	4%	4'-8 1/2" + 1/8" - 1/8"	4'-8 1/2" + 1/8" - 1/8" 4'-8 3/4" for R < 125'	112RE 100RA 100RE 9040 8040 115RE	100RA 100RE 115RE 9040	Inside Rail-Track Radius Under 500'	Inside Rail Girder Guard Rail, Either Vertical or Horizontal	Bridges, Elevated Structures,Columns, Platforms, Track on Embankment, Physical Obstructions	Third Rail, Catenary - 600 DC

Committee 12—Rail Transit
Questionnaire (cont.)

AGENCY	MAXIMUM DESIGN GRADIENT	GAGE TANGENT	GAGE CURVE	RAIL SECTIONS PRESENT	RAIL SECTIONS FUTURE	REQUIREMENTS FOR RAIL GUARDING	METHOD OF RAIL GUARDING	EMERGENCY GUARD RAIL REQUIREMENTS	ELECTRIC CURRENT SUPPLY
				HEAVY RAIL SYSTEMS (Continued)					
Greater Cleveland Regional Transit Authority	6%	4'-8 1/4"	4'-8 1/2"	90 RA 100 RA 115 RE	100 RB 115 RE	Inside Rail under 1,000' Radius and Curves over 5-3/4 Deg	Bolt-on Planed Rail & Rail Spiked 15" inside both Running Rails	Bridges and Elevated Structures	Catenary 600 DC
Greater Cleveland Regional Transit Authority Future (Rail Bus)	6%	4'-8 1/4"	Over 1425' 4'-8 1/4"	115RE 100RA 90RA	115RE 100RB	Inside Rail-Track Radius Under 1000', Curves Over 5 3/4 Degrees	Inside Rail-Bolt-on Planed Rail; Rail Spiked 15" Inside Both Running Rails	Bridges, Elevated Structures	Catenary 600 DC
Los Angeles County Transp. Commission (Proposed)	4%	4'-8 1/2" +1/8,-1/8	(Mainline) 4'-8 1/2" +1/8,-1/8 (Yard) 4'-9" +/- 1/8	115RE	115RE	None	--	Bridges, Elevated Structures, Track Radius Under 1000' Mainline 500' Yard	Third Rail-750 DC
Mass Transit Administration Maryland	4%	4'-8 1/4" 4'-8 1/2"	4'-8 1/2" < 1200	115RE	115RE	None	None	Elevated Structures with Radius Under 3000'; Track Radius Under 3000' on Bridges Only	Third Rail 650 V DC Full Load
Massachusetts Bay Transportation Authority	6%	56 1/2" - 1/2,+ 1	56 3/4" - 1/2, + 3/4	85, 100, 115	115	Track Radius under 1000' Inside Rail, under 100' Both Rails	Bolt on Planed Rail	Bridges and Elevated Structures	Third Rail & Catenary 600V DC
Metro-Dade Transit Agency	3%	4'-8 1/4" - 0 + 1/4	4'-8 1/2" - 0 + 1/2	115 RE	115 RE	None	None	Bridges, Elevated Structures	Third Rail 750 DC
Metropolitan Atlanta Rapid Transit Authority	+/- 4%	4'-8 1/2" + 1/4" - 1/4"	4'-8 1/2" + 1/4" - 1/4"	115 RE	115 RE	None	None	None	Third Rail 600 DC
NJ TRANSIT Rail Operations	2-1/2%	4'-8 1/2" + 1/4"	4'-8 1/2" + 1/2" - 1/4"	115 RE 119 RE 132 RE	115 RE 119 RE 132 RE	None	None	Bridges, Elevated Structures	Catenary 11.5 and 25 KV AC
New York City Transit Authority	Design 3% Actual 5.5%	4'-8 1/4" +/- 1/8	Below 7500' R Varies up to 4'-9"	100 ARA-B 115 RE	100 ARA-B 115 RE	Inside Rail under 1,500' R	Bolt on Planed Rail	Bridges and Elevated Structures and Special Locations	Third Rail 600 V DC

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Committee 12—Rail Transit
Questionnaire (cont.)

AGENCY	MAXIMUM DESIGN GRADIENT	GAGE TANGENT	GAGE CURVE	RAIL SECTIONS PRESENT	RAIL SECTIONS FUTURE	REQUIREMENTS FOR RAIL GUARDING	METHOD OF RAIL GUARDING	EMERGENCY GUARD RAIL REQUIREMENTS	ELECTRIC CURRENT SUPPLY
HEAVY RAIL SYSTEMS (Continued)									
Port Authority Trans-Hudson Corp.	4.5% Tunnels	56 1/2" + 1/2" - 1/2"	56 3/4" + 1/4" - 1/4"	85 ASCE, 100 lb 115 RE	110 lb 115 RE	Inside Rail-Track R Under 750'	Bolt on Planed Rail and Brace and Block at Spring CLips	Bridges	Third Rail 650 DC
Port Authority Transit Corporation	5%	56 1/2"	57"	132RE 100ASCE	132RE 100RB	Inside/Outside Rail-As Necessary	--	Bridges; Elevated Structures; Track Radius Under 500' (Restraining Guard Rail)	Third Rail 700 DC
Toronto Transit Commission	3.5 %	4'-10 7/8" + 1/16, - 0	4'- 11" 500'R to 3000'R, 4'-11 1/8" under 500'R	85# CPR, 100ARA-A, 115RE	85# CPR, 100ARA-A, 115RE	Inside Rail under 2600'R	Horizontal Restraining Rail under 2600' R	Bridges and Portals	Third Rail 550 V DC
Washington Hetro Transit Authority	4%	4'-8 1/4" +/- 1/8"	Varies from 4'-8 1/4" to 4'-9 1/4"	115RE	115RE	Inside Rail-Track Radius Under 750'	Horizontal Restraining Rail under 750' R	Aerial Structures and Retained Fill	Third Rail 750 DC

Committee 12—Rail Transit
Questionnaire (cont.)

AGENCY	TURNOUT & SPECIAL TRACKWORK STANDARDS	MODIFICATIONS TO STANDARDS	WHEEL PROFILE	TRACK SYSTEMS	FASTENING SYSTEMS
			INTERMEDIATE CAPACITY SYSTEMS		
Toronto Transit Commission	AREA	AREA with minor Modifications	Special for Vehicle 16" Diameter	Direct Fixation, CWR, At-Grade and Aerial	Special Direct Fixation using Pandrol Clips
Skytrain, Vancouver	European Geometry Movable Frogs	Extensive	Special for Vehicle 16" Diameter	Direct Fixation, CWR, At-Grade and Aerial	Special Direct Fixation using Pandrol Clips
			LIGHT RAIL SYSTEMS		
Bi-State Development Agency, St. Louis (Proposed)	AREA	Minor	AAR Standard	Wood Tie on Ballast Mainly, Direct Fixation-Tunnel & on 3 Bridges, CWR-Mainline/Bolted-Yard	Cut Spikes & Plates, throughout, Clips on Direct Fixation & ends of Bridges
Calgary Transit	VOV	Standards without Modific.	1:40 Taper, 22mm High x 16mm Wide Flange, European Streetear	Wood & Concrete Tie on Ballast-CWR, At-Grade; Direct Fixation-CWR, Aerial, Tunnel; In Pavement on Elastomer	Wood Tie on Ballast (Pandrol PR631A); Concrete Tie on Ballast (Pandrol PR631A)-Current; Direct Fixation (Lord Plates with Vossloh Clips)-Current
Dallas Area Rapid Transit (Planned)	Modifications to AREA	AREA Stds. with Minor Modific.	AAR M-107 Std.	Wood/Concrete Tie on Ballast-CWR, At-Grade; Direct Fixation-CWR, Aerial, Tunnel	------------------
Edmonton Transit	AREA, Hodific. to AREA	Use Plans Developed by Supplier	Edmonton Transit	Wood Tie on Ballast-CWR, At-Grade, Tunnel; Direct Fixation-CWR, Tunnel	Wood Tie on Ballast-Current; Direct Fixation (Landis Plates with Pandrol Clips)-Current, (Lord Plates with Vesslon Clips)-Future
Greater Cleveland Regional Transit Authority	AREA and NYCTA	AREA	AAR Type AARM-107 Modified (No Taper)	Wood Tie on Ballast-CWR, At-Grade	Double Shank Elastic Spike, Future use of Direct Fixation and In-Pavement on Ballast
Los Angeles County Transp. Commission	AREA, VOV, UIC	UIC, AREA Stds. with Major Modific.	AAR Std. Multiple Wear Cast Steel	Concrete Tie on Ballast-Bolted, CWR, At-Grade, Aerial; Direct Fixation-CWR, Aerial, Tunnel; Embedded Tie in Concrete-CWR, At-Grade	------------------

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Questionnaire (cont.)

LIGHT RAIL SYSTEMS (Continued)

AGENCY	TURNOUT & SPECIAL TRACKWORK STANDARDS	MODIFICATIONS TO STANDARDS	WHEEL PROFILE	TRACK SYSTEMS	FASTENING SYSTEMS
Mass Transit Administration Baltimore (Proposed)	AREA	AREA Stds. with minor modifications	AAR Std.	Direct Fixation on bridges, Embedded in streets, Concrete ties - mainline, Timber ties - Special Trwk. & Yard	Lord Fasteners in Direct Fixation & Pandrol on wood & Concrete Tie
Massachusetts Bay Transportation Authority	AREA, ATEA, Custom Designs	AREA/ATEA-Stds. Without, Minor, Major Modific., Have Distinct Set of Unique Stds.	ATEA (Transit) Modified	Wood Tie/In Pavement on Ballast-Bolted, CWR, At-Grade; Wood Tie on Ballast-Aerial, Tunnel; Direct Fixation-Bolted, Tunnel; On Ties Fastened to Structure	Wood Tie on Ballast-Current (Cut Spike & Pandrol), Future (Pandrol); Direct Fixation, In Pavement on Ballast-Current/ Future
Metropolitan Transit Authority of Harris County Houston (Proposed)	AREA & European	AREA & European with minor modifications	AAR Standard	CWR Systemwide; Wood and Concrete Tie on Ballast, At-grade; Direct Fixation, Aerial and in tunnel	Cut Spike on Wood ties Spring Clip for Direct Fixation and Concrete Ties
Metropolitan Transit Development Board, San Diego	AREA	AREA Stds. without Modific.	AAR Std. Bochum	Wood/Concrete Tie, In Pavement on Ballast-CWR, At-Grade	Wood Tie on Ballast-Current (Spiked & Anchored), Future; Concrete Tie on Ballast-Current (Pomeroy), Future; In Pavement on Ballast-Current (Spiked Anchor), Future
N.F.T. Metro Systems, Inc.	AREA	AREA Stds. with Minor Modific.	AAR Modified	Yard:Wood Tie on Ballast; Mall-at-grade:Girder set in concrete with Gauge Rods; Tunnel:Lord D.F. & duo-block Floating Slab	Yard: Spikes wood tie; Mall: Concrete. No Fastening; Tunnel: Lord D.F.
NJ Transit Bus Operations, Inc	AREA	AREA with minor Modifications	ATEA Standard	CWR Systemwide, Embedded Tie in Concrete at Tunnel Stations, Wood Tie on Ballast	Spikes & Anchors on Wood Ties, Spikes on Embedded Ties
Port Authority of Allegheny County	AREA and ATEA	AREA and ATEA and Rail Supplier Plans	ATEA Type B-3 Modified	Wood Tie on Ballast-Bolted, CWR, At-Grade, Aerial, Tunnel; Embedded Tie in Concrete-Bolted, CWR, At-Grade, Tunnel	Pandrol & cut spike on Wood tie, Lord DF and Steel tie w/ clips for Embedded track

Committee 12—Rail Transit
Questionnaire (cont.)

AGENCY	TURNOUT & SPECIAL TRACKWORK STANDARDS	MODIFICATIONS TO STANDARDS	WHEEL PROFILE	TRACK SYSTEMS	FASTENING SYSTEMS
			LIGHT RAIL SYSTEMS (Continued)		
Regional Transit Authority New Orleans	AREA & ATEA	AREA & ATEA with Minor modifications	ATEA Modified	Wood Tie on Ballast, Direct Fixation, and Embedded Tie in Concrete with Bolted & CWR, all At-Grade	--------
Sacramento Regional Transit Dist.	AREA	AREA Stds. with Minor Modific.	Std. AAR	Wood Tie on Ballast-Bolted, CWR, At-Grade, Aerial; Direct Fixation-CWR, Aerial; In Pavement on Ballast-CWR, At-Grade	AREA plate, cut spike, anchors on Ballast & Embedded; Direct Fixation (Lord) on Aerial
Santa Clara County Transit District	VOV & UIC for embedded t.o.'s & special trackwork & AREA for ballasted turnouts	VOV, UIC and AREA with minor modifications	Custom Designed	CWR and At-Grade Systemwide, Wood Tie on Ballast & Embedded Direct Fixation	Pandrol Plate Spring Clip & Screw Spike - Ballasted; Flat Plate, Anchor Bolt & Rail Clip - Embedded; Pandrol Plate, Spring Clip & Anchor Bolt - Dir.Fix.; all with Stray Current Insulation Provisions
Tidewater Transp. District Commission (Proposed)	AREA	AREA Stds. without Modific.	AAR Std. Bochum	Wood Tie on Ballast-CWR, At-Grade	----------------
Toronto Transit Commission	TTC Standards	Standards unique to TTC	ATEA B-3 Modified	Bolted Rail, Embedded Tie in Concrete, Direct Fixation on some Bridges	Direct Fixation, Cut Spike and Spring Clip on Wood Tie
Tri-Met	AREA	AREA Stds. with Minor Modific.; Use Plans Developed by Supplier	AAR Modified	Wood Tie on Ballast, Embedded Tie in Concrete-CWR, At-Grade; Embedded Tie Bars in Concrete	Wood Tie on Ballast (Cut Spikes)-Current; Embedded Tie in Concrete (Rail Support Elastomer)-Current
			COMMUTER RAIL SYSTEMS		
Long Island RR	AREA	AREA Stds. without Modific.	Std. AAR	Wood Tie on Ballast-Bolted, CWR, Tunnel; Direct Fixation-CWR Slab Track and Open Deck	Wood Tie (Lock Spike & Cut Spike/Pandrol) - Current, (Pandrol) - Future; Direct Fixation (Landis/Pandrol)-Current & Future; Embedded Tie in Concrete (Pandrol) & Floating Slab (Landis/Pandrol) - Future

Committee 12—Rail Transit
Questionnaire (cont.)

AGENCY	TURNOUT & SPECIAL TRACKWORK STANDARDS	MODIFICATIONS TO STANDARDS	WHEEL PROFILE	TRACK SYSTEMS	FASTENING SYSTEMS
COMMUTER RAIL SYSTEMS (Continued)					
Metro-North Commuter Railroad	AREA and modifications to Metro-North & CONRAIL	AREA & CONRAIL with Minor Mod. & Supplier Plans	AAR Standard	Wood/Concrete Tie on Ballast, Direct Fixation-CWR; Wood Tie on Ballast-Bolted	Wood Tie on Ballast-Current (Cut Spike & Pandrol); Concrete Tie on Ballast-Current (Pandral), Future; Direct Fixation-Current, Future; Duo-Block Concrete Tie-Future
Staten Island Rapid Transit	AREA	AREA Stds. without Modific.; Stds. with Minor Modific.	Std. ATEA (Transit)	Wood Tie on Ballast-Bolted, CWR, At-Grade	--------------------
HEAVY RAIL SYSTEMS					
Bay Area Rapid Transit	AREA	AREA modified to 66" guage	AAR Modified Cylindrical Tread and Steel Rim on Aluminum Wheel	Wood/Concrete Tie on Ballast-CWR, At-Grade; Direct Fixation-CWR, Aerial, Tunnel	Concrete Ties with Spring Clips, Direct Fixation (Landis)
Chicago Transit Authority	AREA, Chicago Rapid Transit (Specialty Design)	AREA-Minor Mod. CRT-Unique Stds.	AAR, Steel Std. Cylindrical	Wood Tie on Ballast-Bolted, CWR, At-Grade, Aerial, Tunnel; Direct Fixation-Bolted, CWR, Aerial, Tunnel; Embedded Tie in Concrete-Bolted, CWR, Tunnel	Wood Tie on Ballast (Plan No. 4 Tie Plate with 2 Spikes)-Current, (Pandrol w/Lockspike); Direct Fixation (Landis/Lord Fastener w/Rigid Clip or Pandrol)-Current, (Landis/Lord Fastenings); Embedded Tie in Concrete (Compression Clip Screwspike to Oak)-Current, (Noise Dampening); Duo-Block Concrete Tie (2 sidings French RS Design)
Greater Cleveland Regional Transit Authority	AREA and NYCTA	AREA	AAR Type M107 Standard 1" in 20 Taper	Wood Tie on Ballast-Current/Future; Direct Fixation, In Pavement on Ballast-Future	Double Shank Elastic Rail Spike-Current
Greater Cleveland Regional Transit Authority Future (Rail Bus)	AREA; Modifications to NYCTA	AREA Stds. with Minor Modific.; Use Plans Developed by Supplier	AAR M107 Std. (1" in 20 Taper)	Wood Tie on Ballast, Direct Fixation, Floating Slab - CWR, At-Grade and in Tunnel	-------

Committee 12—Rail Transit
Questionnaire (cont.)

AGENCY	TURNOUT & SPECIAL TRACKWORK STANDARDS	MODIFICATIONS TO STANDARDS	WHEEL PROFILE	TRACK SYSTEMS	FASTENING SYSTEMS
			HEAVY RAIL SYSTEMS	(Continued)	
Los Angeles County Transp. Commission	AREA	AREA Stds. with Minor Modific.	AAR Wrought Steel Std.; ATEA (Transit) AAR M-107	Wood Tie on Ballast-CWR, At-Grade; Direct Fixation, Embedded Tie in Concrete, Floating Slab-CWR, Tunnel	----------------
Mass Transit Administration Maryland	AREA	--	AAR Standard	Wood/Concrete Tie on Ballast-CWR, At-Grade; Direct Fixation, Embedded Tie in Concrete-CWR, Aerial, Tunnel; In Pavement on Ballast-CWR; Floating Slab, Duo-Block Concrete Tie-CWR, Tunnel	Wood Tie on Ballast (Pandrol, Side Winder); Concrete Tie on Ballast (Truetemper-5); Direct Fixation (Hixon); Embedded Tie in Concrete (Hixon); Floating Slab (Hixon-D.F.)
Massachusetts Bay Transportation Authority	AREA	AREA with Minor and Major Modifications	Standard AAR	Bolted & CWR on Wood & Concrete ties & Direct Fixation, Wood & Dir. Fix. At-grade, Aerial & Tunnel, Embedded tie in concrete, Floating slab and Duo-Block	Cut Spike, Landis, Pandrol, Moses, Sidewinder & Misc.
Metro-Dade Transit Agency	AREA	AREA Stds. with Minor Modific.	--	Wood/Concrete Tie on Ballast-At-Grade; Direct Fixation-Aerial	Wood Tie on Ballast (Cut Spike); Concrete Tie on Ballast (Unit Clip); Direct Fixation (Pandrol Clip)
Metropolitan Atlanta Rapid Transit Authority	AREA with Minor Modifications	AREA with Major Modifications	AAR Modified 1:20	Wood Tie (Special Track-work only) & Concrete Tie on Ballast; Direct Fixation - Aerial & Tunnels; Embedded Tie - Floating Slab	Wood tie w/rigid clips on DF, Concrete tie w/ Spring Clips, Direct Fixation w/ Rigid & Spring Clips, 2 Block embedded tie w/ Spring Clips, Floating Slab w/ DF w/ Rigid & Spring Clips
NJ TRANSIT Rail Operations	AREA, NJ Transit	AREA and Plans Developed by Supplier	AAR Narrow Flange - Standard	Wood Tie on Ballast-Bolted, CWR, At-Grade, Tunnel	Wood Tie on Ballast-Current (Cut Spikes), Future (Elastomeric)

Committee 12—Rail Transit
Questionnaire (cont.)

HEAVY RAIL SYSTEMS (Continued)

AGENCY	TURNOUT & SPECIAL TRACKWORK STANDARDS	MODIFICATIONS TO STANDARDS	WHEEL PROFILE	TRACK SYSTEMS	FASTENING SYSTEMS
New York City Transit Authority	NYCTA Standards Knuckle Switches	AREA Standards Modified to NYCTA Standards	AAR Modified NYCTA 703-3001-P	Wood Tie on Ballast-Bolted & CWR, At-Grade Aerial & Tunnel; Direct Fixation & Embedded Tie in Concrete - Bolted & CWR, Aerial & Tunnel	Wood Tie on Ballast (14" std. & Pandrol); Direct Fixation (Container, Pandrol & Landis); Embedded Tie in Concrete (14" std., Pandrol & Resilient)
Port Authority Trans-Hudson Corp.	AREA and PATH and NYCTA	Old Hudson & Manhatten RR Standards	AAR Standard Cylinder Wheels (flat)	Wood Tie on Ballast-Bolted, CWR, At-Grade; Wood Tie/In Pavement on Ballast, Direct Fixation-Tunnel	----------------
Port Authority Transit Corporation	AREA	AREA Stds. without Modific.	Std. AAR	Wood Tie on Ballast-Bolted, CWR, At-Grade, Aerial; Direct Fixation-CWR, Aerial; Embedded Tie in Concrete-Bolted, CWR, Tunnel	Wood Tie on Ballast (Rails Co. Clip)-Current, (Pandrol)-Future; Concrete Tie on Ballast (Pandrol)-Future; Direct Fixation (Rails Co. Comp. Clip)-Current; Embedded Tie in Concrete (Screw Spikes)-Current
Toronto Transit Commission	AREA with Modifications	Major Modifications to AREA	TTC Designed	Bolted and CWR systemwide, Direct Fixation and Floating in Tunnel, Concrete & Wood Tie on Ballast at-grade	Direct Fixation, Concrete Ties with Pandrol, Cut Spike and Spring Clip on Wood Tie
Washington Metro Transit Authority	AREA	AREA Stds. with Minor Modific.	British Worn Profile	Wood Tie on Ballast-CWR, At-Grade; Direct Fixation, Floating Slab-CWR, Tunnel; Direct Fixation-Aerial	Wood Tie on Ballast (Tie Plate & Spike)-Current; Direct Fixation (D.F. Fasteners)-Current/Future; Floating Slab (D.F. Fasteners)-Current/Future

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COMMITTEE 27 — MAINTENANCE OF WAY WORK EQUIPMENT

Chairman: J. J. Hannaford

BAR CODES AND THEIR APPLICATION FOR ROADWAY WORK EQUIPMENT

Subcommittee Chairman: J. L. Condon

1. INTRODUCTION

Equipment maintenance and management in today's world is rapidly gaining a level of sophistication never before experienced in the industry. Sophisticated management is necessary to cope with the increasing complexity of day-to-day operations; as a result, good managers of equipment cannot afford to operate without various forms of computerization.

One of the most important waves of technology sweeping American industry is the use of bar codes for Systematic Data Collection. It is driven by the need for accurate and timely data gathering from the manufacturing, inspection, maintenance, transportation, material acquisition and inventory cycles of a business operation. There is a natural fit in equipment management where machine identification, part numbers and related information are basic and well suited to this technology.

BN Codes have gained acceptance as one of the most accurate and practical media to implement automatic collection of printed data. Bar codes are achieving this wide-spread popularlity because they can be incorporated in the primary source marking of products from production to consumption.

2. BENEFITS OF BAR CODES

Bar codes streamline identification. The black and white bars seen on most all grocery items in a supermarket represent a unique identification for that specific product. Bar codes have received overwhelming acceptance because they offer the simplest and most accurate, cost-effective approach for identifying objects by using reading machines (Scanners).

Some of the more frequent errors involved with a manual data entry system are as follows:

- Incorrect parts numbers
- Transposing of alpha or numeric characters
- Incorrect order units, i.e., each, feet, gallons, etc.
- Insufficient or incorrect ordering description
- Missing or incorrect shipping instructions or addresses
- Illegible handwriting

Some of the main advantages of bar codes are as follows:

a. Accuracy of data input:

One of the primary advantages of bar codes over other technologies is its low susceptibility to errors involved with data input.

The estimated error rate for generating errors due to interpreting handwritten alpha or numeric data is one error per 1,000 characters generated. This error rate is greatly influenced by the penmanship of the individual generating the document. The estimated error rate for keyed data entry is one error per 10,000 key strokes; whereas, the rate for Bar Code scanning is one error per 3,000,000 characters scanned.

b. Speed of entering data into the computer system:

Scanning a bar code is much faster than manually recording information or keying data into a terminal.

c. Timeliness of information for more effective management of resources and repair parts inventories:

Bar codes information can be immediately transferred to a host computer, and real-time data collection enables timely information to be accessed almost instantly.

d. Labor savings realized through elimination of manual systems:

Improved efficiency can be realized by substituting bar code systems in place of manual systems, resulting in increased productivity and reduced labor costs.

3. EQUIPMENT

One of the compact type portable units currently used for material acquisition is portable data terminal with 32K RAM including an integral printer. The scanner is a contact type, high density, laser wand with 6 Mil. aperture.

3.1 Scanners

Reading devices (or scanners) fall into two categories, contact and non-contact readers. Contact readers are normally handheld units, while non-contact readers can either be handheld or stationary units.

a. Contact Readers:

Contact readers must either touch or come in close proximity to the bar code symbol. The most common type of contact reader is a pen wand or light pen. They serve as an excellent substitute for the traditional clipboard, paper and pencil, or keyboard data-entry and collection methods. Primary benefits from using contact readers include a reduction in the number of clerical errors in recorded data, a reduction in labor and paperwork to process the data, faster and more accurate inventory taking, material acquisition or payroll document completion. Careful attention must be given to match the wand resolution to the bar code density. A high-density resolution wand used to read a low-density symbol might see an ink spot as a bar, or an ink void as a space. Conversely, a low-resolution wand may not be able to recognize the narrow bar of a high-density bar code.

The angle at which the wand is positioned to the surface of the symbol (45-90 degrees), as well as the speed at which the wand is moved across the symbol (3-6 inches per second), are both key parameters affecting high first-pass read rate.

b. Non-Contact Readers:

Non-contact readers include handheld and stationary scanners. The main characteristic of these scanners is that they don't have to come in contact with the bar code symbol and can read bar codes up to several feet depending on the symbol size and scanner type. One of the disadvantages of using non-contact scanners is the possibility of reading the wrong bar code when several bar codes are located in close proximity, as would be the case with work equipment repair parts books.

4. BAR CODE FORMAT

The bar code format that has been standardized by many railroads and the current material acquisition process is Code 39 (3 of 9). Code 39's flexibility to encode alpha and numeric characters has contributed to its widespread use, with some of the prominent advantages being:

- Incorporates alpha and/or numeric characters
- Codes can be variable in length
- Allows bi-directional scanning
- Density is approximately 3-9.5 characters per inch

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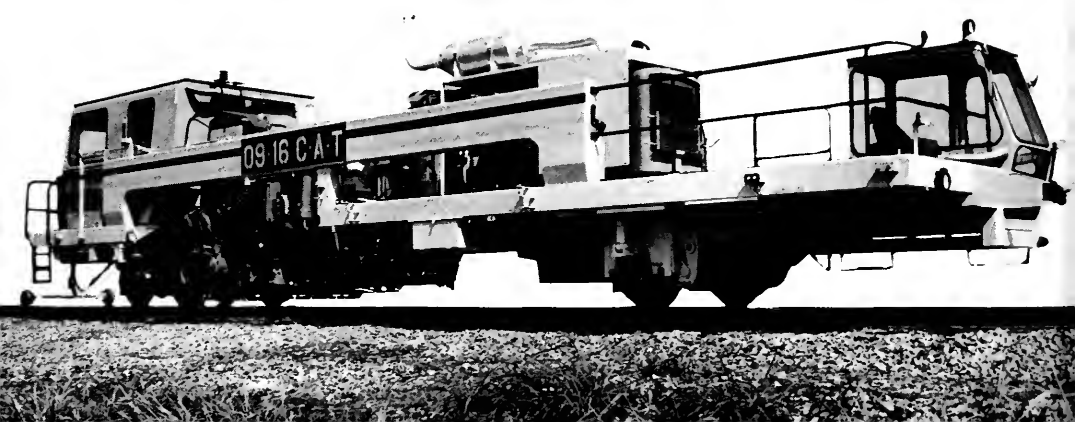


- Applications include LOGMARS (Department of Defense), GSA, AIAG (automotive) and wide acceptance throughout general industry.
- The quiet zone is 10 times the width of the narrow bar.

The 3 of 9 bar code is a variable length, bi-directional, discrete, self-checking alpha-numeric bar code. Its data character set contains 43 characters:

0,9, A-Z,-,.,$,/, + ,% and space.

Three of the nine elements are wide and six are narrow. A common character (*) is used exclusively for both a start and stop character and must be included in every bar code symbol to provide the bar code to be bi-directionally scanned.

Typical samples of a low medium and hi-density code of 3 of 9 bar code is shown below:

Low Density:

123456

Medium Density:

7

2 2 5 4 6 8

L A T C H

15b

2 3 4 4 0 1

S P A C E R

High Density

7

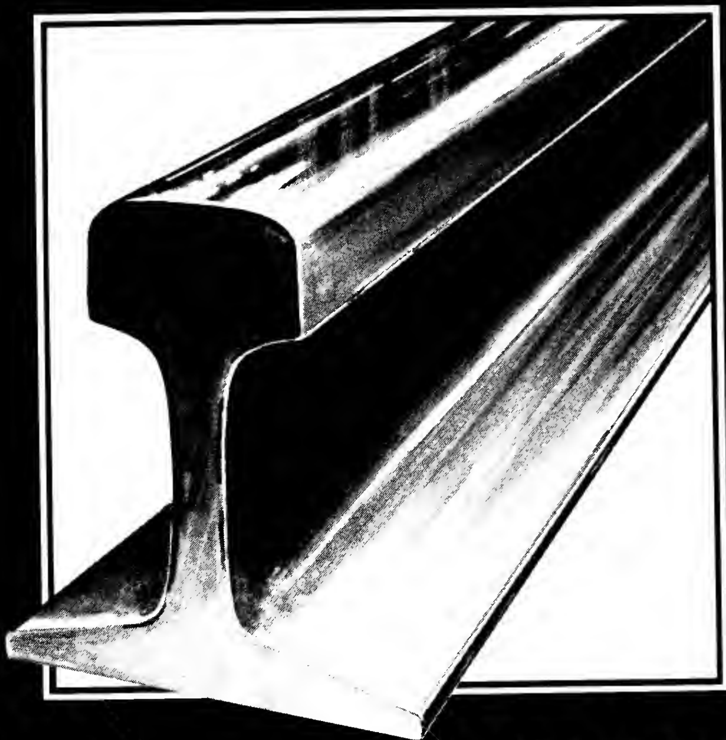
* 2 2 5 4 6 8 *

* B O S S *

15b

* 2 2 4 4 0 1 *

* S P A C E R *



5. Applications

There are currently three primary applications which are being pursued for bar code use with Roadway Work Equipment:

1. Repair parts, material acquisition
2. Repair parts, material inventory control system,
3. Collection of payroll data information for shop and field maintenance personnel.

Great efforts are currently being made to incorporate bar codes into the material acquisition process for work equipment field and shop maintenance personnel to ease the data entry process. It is obvious this type of process greatly reduces the potential for data entry errors.

6. MANUFACTURERS REQUIREMENTS FOR PARTS BOOKS

In order to achieve a level of uniformity throughout the railroad industry in the work equipment departments, it is required the following guidelines be adhered to:

6.1 The bar code comply with the Code 39 (3 of 9) format guidelines.

6.2 The parts books will contain bar codes, and human readable information for the manufacturers part number as well as the noun description for that particular part number.

6.3 The maximum readable characters for part numbers and noun description will be 16 characters. This does not include the start/stop (*) characters.

6.4 The "quite zone" preceding and following the start/stop character must be a minumum of 1/4 inch.

6.5 The bar codes should be 1/4" in height to again minimize space requirements, and in no instances should the bar codes be less than 1/4" high.

6.6 The bar code symbols shall use the hi-density format, 7-9 characters per inch, to make the best utilization of available space. This will also be required to minimize the expansion in overall size of existing non-bar coded parts books.

6.7 Common readily available standard hardware type items such as wrought iron washers, hex bolts and nuts, machine screws, cotter keys, hydraulic hoses, fittings, non-special adapters, etc. should not be coded. This will assist in conserving valuable space in the parts books. The parts books will contain human readable part numbers, as well as the corresponding detailed non-truncated noun description for all items of the parts books. This can be accomplished through use of a bill of material layout or similar format. It should be noted that non-bar coded items could still be ordered by manually entering the part number and non description via the handheld computer.

6.8 The human readable and bar coded part number and noun description for each item in the parts book should be laid out to be operator friendly; with each item being easily recognizable and set apart or divided from each other to minimize confusion and the possibility of the operator inadvertently ordering incorrect repair parts.

6.9 The high density bar codes must have a high"first read rate," meaning the percentage of correct readings that will be obtained in one pass of the scanner over the bar code symbol.

6.10 It is recommended the laser printer used to generate bar codes have the capability of producing print with a minimum of 300 dots per inch, and periodic monitoring of the toner adjustment has found to provide consistency in "First Read Rate" ability.

6.11 The manufacturers part number should be compressed so there are no spaces or dashes and numeric character strings. Examples:

Traditional Part #	*Revised Part Number Format*
A-7288-Y-01	A728Y01
0-1406079-0-02	01406079002

Providing these guidelines are followed, the sophisticated and time saving bar code parts ordering data collection system can be used to a great advantage.

EVALUATION OF ELECTRIC FLASH BUTT WELDS ABRIDGED AAR REPORT R-765

By: M. J. Wisnowski*

1.0 INTRODUCTION

Most railroads have acceptance criteria for electric flash butt rail welds. Those that do not, turn to the American Railway Engineering Association (A.R.E.A.). However, the A.R.E.A. Manual for Railway Engineering does not have criteria for the acceptance of rail welds and the only published criterion appears in references 1 and 2. Here it is stated that "for satisfactory service performance a minimum of 1.5 inches of deflection and 140,000 psi modulus of rupture are being used as a criterion for oxyacetylene and electric-flash pressure butt welds" in the slow bend test. These values were developed by the Pennsylvania Railroad at that time when carbon-steel rail with a hardness of about 248 BHN was the predominant rail in use. Since then, a number of alloy-steel and heat treated higher hardness rail have emerged. Moreover, the hardness of carbon steel rail has increased to about 300 BHN to improve wear resistance by increasing the manganese and chromium contents and, in some cases, residual element contents as well. Therefore, the criteria previously intended for welds made from carbon-steel rail may be out of date. Accordingly, acceptance criteria that can be used for welds made from rail of the different chemical compositions and heat treatments are needed.

The test program and its results described in this report are intended to develop data establishing acceptance criteria for rail welds. It was decided that the program would develop metallurgical property information and would establish structural strength as determined by slow bend testing. The initial effort was to be directed at electric-flash-butt (EFB) welded carbon-steel rails; EFB welded alloy-steel and heat-treated rails and possibly thermite-welded rails would be studied later.

2.0 PURPOSE OF EXPERIMENT

The primary purpose of this experiment was to determine the slow bend test properties and metallurgical characteristics of electric flash butt rail welds. These welds were made with carbon steel rail of three slightly different chemical compositions, two section sizes and by four different-type welding machines. A secondary purpose was to provide information from unwelded specimens.

3.0 DESIGN OF EXPERIMENT

The experiment was designed so that each different machine welded rails from the same populations. This was done so that the variability associated with each welder, composition, and section size could be assessed separately without confounding. To achieve this, one rail length of each section (115, 132RE) in each composition type was shipped to each of the four welding plants participating in the program.

Four 39 foot rail lengths from the same heat were selected from each of the following compositions types in the 115 and 132RE sections.

1. Carbon-steel rail with the carbon content on the low end of the allowable range.
2. Carbon-steel rail with the carbon content on the high end of the allowable range.
3. Carbon-steel with a manganese content of about 1.20 percent and a chromium content of about 0.20 percent. This is also referred to as medium hardness because its hardness is near 300 BHN.

These rails were produced by Bethlehem Steel, United States Steel, and Colorado Fuel and Iron. The rails from CF&I and U.S. Steel were ingot cast; those from Bethlehem were strand cast. The Bethlehem steel was electric arc furnace melted while that from CF&I and USS was melted in the basic oxygen furnace.

*Senior Test Engineer, Association of American Railroads, Chicago Technical Center

The welding machines were:

1. A-I welder, 25Hz A.C.
2. Schlatter Model GAS-80DC welder.
3. A-I welder, 60Hz A.C.
4. Chemetron Corporation welder, 10.6Hz A.C.

A short piece of rail was cut from each rail length to be used as a slow bend test reference specimen. The remaining lengths of rail were cut and welded to form the following composition combinations in triplicate:

1. Low carbon to low carbon.
2. High carbon to high carbon.
3. Medium hardness to medium hardness.
4. Low carbon to high carbon.
5. Low carbon to medium hardness.
6. High carbon to medium hardness.

Each weld plant used the welding practice most appropriate for each weld including hot sheering, grinding, and inspection. Weld charts were furnished to document the weld parameters for each weld.

One specimen of each triplicate set was designated for slow bend testing, one for metallurgical studies and one for use in other studies.

4.0 DESCRIPTION OF TESTS

All metallurgical and slow bend tests except for chemical analyses were conducted at the AAR Chicago Technical Center.

4.1 Metallurgical Tests

Standard chemical, metallurgical and mechanical tests were performed on the rails and weldments as indicated below. These tests included:

(a) Chemical analysis—Coupons were obtained from the midwidth of the head of the six reference specimens cut at each welding plant. These analyses were conducted at an independent laboratory and included the determination of C, Mn, P, S, Si, Ni, Cr, Mo and Cu.

(b) Macroscopic examination—To determine rail steel quality, transverse sections were taken from the end of each reference specimen. These sections were ground and then etched with a hot 50% aqueous solution of hydrochloric acid. In addition, to determine the shape and width of the heat affected zone, six-inch-long sections were cut from the welded rail specimens designated for metallurgical study in a longitudinal-direction and vertical plane through the center of the section. These sections were ground and then etched with a 10% nital solution.

(c) Microscopic examination—Metallographic specimens of the weld fusion line (weld interface) and adjoining rail metal were taken from the end of the base flange of each welded specimen. The plan examined was longitudinal in direction and horizontal midway through the thickness of the base flange. The specimens were etched in 4% nital.

(d) Tension Tests—To determine tensile properties, tensile specimens (.500 in. dia.; 2″ gage length) were taken longitudinally at the mid-width location in the head from the end of each reference rail. On the metallurgical test rail weldments, the tensiles were taken at the mid-width location in the head with the weld fusion line at the midlength of the gauge section. These tension tests were conducted in accordance with A.S.T.M. A370; the 0.2% offset yield strength, ultimate tensile strength, percent elongation in 2 inches and percent reduction of area were determined.

(e) Hardness Tests—A hardness survey was conducted on the macroetch specimen cut to study the shape and width of the heat affected zone. The hardness checks were taken longitudinally across the weld fusion line 1/8 in. below the running surface of the rail head. Hardness checks were taken with a Rockwell hardness tester using the R_c scale and the results were converted to BHN's.

4.2 Slow Bend Tests

Slow bend tests were conducted on both welded and unwelded specimens in the Tinius Olson one-million-pound-capacity press. Specimens were placed head up on a fixture with base supports 48 inches apart. This fixture was designed so that one support is stationary and the other swivels to eliminate the torsional loading that might result from uneven bearing between the rail base and the support. Loading was applied to the rail head at two loading points spaced 12 inches apart. For welded specimens, the weld was centered in the fixture. The tests were conducted until specimen fracture or 4 inches of deflection, whichever came first.

During testing, deflections and loads were recorded at regular intervals. The deflection was obtained with a displacement transducer positioned above the machine cross head. Load readings were obtained from a load cell. The output from these measuring devices was sent to a PC-based data acquisition system. The computer was programmed to calculate, store and print the load, deflection, modulus of rupture, energy to fracture and the modulus of rupture/energy to fracture ratio.

Modulus of rupture is defined by Laurson and Cox (3) as the maximum (elastic) stress calculated from the maximum bending moment M applied in the expression $S = Mc/I$[1]. Laurson and Cox point out that the modulus of rupture "cannot be considered as the unit stress in the outermost fibers of the beam at the moment of failure, because the equation $S = Mc/I$ holds true only when no unit fiber stress in the beam exceeds the proportional limit. When a beam is stressed to failure, the deformations of the fibers continue throughout the test to be proportional to their distance from the neutral axis... Since the proportional limit is exceeded in the outer fibers, however, Hooke's law no longer holds true for them, and the stresses in the fibers of the beam are not proportional to their distance from the neutral axis. The modulus of rupture is greater than the actual stress in the outer fibers and bears no fixed relation to that stress. The more brittle the material, the more closely the modulus of rupture approaches the true stress."

Energy to fracture is represented by the area under a load-deflection curve. The unit of energy to fracture is foot-pounds.

In this report modulus of rupture and energy to fracture are used in describing the slow bend test properties of specimens that fractured. Modulus at maximum load and energy at maximum load are used for specimens that did not fracture but can be applied as well to specimens that fractured.

5.0 RESULTS AND DISCUSSION

5.1 Chemical Composition

The most notable differences among the compositions were the higher manganese and chromium contents of the medium hard steel. The residual elements (Ni and Cu) were somewhat higher in those rails where steel making was accomplished in the electric arc furnace (Bethlehem Steel).

Most of the check analyses were consistent with the ladle analyses used to select the rails for the experiment. However, although the ladle carbon for the 115RE high carbon rail was reported to be 0.77 percent, the check analysis showed it to range from 0.74 to 0.75 percent. Although this rail probably

[1] S = elastic stress in psi
M = bending in lb-in
c = distance from center line of beam to fiber
I = moment of inertia in $inches^4$

should be classified as a mid range carbon rail on the basis of the check analysis, it will be referred to as a high carbon rail throughout this report.

5.2 Macroetch Quality

Macroetched transverse sections revealed the following imperfections:

(1) Internal

(a) Segregation streak in center of web (closed),
(b) Segregation streak or secondary pipe in center of web (open),
(c) Area of segregation (dark spot at bottom of web).

(2) Surface and subsurface

(a) Seams,
(b) Subsurface voids,
(c) Non-metallic stringer extending to the surface in the head-web fillet.

Seams and subsurface voids were noted in rails made by the ingot practice (see Table 1). Subsurface voids and seams located in the base might degrade the slow bend test properties as they would be located in an area where maximum tensile stresses are developed. Seams and subsurface voids were not found on rails made by the strand-cast practice, but these rails were noted to have long segregation streaks in the center of the web. However, because the location of this center segregation was near the neutral axis, it would be expected that this condition would have little effect on the slow bend test properties.

Table 1.

Ingot Cast	*Strand Cast*
115RE Low Carbon	115RE Medium Hardness
115RE High Carbon	132RE Low Carbon
132RE High Carbon	132RE Medium Hardness

5.3 Macrostructure of Welded Rail

The variation in the width of the heat-affected-zone boundaries from head to base indicates uneven current distribution through the rail section during welding. The difference in HAZ width between the different welders is related to energy input resulting from the use of different welding parameters. The widest HAZ for the six 115RE specimens produced by each welder were:

Welder 1	1-1/16″	to 1-7/32″
Welder 2	1-5/8″	to 2-7/16″
Welder 3	1-7/16″	to 1-17/32″
Welder 4	1-19/32″	to 2″

The widest HAZ was produced by Welder 2 (Schlatter/DC) followed by Welder 4 (Chemetron/10.6Hz), Welder 3 (AI/60Hz) and Welder 1 (AI/25Hz) which had the narrowest heat pattern. The widest HAZ for the six 132RE specimens produced by each welder were:

Welder 1	1-3/16″	to 1-9/32″
Welder 2	1-3/4″	to 2-1/32″
Welder 3	1-5/16″	to 1-13/32″
Welder 4	1-13/32″	to 2-3/16″

Here, the welds produced by Welders 4 and 2 had the widest HAZ followed by those produced by Welders 3 and 1. Thus for both rail sections, Welders 2 and 4 produced wider welds than Welders 1 and 3.

5.4 Hardness of Welded Rail

Hardness tests made longitudinally across welds revealed the hardness of the unaffected rail metal on either side of the joint, the hardness across the heat affected zone and the hardness at the weld fusion line. In all cases, the hardness increased in the rail metal near the weld interface and dropped in the thin band at the extremes of the heat-affected zone. The distance between the softer region of the heat affected zone and the weld fusion line varied among the different rail sections and welders. The maximum hardness increase and decrease was $+ 6.8\ R_C$ and $-7.1\ R_C$ for the 115RE specimens and $+ 7.2\ R_C$ and $- 6.6\ R_C$ for the 132RE specimens. It was noted that the max./min. range is generally greater for the MH (Medium Hard)-MH welds than for others.

5.5 Tension and Hardness Tests

5.5.1 Unwelded Rail

The behavior of the tensile properties with increased carbon content was irregular. Although the tensile strength increased consistently with carbon content, the yield strength increased consistently with carbon content, the yield strength behaved oppositely in the 132RE rail. The medium hardness rail was consistently harder and stronger with regard to yield and tensile strength than either of the other two composition types. But in the case of the 115RE rail, the ductility measures of the medium hard rail were somewhat inferior to those of the other two composition types. Perhaps this can be associated with residual alloy content and possible differences in cooling practice after rolling, characteristic of the different mills. The low carbon 132RE rail had slightly higher Ni and Cr contents and a substantially higher Cu content than the high carbon 132RE rail.

5.5.2 Welded Rail

Specimens with poor ductility fractured with some degree of incomplete fusion at the weld interface; the specimens exhibiting satisfactory ductilities fractured generally in the heat-affected zone.

Of the 115RE weld specimens, the HC (High Carbon)-HC, MH (Medium Hard)-MH, LC (Low Carbon)-MH specimens produced by Welder 1, and the LC-HC specimens produced by Welder 3 had the lowest elongation and reduction of area. Also the Welder 4 LC-HC specimen had an elongation in-line with the specimens of better ductility but the reduction of area was very low. For the 132RE weld specimens, the Welder 4 LC-LC, Welder 1 LC-MH and Welder 2 LC-MH specimens had the lowest elongations and reductions of area. There was a total of eight specimens with low elongation and reduction of area. Of these, four were produced by Welder 1, two by Welder 4, one by Welder 3 and one by Welder 2. When categorized by compositional differences, the low ductility specimens were 1 LC-LC, 1 HC-HC, 1 MH-MH, 2 LC-HC, 3 LC-MH and 0 HC-MH. Thus none of the welders were immune to producing low ductility welds.

5.6 Microstructure of Weld Specimens

The metallographic examination conducted on the weld specimens to determine what microstructures were present showed that no martensite or bainite was present in any of the rail weldments.

5.7 Slow Bend Properties

5.7.1 Unwelded Rail

All but two of the 115 and 132RE specimens did not break at deflections of up to 4 inches. The two that fractured were 115RE LC and HC. Metallographic examination of the fracture initiation sites failed to reveal the cause of premature failure. The average results (including and excluding data for rails that fractured) are listed in Exhibit 1. The differences in structural strength between the 115RE and 132RE rails is apparent. Further, the results for 132RE HC rail are unexpectedly lower than the results for the 132RE LC rail. A Student's T test of the data showed that the difference in properties was statistically insignificant.

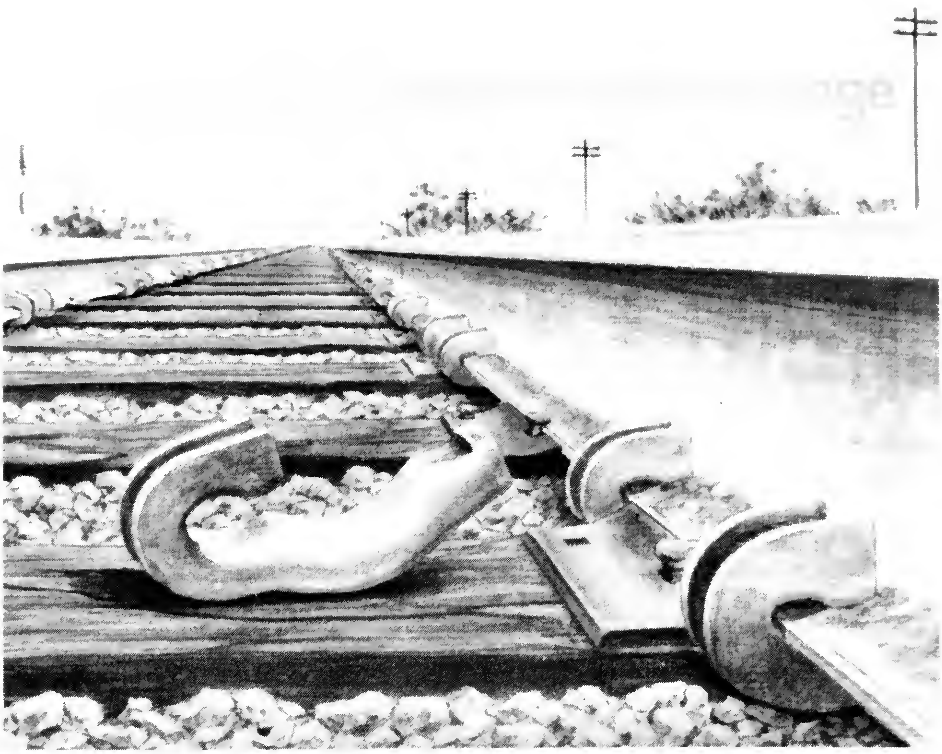


Exhibit 1.
AVERAGE SLOW BEND PROPERTIES OF UNWELDED REFERENCE RAILS

115RE Rail

Composition and Casting Practice	Maximum Load (lbs)	Maximum Deflec- tion (in)	Maximum Energy (ft-lbs)	Modulus at Max Load (p.s.i.)	Energy/ Modulus Ratio
Low Carbon (Ingot)	364,000	4.01	99,200	148,900	0.667
High Carbon (Ingot)					
Fracture Excluded	382,900	4.01	103,400	156,600	0.660
Fracture Included	360,000	3.34	82,900	147,300	0.540
Medium Hardness (Strand)					
Fracture Excluded	441,300	4.02	117,800	180,500	0.653
Fracture Included	412,100	3.30	93,300	168,600	0.526

132RE Rail

Composition and Casting Practice	Maximum Load (lbs)	Maximum Deflec- tion (in)	Maximum Energy (ft-lbs)	Modulus at Max Load (p.s.i.)	Energy/ Modulus Ratio
Low Carbon (Strand)	467,500	4.01	127,200	152,500	0.834
High Carbon (Ingot)	460,700	4.02	120,700	150,200	0.804
Medium Hardness (Strand)	497,900	4.01	133,600	162,300	0.822


In products and in service, UNIT is
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power. In fact, our spring anchor
100% at 10,000 pounds, and the
by 60% at 8,000 pounds. And our
so exacting, only a quarter of one
anchors are returned.
We provide complete technical
your rail gangs, with thousands
field—more than any other anchor
Our record for on-time deliveries is
well, with 95% of our anchor
on-time by our customers' requested
track delivery and service
schedule.
Holding power.
On-time delivery. In

Exhibit 2.
SUMMARY OF SLOW BEND PROPERTIES FOR WELDED RAIL WITH SAME COMPOSITIONS

Compositions		Maximum Load (lbs)	Maximum Deflection (in)	Maximum Energy (ft-lbs)	Modulus at Max Load (p.s.i.)	Energy/ Modulus Ratio
			115RE			
LC to LC						
Range	min	341,800	2.32	49,300	139,800	0.350
	max	372,600	2.86	66,400	152,400	0.452
Average		353,400	2.59	57,700	144,600	0.398
HC to HC						
Range	min	304,200	1.26	21,900	124,400	0.176
	max	374,800	2.54	59,000	153,300	0.385
Average		342,300	2.00	42,200	140,000	0.294
MH to MH						
Range	min	400,000	2.03	48,100	163,600	0.294
	max	412,300	2.27	56,800	168,700	0.338
Average		406,800	2.15	52,800	166,400	0.317
			132RE			
LC to LC						
Range	min	417,200	1.89	48,400	136,000	0.356
	max	467,100	2.77	81,500	152,300	0.535
Average		440,700	2.31	64,100	143,700	0.443
HC to HC						
Range	min	380,000	1.77	39,700	123,900	0.321
	max	475,500	4.02*	126,800	155,100	0.818
Average		432,700	3.14	90,900	141,100	0.628
MH to MH						
Range	min	430,200	1.57	40,600	140,300	0.285
	max	477,300	4.00*	132,800	155,600	0.861
Average		454,100	2.51	75,400	148,100	0.501

* Specimen did not break.

5.7.2 Welded Rail

The ranges and average slow bend properties are tabulated in Exhibits 2 (same composition) and 3 (different composition).

The results show an unexpectedly wide variability within each group. For example, the averages, maximums, and minimums of the modulus at maximum load did not show a consistent relationship with chemical composition. Moreover, the maximum/minimum of energy varied by up to 3:1 or more for like rail welds andup to 6:1 or more for mixed composition welds.

Exhibit 3.
SUMMARY OF SLOW BEND PROPERTIES FOR WELDED RAIL WITH DIFFERENT COMPOSITIONS

Compositions		Maximum Load (lbs)	Maximum Deflection (in)	Maximum Energy (ft-lbs)	Modulus at Max Load (p.s.i.)	Energy/ Modulus Ratio
115RE						
LC to HC						
Range	min	286,400	1.13	18,300	117,200	0.156
	max	383,000	4.00*	102,400	156,700	0.653
Average		348,300	2.78	65,300	142,500	0.440
LC to MH						
Range	min	302,000	1.11	19,300	123,500	0.156
	max	385,900	3.99	105,200	157,900	0.669
Average		354,200	2.51	60,700	144,900	0.400
HC to MH						
Range	min	295,400	0.92	13,500	120,800	0.112
	max	437,600	3.72	103,700	179,000	0.579
Average		361,500	2.27	55,300	147,900	0.342
132RE						
LC to HC						
Range	min	419,300	2.07	52,300	136,700	0.382
	max	467,000	3.20	96,400	152,300	0.644
Average		437,200	2.63	73,800	142,600	0.513
LC to MH						
Range	min	390,900	1.34	31,000	127,500	0.243
	max	490,800	4.04*	135,300	162,600	0.845
Average		456,900	2.87	89,800	149,000	0.579
HC to MH						
Range	min	409,300	1.74	41,300	133,500	0.310
	max	482,900	2.76	83,000	157,500	0.527
Average		455,400	2.36	66,400	148,500	0.443

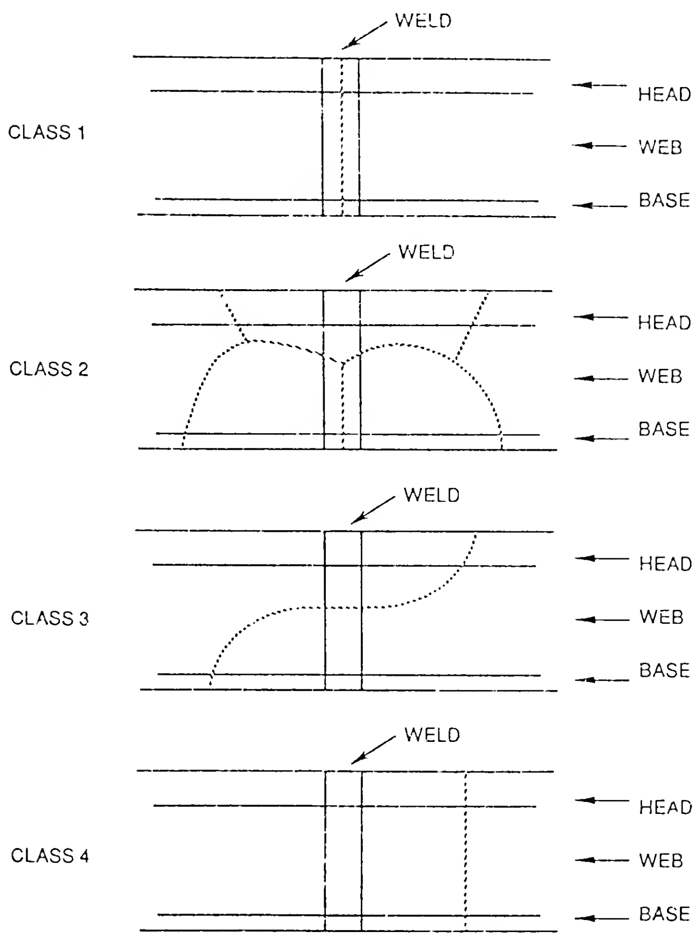
* Specimen did not break.

5.7.3 Fracture Path

There were four basic classes of fracture path: (1) vertically through entire weld interface (2) vertically through weld interface in the lower half of specimen and then longitudinally through the web (3) longitudinally across weld in the web and (4) through rail only, away from the weld. These are illustrated in Exhibit 4. In addition to these four classes of fracture, some weld specimens did not fail. The number of weld specimens that fell into each of categories is as follows:

Category	115RE	132RE	Total
Class 1	6	6	12
Class 2	8	13	21
Class 3	8	1	9
Class 4	1	0	1
Did not fail	1	4	5

Exhibit 4.
CLASSES OF RAIL WELD FRACTURES DEVELOPED FROM SLOW BEND TESTING



5.7.4 Visual Examination of Fracture Surfaces

Visual examination of the fracture surfaces showed the presence of defects that can be grouped into four categories as follows:

(1) Steel Quality
  (a) Heavy segregation in center of web
  (b) Vertical separation in center of web
  (c) Stress concentrations from stamped characters

(2) Welding practice
  (a) Entrapments at weld interface
  (b) Electrode burns at bottom of base and on head of rail.

(3) Inherent characteristic of weld process
  (a) Incomplete fusion at weld interface

(4) Workmanship
  (a) Longitudinal gouges on bottom of base and in web/base fillet from shearing
  (b) Heavy grinding marks
  (c) Nicks at end of base flange

Of the defects, the most common were entrapments and incomplete fusion at the weld interface.

Defects located below the neutral axis can have especial effects on the slow bend test results. Defects located above the neutral axis, such as in electrode burns noted, had little effect on the slow bend test properties, i.e., none of *these* welds exhibited particularly low bend properties.

5.8 Weld Charts

In order to attempt a correlation between welding parameters and the characteristics of the weldments, the following parameters were evaluated from weld charts developed, however, no correlation was found to exist.

Welding Parameters

Burnoff duration
Number of preheats
Average preheat time
Average interim sputter time
Total preheat time
Final flash time
Total welding time
Amount of upset and
Upset time

It was noted that continuity of current flow during final flash, especially the later part of the final flash, is essential to avoid excessive cratering of the weld interface.

5.8.1 Welds Subjected to Slow Bend Test

Welder 4 had the greatest consistency in total welding time (6-8 seconds variation) while Welder 3 had the greatest variability (33 seconds for 115RE rail). Final flash time varied considerably from welder to welder. The average time was near 30 seconds but was as little as 11.3 seconds with Welder 1 and as large as 75 seconds on Welder 3*. The upsets achieved with Welders 1, 2, and 4 fell within the range of 0.59″ to 1.00″, Welder 3 tended to produce a somewhat narrower range of upsets at the lower end of the scale.

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*Both Welders 1 and 3 were AI welders but the operating frequencies were different being 25Hz for Welder 1 and 60Hz for Welder 3.

With the cross sectional areas of the 115RE and 132RE sections being 11.25 sq. in.and 12.95 sq. in., respectively, the rail with the larger cross sectional area might be expected to take longer to weld, providing that the welding currents used are the same. However, this was not always the case. The total welding time of some 115RE specimens was longer than that for the chemically equivalent 132RE specimens. The 115RE welds with a longer welding time are Welder 1's HC-HC and LC-HC, Welder 3's HC-HC, MH-MH, LC-HC and HC-MH and all but the LC-LC specimen from Welder 4.

5.8.2 Metallurgical Test Weldments

As in the case of the slow bend weldments, Welder 4 had the greatest total welding time, but only for the 115RE rail. Welder 2 was more consistent in total welding time for 132RE rail. Again final flash time varied considerably with Welder 1 having much shorter final flash times than did Welder 3. Upsets varied from 0.6″ to 1.08″. Welder 2 produced the widest range of upset on 115RE rail (0.36″) and Welder 4 had the greatest range of upset (0.30″) on the 132RE rail.

The 115RE LC-HC specimen produced by Welders 2, 3 and 4 had a longer total welding time than the 132RE specimen with comparable chemical composition. All 115RE specimens produced by the Welder 3 and Welder 4 had longer total welding times than their chemically equivalent 132RE specimens.

6.0 ANALYSIS OF RESULTS

The large variation of slow bend characteristics causes concern about the causes thereof. The analysis which follows will seek to define the cause/effect relationships at least to the extent that they can be revealed in the data which has been gathered.

A high energy to fracture ratio could be obtained as a result of a large deflection even if the load was low. Similarly, a high modulus of rupture could be obtained with a very low energy to fracture because modulus of rupture is based on maximum load without consideration of deflection. The energy/modulus ratio is presented because it provides a link between the strength parameter, modulus of rupture, and the toughness parameter, energy to fracture (or energy to maximum load for specimens not fracturing). Because energy to fracture is a toughness term and contains both load and deflection contributions, it is used in the following analyses as a suitable measure by which to rank the different weldments.

6.1 Effect of Welder

To determine whether the four welders produced discernibly different welds, the slow bend tests were tabulated in order of increasing energy to fracture (maximum load) values. Results show that the welders appear rather randomly distributed from the lowest to the highest energies to fracture.

6.2 Effect of Rail Metallurgy

The different compositions were randomly distributed through the tables from lowest to the highest energy at maximum load. For instance, LC-MH, HC-MH, and LC-HC welds are found at both the top and bottom of the energy range in the 115RE rail. With the 115RE there was an interaction, clustering of like composition welds at the center of the table, but that pattern was not repeated for the 132RE rail.

6.3 Effect of Weld Imperfections

To determine whether correlations among the imperfections and slow bend test properties existed, the slow bend data were ranked in order of increasing energy at maximum load along with a listing of the types of base defects observed on each specimen and the fracture appearance classification. The most prevalent imperfections observed were entrapments and incomplete fusion. Specimens exhibiting entrapments and incomplete fusion were found over the entire range of energy at maximum load in both 115RE and 132RE weldments. The greatest number of these specimens was found below 48,100 ft-lbs for the 115RE specimens. This greater number is not as apparent in 132RE specimens because 15 of the 20 fractured specimens exhibited entrapment and, of the remaining five, three exhibited incomplete fusion. From this it would be reasonable to say that no correlation between energy at maximum load and imperfections was evident.

6.4 Effect of Fracture Path

The four classes of fractures are (1) break entirely through weld interface (2) break through weld interface only in lower half of specimen (3) break longitudinally across weld upset and (4) break through rail away from the weld. Sketches of these fractures have been shown in Exhibit 4. Exhibit 5 shows the number of welds in each of three energy groups. These energy groups were established by (1) fractile thirds of population and (2) thirds of the energy range. A number of specimens with class 1 fractures are among the specimens having the lowest energy to fracture values but can also be found among the highest as well. Similarly, a number of 115RE specimens with a class 3 fracture appearance are among the specimens having the highest energy to fracture values reported. The greatest density of fractures with the class 2 appearance fall within the midrange of the energy to fracture values reported.

Class 3 fractures go through the rail across the weld joint and are generally, but not always, associated with higher energy to rupture level. The lowest slow bend test values reported for class 3 fractures were for the specimen ranked 10, made by Welder 1 from rails of LC-LC composition. The modulus of rupture for this weld is very close to the 140,000 p.s.i. modulus of rupture used as a guide in the past. Welder 4 is notable by its absence in having class 3 weld fractures. However, Welder 4 did produce 2 nonfailure welds while each of the other welders produced only one each.

6.5 Effect of HAZ Width

In assessing whether there is a correlation between the slow bend characteristics and the width of the heat affected zone, the reader must remember that the slow bend test properties were obtained from one set of weld specimens whereas the width of the heat affected zone was obtained from a second set of specimens welded at the same time in a nominally 'identical' manner.

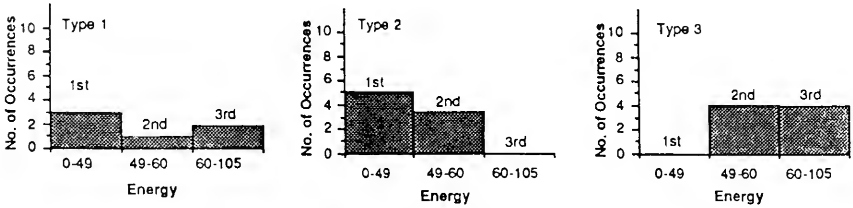
In a given production welding run with the same nominal welding parameters, the heat affected zone (H.A.Z.) widths should be relatively consistent throughout the run. Although the welding parameters were supposed to be the same, variations in the width of the heat affected zone were noted in specimens produced by the same welder. Exhibit 6 tabulates the range of modulii and energies at maximum load values reported.

If one makes the assumption that the range of HAZ widths observed on the welds made for metallurgical characterization and mechanical test specimens would be the same as that for the slow bend test weldments, then the ranges of the characteristics can be plotted against the ranges of the HAZ variation in the fashion shown in Exhibit 7. The plots show that there does not appear to be a systematic trend of HAZ width to influence the slow bend characteristics. Indeed wide welds appear to perform (in slow bending) as well as narrow welds.

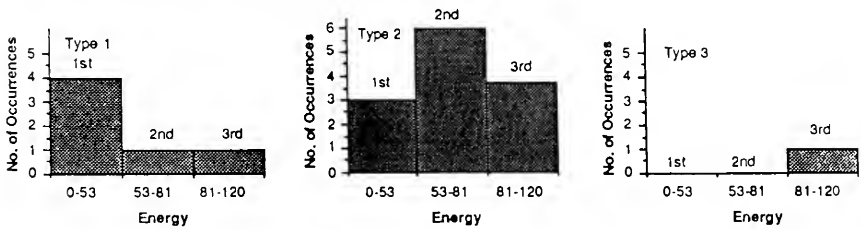
6.6 Effect of Weld Parameters

A correlation between the energy to fracture and the weld parameters in the weld cycle was sought. An appropriate way to do this would be to determine the amount of electrical energy consumed in each phase of the weld cycle and determine whether energy to fracture varied systematically with electrical energy consumed. But calibration information, which was needed to establish primary current was not available from all welders and so the electrical energy used to make these welds could not be calculated. However, reliable information was received for Welder 1 which enabled calculation of the electrical energy used in the fabrication of the welds made at that plant. A close correlation exists between total welding time and electrical energy. Therefore total welding time was believed to be a suitable basis for comparison on any single welder although comparisons from one welder to another would be uncertain.

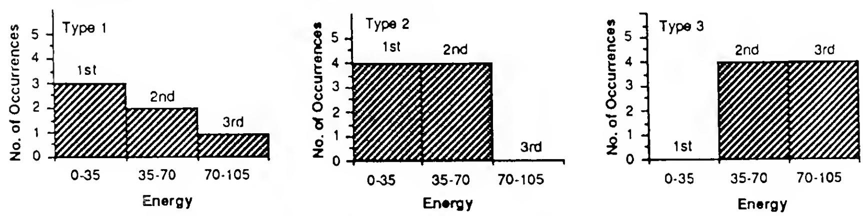
GROUPED BY FRACTILE THIRDS OF POPULATION FOR 115RE



GROUPED BY FRACTILE THIRDS OF POPULATION FOR 132RE



GROUPED BY THIRDS OF ENERGY RANGE FOR 115RE



GROUPED BY THIRDS OF ENERGY RANGE FOR 132RE

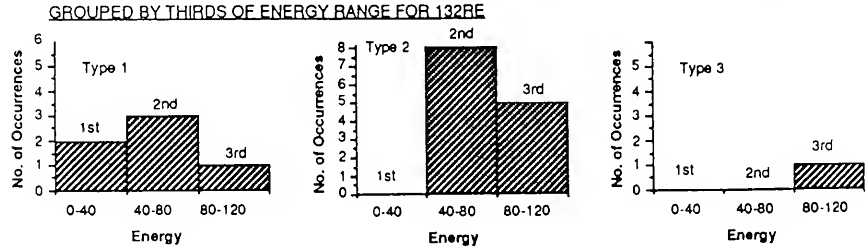


Exhibit 5.
DISTRIBUTION OF CLASSIFICATIONS OF FRACTURE BY FRACTILE THIRDS OF THE POPULATION AND BY THIRDS OF THE ENERGY RANGE.

Exhibit 6.
RANGES OF MODULII AT MAXIMUM LOAD AND ENERGIES AT MAXIMUM LOAD

115RE SPECIMENS

WELDER	MODULUS AT MAXIMUM LOAD RANGE - PSI	AVERAGE	RANGE OF ENERGY AT MAXIMUM LOAD - FT.LBS	AVERAGE
1	120,845 - 165,395	142,670	13,547 - 105,155	53,349
2	140,973 - 179,018	154,991	32,175 - 103,731	60,471
3	117,164 - 167,932	150,430	18,272 - 79,698	54,226
4	123,545 - 168,668	141,804	19,324 - 86,031	47,309

132RE SPECIMENS

WELDER	MODULUS AT MAXIMUM LOAD RANGE - PSI	AVERAGE	RANGE OF ENERGY AT MAXIMUM LOAD - FT.LBS	AVERAGE
1	123,913 - 160,043	143,734	39,718 - 135,307	73,357
2	127,467 - 155,641	146,701	30,979 - 126,778	76,238
3	133,467 - 154,174	143,554	41,321 - 132,782	75,734
4	136,728 - 162,554	147,962	40,586 - 134,861	47,309

A significant scatter of the data and the general absence of a well defined trend of behavior suggests that no correlation exists between the energy to fracture and welding times, and by inference then to the electrical energy input at any given welder. Likewise, no readily discernible correlation between the composition pairing and the energy to fracture could be detected. Plots show that some welders exhibited much more scatter of welding times than did others. While Welder 4 was very consistent in total welding time (115RE rail). And Welders 2 & 4 were very consistent in total preheat time (115RE rail), there existed very wide scatter in slow bend energy to fracture.

7.0 DISCUSSION

This investigation was conducted to develop the data that could be considered for use in establishing acceptance criteria for rail welds. An analysis of the test data has shown that a correlation between the slow bend characteristics and the welder and the rail metallurgical characteristics was not evident.

The observation that slow bend test properties were associated with the different fracture shapes might be useful in establishing acceptable slow bend test properties. Specimens with fractures going longitudinally across the weld upset (class 3) were among the specimens having the highest energy to fracture values. Specimens that broke entirely through the weld interface (class 1) were found among the specimens having the lowest energy to fracture values. The lowest value reported for these having a class 3 fracture was from a 115RE weld specimen made from a low carbon to low carbon compositional

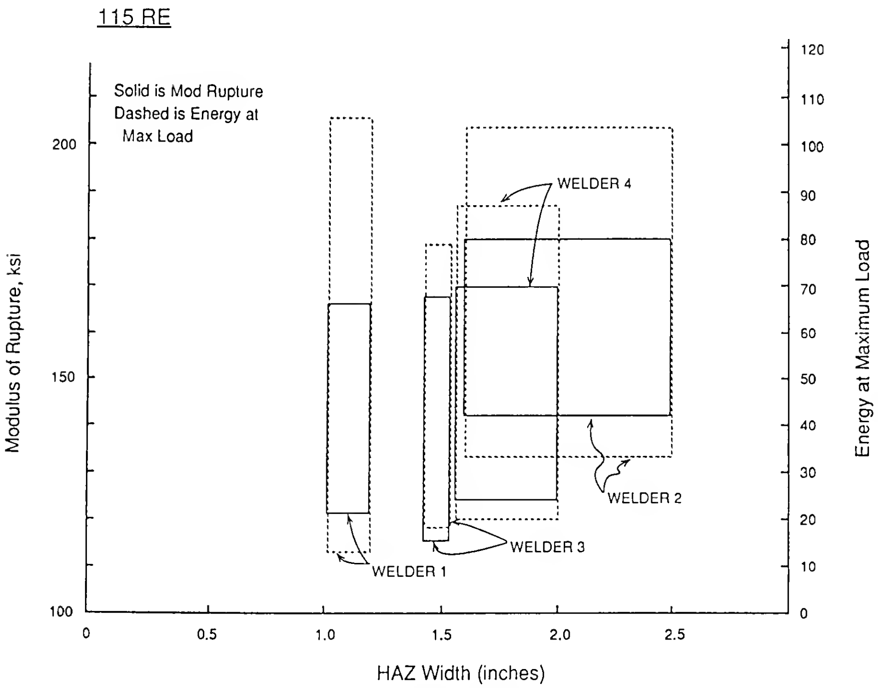


Exhibit 7.
SLOW BEND CHARACTERISTICS AS A FUNCTION OF HAZ WIDTH.

combination. The slow bend test properties of this specimen were:

Maximum load:	341,800 lbs.
Maximum deflection:	2.34 in.
Modulus of rupture:	139,127 p.s.i.
Energy to fracture:	49,380 ft. lbs.
Energy/modulus ratio:	0.353

Because this weld broke through rail metal across the weld rather than along the weld fusion line, the slow bend test properties were not influenced by the entrapments at the weld interface. This observation suggests that an acceptance criteria which recognizes crack path trajectory might be helpful.

8.0 CONCLUSIONS

This investigation disclosed the following information.

(1) Weld quality, as judged by slow bend energy to fracture or modulus of rupture values, appeared to be independent of welder type.

(2) Weld quality also appeared to be independent of rail composition combination.

(3) Weld quality (slow bend test performance) also was independent of imperfections observed on the fracture surfaces.

(4) The fracture appearance classifications for the slow bend tests generally did not correlate with slow bend test properties. However, for 115RE specimens, the majority of the specimens with class 3 fractures also had good bend properties.

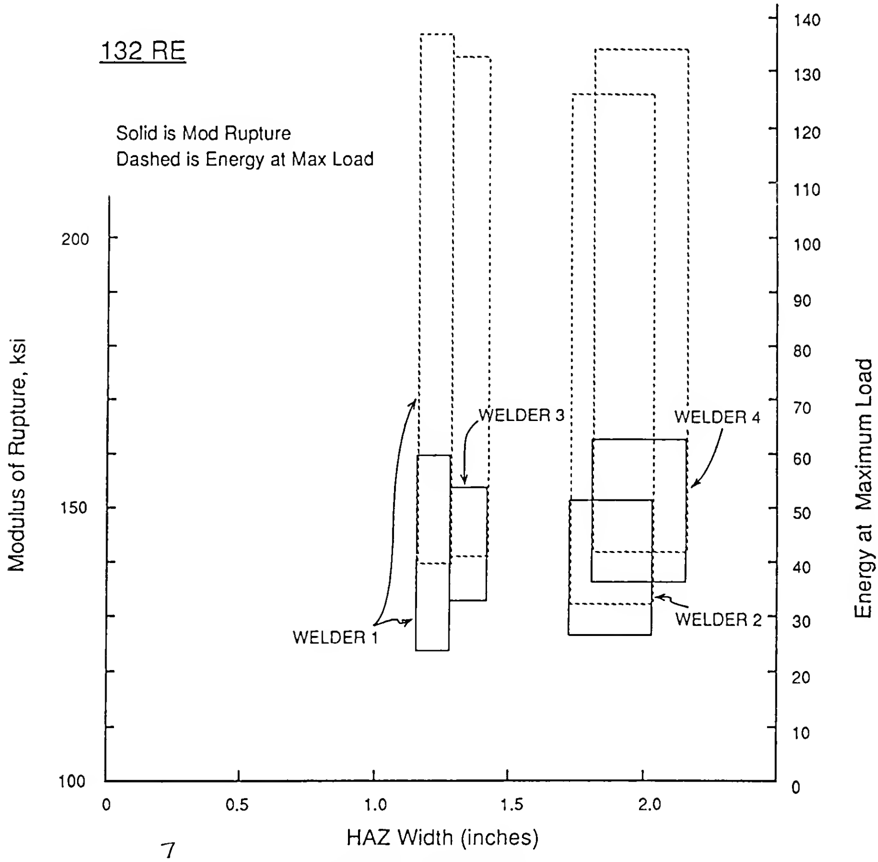


Exhibit 7. (Continued)
SLOW BEND CHARACTERISTICS AS A FUNCTION OF HAZ WIDTH.

(5) There does not appear to be a systematic relation of width of heat affected zone and slow bend characteristics.

(6) The significant scatter of the data and the general absence of a well defined trend of behavior suggests that no correlation exists between the slow-bend energy to fracture and welding times, and by inference then to the electrical energy input at any given welder.

(7) Overall, the results have shown that correlations among slow bend characteristics, welder, and rail metallurgical characteristics were not evident.

9.0 REFERENCES

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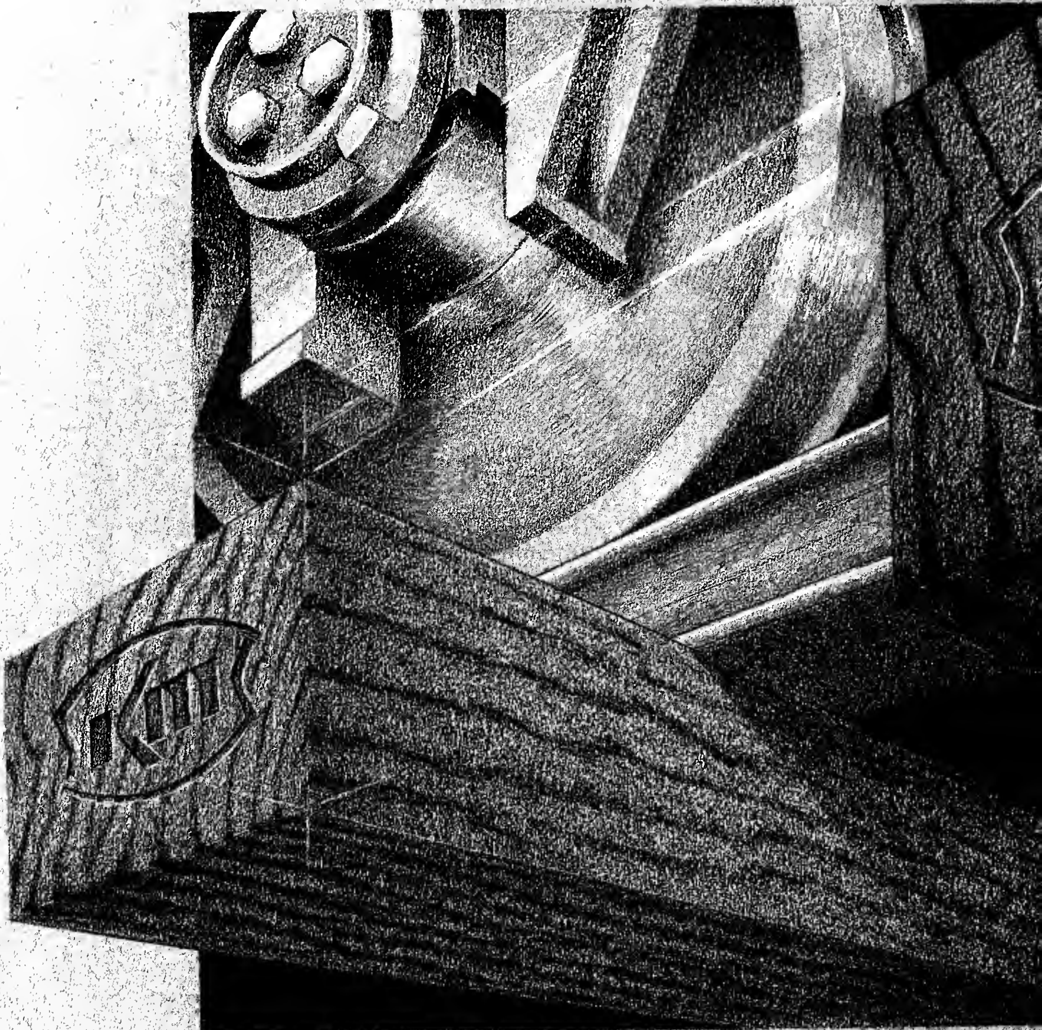

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Present City of Topolobampo.

Chihuahua Pacific Line to Topolobampo

A new enlarged port facility is under construction in the city of Topolobampo, located in the Mexican state of Sinaloa. Its port facility fits in with plans to improve tunnel clearances to allow double stack services on the Chihuahua Pacific line of the National Railways of Mexico. The Chihuahua Pacific line is on the shortest rail route to a Pacific Ocean Port from much of the central and eastern U.S., as well as the Toronto, Canada area.

The area colored yellow shows where Topolobampo is the closest port on the Pacific by rail.

Spectacular railroad construction amid outstanding tropical mountain scenery is common on the Chihuahua Pacific line as in this scene of Temoris.

Because of the East-West orientation of U.S. & Canada, Americans & Canadians do not ordinarily consider the Mexican Pacific coast for rail transportation. A glance at a world map, however, quickly shows the advantages of this coast. The sketch on the previous page shows in yellow those areas of the U.S. and Canada that are closer by rail to Topolobampo than any Pacific Port.

The Chihuahua Pacific line which runs from Presidio, Texas to Topolobampo through the Mexican state of Chihuahua and its capital city, Chihuahua, was completed in 1961 by Mexico after having been started by U.S. interests in 1902. The railway project was originally known as the Kansas City, Mexico and Orient. A private company completed the construction of three different sections, each of which were separated because the connecting lines had not been constructed. Operations took place from Alpine, a town in western Texas, to Wichita, Kansas, and two locations in Mexico: one in the vicinity of the city of Chihuahua, and the other from the Pacific at Topolobampo across the coastal plains to the western edge of the Sierra Madres. Under Santa Fe ownership in the late 1920's the section from Alpine, Texas to the Mexican border was completed, finishing the line from Wichita to the Pacific at Topolobampo except for a 170 mile gap across the Sierra Madres. It was considered impossible by most engineers to build on without cog or cable assistance. Especially daunting was the nearly 8000-ft. drop through terrain interspersed with canyons with near-vertical cliffs over 3000 ft. high. The challenge was later taken on in the 1940's by a Mexican Civil Engineer, Francisco Tongo, who through a series of bold tunnels and alignment innovations designed a route with a maximum 2.5% grade. Construction on the line, owned by the Mexican Government since 1940, was resumed in the 1950's and finally completed in 1961. As shown on the front and back covers, as well as this page and the foldout on the right, the Chihuahua Pacific has some of the most spectacular railway engineering achievements in North America.

Panorama of 3 levels of track with horsehoe curve at Temoris on the Chihuahua Pacific Line.

SEE FOLDOUT

Panorama of mountainous peninsula protecting harbor at Topolobampo.

The most difficult [illegible] engineer [illegible] was at a [illegible] known as Temoris. Here the railroad [illegible] a stream in the canyon [illegible] a waterfall. T[illegible] descend the height of the waterfall, the line pierces the [illegible] of the canyon [illegible] upstream from the waterfall and then emerges out of the side of the canyon [illegible] downstream onto [illegible]. At the [illegible] there is a startling view of the great depth of the canyon of the R[illegible] Septentrion River below. The track continues in the downstream direction on a narrow shelf and enters a tunnel which completely reverses [illegible]

[illegible]

[illegible] over the Chihuahua Pacific [illegible] from Chihuahua, as well as other stretches of track from Ciudad Juarez (across from El Paso, Texas) to Mazatlan.

The potential of Topolobampo is quite [illegible], especially if the U.S., Canada and Mexico [illegible] on a North American free trade zone. The photos on the left show AREA Board of Direction member Gonzalo Rivera of the National Railways of Mexico making an on-site check of progress on the new port facilities, which will include a new line for rail access. Topolobampo is a natural Harbor protected by a mountainous peninsula to the southeast, as shown in the fold out panorama above. While presently a small coastal town, we could be looking at a future San Francisco of the south.

AREA Board of Direction member from National Railways of Mexico Gonzalo Rivera confers on port construction in progress.

Enormous new cut provides access for road and rail to new port area.

truss bridge about 300 feet high and nearly 1000 feet long where the line crosses the Rio Chinipas near the mouth of the canyon of the Rio Septentrion. The line then passes through a 6035 foot tunnel, the longest railroad tunnel in Latin America. With the kind support of Mr. Jose Humberto Musconi, Director General of the National Railways of Mexico, the AREA 1992 fall conference is planned for November 11-14 in Chihuahua. Plans for the conference include an inspection by special train (this article is continued on lower center of previous page)

Present Port of Topolobampo.

PRESENTATIONS TO THE
A.R.E.A. FALL TECHNICAL CONFERENCE
NOVEMBER 19, 1991
NEW YORK CITY, NEW YORK

EMPIRE CONNECTION ON AMTRAK

By: R. D. Johnson*

On April 7, 1991 all New York state service trains were routed from Grand Central Terminal to New York's Penn Station. The opening of the Empire Connection has been known during the construction phase as the "West Side Connection." The project consisted of construction and rehabilitation of the rail line along the west side of Manhattan from Penn Station to Spuyten Duyvil Bridge and the connection to the Metro North Commuter Railroad.

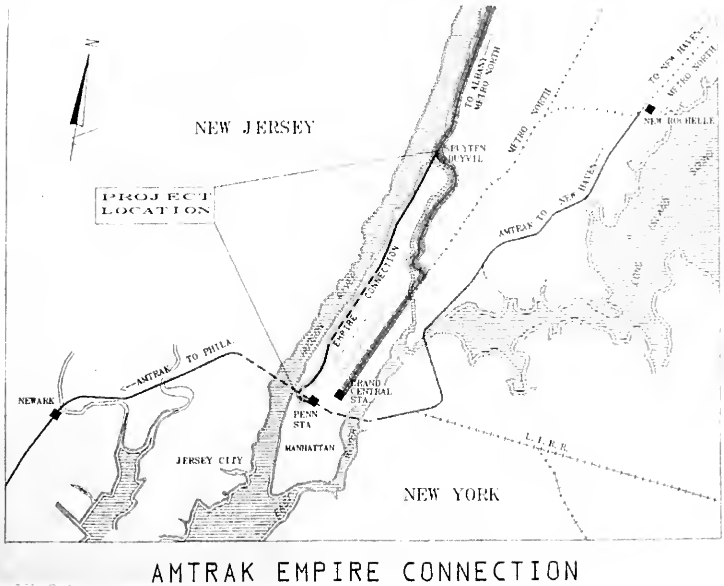


Photo 1. Former Grand Central and new Penn Station Empire connections.

A diagram (Photo 1) shows the previous service from Grand Central Station up the Metro North Commuter Railroad to the Spuyten Duyvil Bridge and then northwards towards Albany. The line directly east of the Hudson River shows the new alignment of the Empire Connection from New York Penn Station to the Spuyten Duyvil Bridge where the route connects with the Metro North Commuter Railroad. This ten mile connection has eliminated the necessity for passengers to transfer in New York City from one station to another and has consolidated all Amtrak services at New York Penn Station. Amtrak had provided bus service between stations. However, the buses had to contend with traffic congestion which was usually not cooperative. A second transfer alternative was by taxi. With the density of requirement, this alternative suffered from supply and demand effects. City traffic conditions impacted this alternative as well. The third alternative was by subway. To the uninitiated, and non-New Yorker, this was certainly not user friendly. Added to this were the conditions the passenger encountered and the difficulty baggage presented in the normal crowded conditions.

Resulting from the new Penn Station connection schedules for the Empire Service trains have been reduced between 5 to 13 minutes. An operating cost decrease of $2.2 million per year has been realized. Additional passenger ridership of 117,000 per year will be generated resulting in 23 million more passenger miles per year and produce additional revenue of $9.3 million. Amtrak purchased the property for $4 million and the construction costs were shared 40% by New York state and 60% by Amtrak up to a total of $96 million. This route is a double track railroad for approximately 9 miles with 1 mile of single track. Presently, 158 trains a week traverse this route.

*Chief Engineer, Northeast Corridor Improvement Project and Special Projects, Amtrak

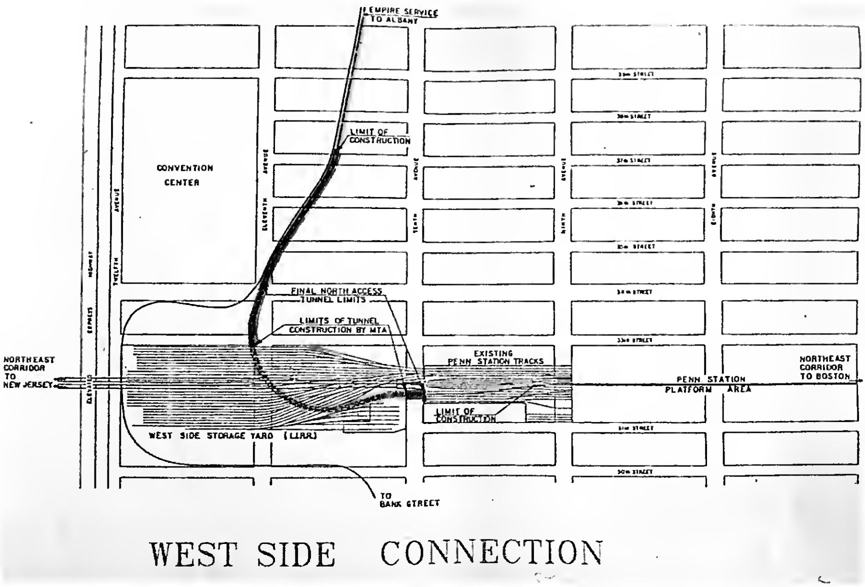


Photo 2. New alignment constructed in vicinity of Penn Station.

To orientate yourself, Penn Station is shown in the center of Photo 2 and the initial portion of the alignment shown indicates the first construction project which went under 10th avenue. The next portion under the yard is "the box" which was built in the early 1980's before the Long Island Railroad built their storage yard above. Funding was provided by the Northeast Corridor Improvement Project. The line portion from the storage yard to near 37th Street is the North Access Tunnel which brings the railroad up to an at-grade situation. The final line portion going off the top of Photo 2 shows the continued construction of the track facilities.

The Lerner Building adjacent to 10th Avenue is a multi-storied building containing delicate instrumentation. At this site tracks have been constructed below not only the street, but also the building structure. The original plans identified that the support for the Lerner Building was tied directly into a rock face beneath the building and that the concrete supports were affixed solidly to the rock foundation. Consequently, plans were developed accordingly. As the project began when the first breakthrough was made of the concrete facing, it was discovered that there was a void and that the concrete was not tied into the rock face support. This necessitated all work to cease and required that a complete redesign be developed to support the Lerner Building and the adjacent highway structure. A needle beam (Photo 3) had to be provided to support the building over the tunnel location to ensure that no settlement occurred. During the transfer of the loading of the structure to temporary support and then to final support, considerable care was taken to guarantee that no settlement resulted. Precise instrumentation was required to monitor and verify all load transfer activities. The needle beam location was directly beneath the face of the Lerner Building and was critical to its continued foundation support.

After the installation of the needle beam and the load transfer, tunnel opening through the facing concrete revealed not only a great void but also a location for the dumping of unused materials during the previous construction support contract. Rock excavation continued and entrance into the box tunnel was accomplished. Several tracks in "A" yard in Penn Station were shortened along with the electrification to allow construction work to progress. Supporting beams and concrete sections were

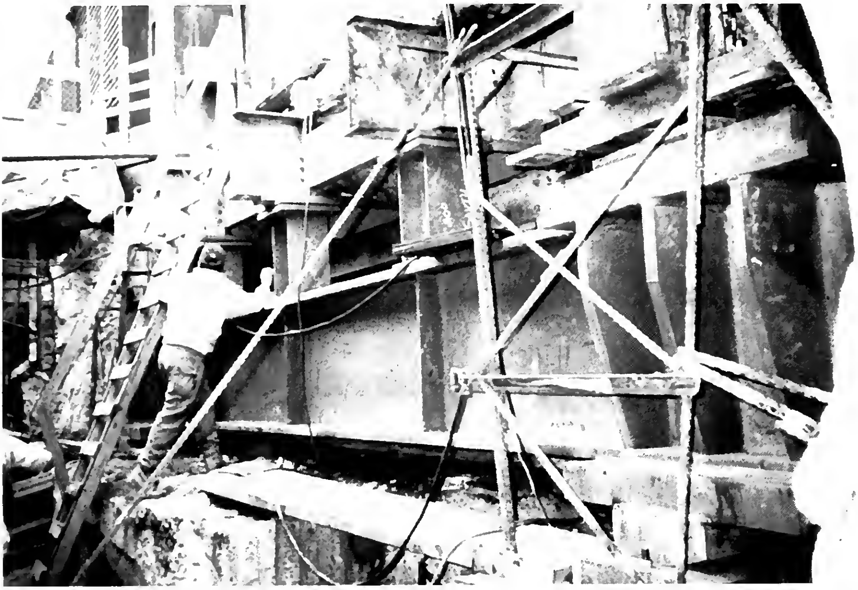


Photo 3. Needle beam installation for Lerner Building.

erected which allowed continued highway usage of 10th Avenue during construction. This method allowed the 10th Avenue construction to be done in a cut and cover type operation. New support columns were erected to support the needle beam. These were then integrated into the side wall tunnel supports. The new 10th Avenue Tunnel was connected to the previously constructed box tunnel which ended on the south side of 10th Avenue. An aerial view (Photo 4) identifies and illustrates the alignment

Photo 4. Aerial view of Long Island Rail Road west storage yard prior to its construction. Alignment of west side tunnel is visible.

of the box as it was being constructed prior to the Long Island Yard being built. In the distance is the Hudson River. The Long Island Yard has been completed and is a multi-track servicing an inspection facility.

The alignment of the box has two 8°30′ curves and one 4° curve in its 2500 feet length and has a maximum grade of 2%. Walkways are provided on both sides for emergency evacuation if necessary. Staggering lighting on both sides of the wall provides full illumination. A dry standpipe water system is erected on the walls of the tunnel. Full communication capabilities for radio contacts are throughout the tunnel. Within the tunnel direct fixation track, utilizing Pandrol clips with Load Master heavy axle pads, is used. Third rail propulsion capability is provided within the tunnel. Fiber glass protection shielding as well as rail support connections are utilized throughout. With fiber glass materials, longer component life will be realized.

The rail line had been unused for many years and over the years became a normal dumping ground for debris. A right of way cleanup contract was awarded to clean the area of debris, and uncover the right of way. Fencing was erected in an attempt to eliminate future dumping and trespassing. The effects of this work were quite dramatic.

Construction documents were prepared for the connection of the North Access Tunnel to the box based again upon the as built plans of the box. Excavation began toward track 30 which is the outermost track in the yard. The as built plans indicated that the box extended to the edge of the property line and was beyond the operating railroad. However, excavation again revealed that the drawings were error. It was necessary to progress negotiations with the Long Island Railroad to occupy their property which necessitated placing track 30 out of service for a period of time to extend the box and connect it to the North Access Tunnel. The supports for the overhead bridge highway may have been a reason for terminating the box prior to the property line.

Throughout the North Access Tunnel area there are considerable streets, highways, and buildings which have their supports going down to rock foundations. As you can imagine this necessitated considerable detail design at each specific location. As the excavation moved ahead, various different types of supporting foundations were encountered (Photo 5). A great deal of construction activity occurred in a very confined area. The overhead structures had to be fully supported and in certain areas additional rock bolting to provide this support was required as the depth of the excavation progressed.

Photo 5. View of obstacles encountered at north tunnel access area.

Immediately adjacent to the Long Island Railroad property, a major sanitary sewer was located that was in the alignment of the tunnel. The wooden framing was still in existence when the sewer was exposed. Numerous discussions and negotiations with the New York Water Department were held to develop a syphon system through this area which allowed the sewer to be lowered below the base of the tunnel. A great deal of rock excavation and additional support for the overhead structures occurred during this phase of work. The completed sewer box connection is located immediately beneath the tunnel floor and is bridged by the tunnel itself.

As the north access tunnel work progressed northward from the box structure, the grade was elevated to bring the trackage up to the ground surface. Inverted U shape supports were erected to open the tunnel alignment which provided overhead structure support (Photo 6). The Jacob Javits Convention Center is immediately adjacent to the right of way. This huge glass structure occupies four square blocks and is visible from the tracks. Hoe rams were utilized to begin the rock excavation after the topsoil was removed. Necessary drilling and blasting took place as the depth increased. A "U" shaped concrete cross section structure began approximately at 34th Street and elevated the track to ground level. The alignment of the trackage and the alignment of the overhead structures did not always correspond, so many different types of support foundations were necessary. At each location strain gauges and detailed measurements were taken to ensure that no lateral or vertical deflections occurred.

Photo 6. Inverted U-shapes near tunnel entrance for overhead structure support.

As construction progressed, the tunnel was tied in directly with the underlying rock strata and the floor of the tunnel was poured with a "V" lock support throughout. Many of the support foundations for overhead structures are not visible as they are within the walls of the structure itself. Considerable forming work was necessary. A large amount of reinforcing steel was required in the construction. Sump pumps are strategically located in the box as it is not totally waterproof. Catenary has been erected throughout the tunnel and extends to the double track portion just beyond the tunnel entrance. The supports for the overhead structures are visible in the "U" type structure. A great number are along the entire length of this portion of the construction project.

The "U" shaped trough was constructed without the final track structure which was completed later as more finite control was required. Because of the overhead structure support requirements, various different methods were necessary to provide required side clearances. In some instances, walkways were provided behind overhead support structures due to these clearance restrictions. Third rail and electric traction propulsion is available to approximately mile post 1 which is beyond the double track location at Empire interlocking. A complete fan system is in place to provide 126,000 CFM air supply. Four impulse fans are also located in the tunnel to assist in air movement capable of 20,000 CFM each.

Considerable cleanup was required, along with a great deal of tree and brush removal so as to expose the right of way to allow work to progress. Due to the slower speeds coming out of the tunnel area, a number 20 turnout begins the double track railroad. The tracks are constructed with wooden ties and continuously welded rail throughout.

In certain areas there was very poor drainage. This was complicated by overhead structures. Water was diverted onto the railroad and no drainage system was present. The correction required a rather detailed longitudinal drainage system. There was one location where the dumping of unused petroleum materials drained onto the railroad. This necessitated a rather lengthy negotiation period with an outside company to ensure its termination, removal and clean up.

Between approximately 60th Street and 72nd Street is the area where the Trump organization may be developing and constructing a major real estate complex. This area was basically overgrown and is adjacent to the park overbuild area. The double track railroad will extend through this area and should the complex be built there is required clearance above the track for any possible consideration of electrification being installed at some later date.

The St. Clair Viaduct is 2,050 feet in length and runs parallel to a portion of the West Side Highway which is itself adjacent to the Hudson River. Being unused for some time it was greatly overgrown and the ballast structure was complete fouled. The steel support for the viaduct was in great need of repair. Some portions of the steel were completely rusted away. Underneath various areas of the viaduct, businesses had been constructed limiting accessibility to many parts of the viaduct structure. In many cases these structures were immediately adjacent to the viaduct supports themselves. The entire bridge structure was uncovered and drainage repairs were performed due to deteriorated conditions. Broken or decaying portions were moved and the drainage system was reconstructed. Waterproofing materials were applied to the length of the bridge structure. Necessary ballast was then placed prior to the tracks being laid.

The area through the George Washington Cut was also greatly overgrown. There were originally two tracks in this area and after reconstruction occurred, a detailed survey was undertaken to investigate the clearances which existed. A concrete cableway adjacent to the track was greatly deteriorated. In this area the West Side Highway is located immediately adjacent to the railroad right of way. Many rock bolts had been installed in the rock face to provide stability to the rock and also the overhead highway structure. The rock face has many cracks extending throughout its entire length and height. Considerable deterioration has occurred over the years to the rock bolts. After final alignment had been verified by clearance documentation, additional work was required concerning removal of not only a portion of the concrete cableway, but also some of the rock face itself. Some new rock bolts were also installed. The double track extends throughout the entire length of the George Washington Cut. The railroad right of way provides a very scenic view for passengers traveling along the route.

At Dyckman Street there is an overhead bridge which required steel and abutment repairs performed. The entire structure was painted and total rehabilitation of the structure took place.

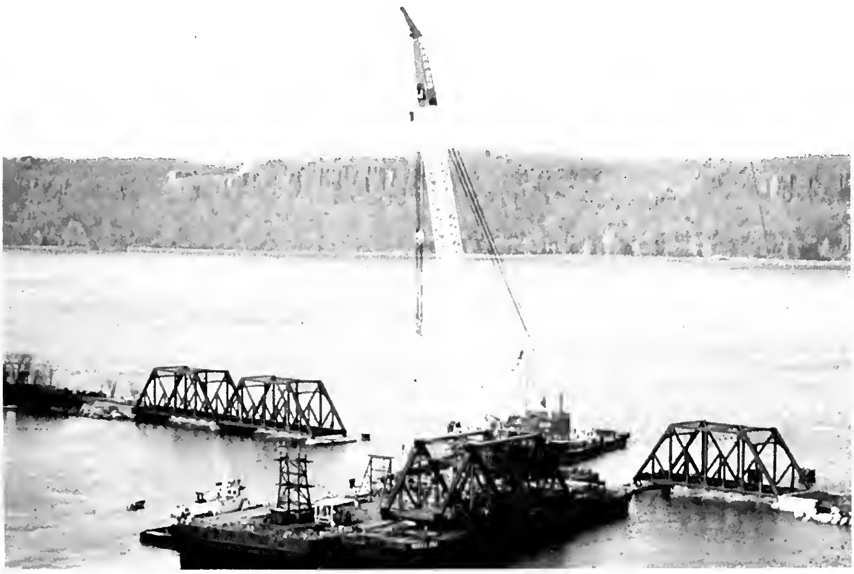


Photo 7. Spuyten Duyvil bridge replacement after rehabilitation.

The Spuyten Duyvil Bridge is located at the north end of the project immediately adjacent to the Metro North Commuter Railroad. The bridge is composed of three 106 foot long trusses with a swing span of 186 feet in length. Circle Line tour boats pass every thirty minutes in the summer time. Pier rehabilitation both above and below the water line was necessary. The entire bridge was removed from the site and floated out on barges. Necessary repairs and construction were completed off site. Off loading from the barges took place away from the bridge location and after the reconstruction was accomplished they were reloaded and floated back into positioning for re-erection. The three approach spans were reinstalled first with the swing span being re-erected in three different sections on the site due to its size and weight. New steel has been used throughout the bridge. A new track and new operating mechanism have been installed with controls contained on top of the bridge itself. The double track ends just before the Spuyten Duyvil Bridge with an equilateral #20 turnout. Reverse signal running extends throughout the entire length of the project. The connection to the Metro North Commuter Railroad occurs at DV interlocking. The trackage parallels the interlocking and interfaces with new switches for movement northward to Albany, Niagara Falls, Toronto, Montreal and Chicago.

Inaugural ceremonies took place on Thursday, April 4th, 1991. The second main track of the double track route was placed in service September 29, 1991. Residents not only of Rensselaer, but also Albany were present for the opening ceremonies. A turbo train inaugural special was run with many dignitaries and ceremonies held along the route. The Lieutenant Governor of New York, officials from the Federal Railroad Administration, and Amtrak's president spoke at each location. Continuing a long standing tradition, a fire boat welcomed the inaugural run at the Spuyten Duyvil Bridge signifying a major new accomplishment with appropriate welcoming ceremonies into New York City.

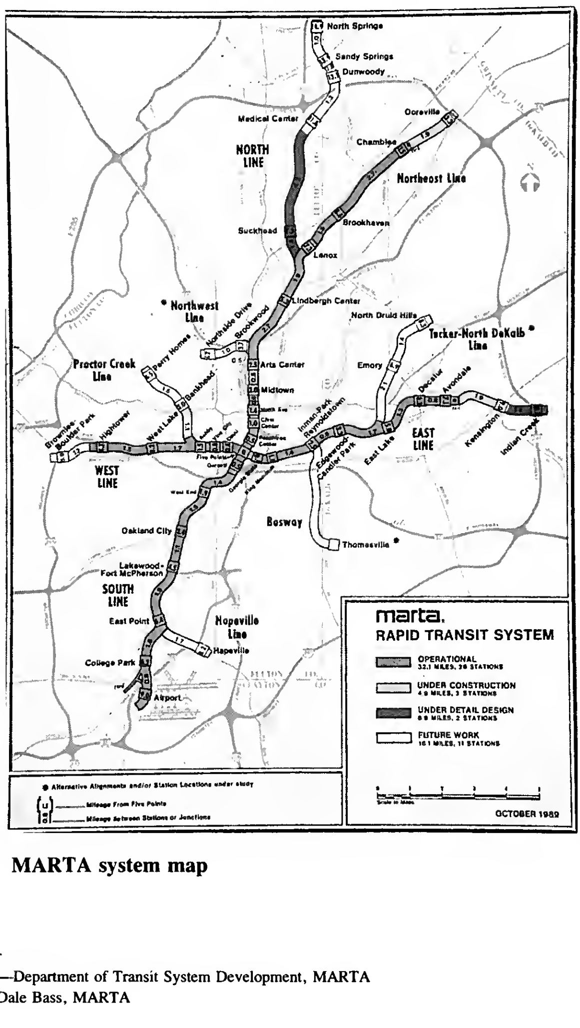
Thank you very much.

CURRENT CONSTRUCTION ON THE MARTA SYSTEM**

By: Lyn D. Wylder*

The Metropolitan Atlanta Rapid Transit Authority (MARTA) was approved by voters in 1971 to provide a heavy rail transit system to the people of Atlanta. The design of the system began in 1972 and construction began in 1975. The first operating segments were opened in 1979 and openings have continued throughout the years. The system now has 34 miles of double revenue track, 29 stations and two rail yards. A fleet of 680 buses supplement service by the rail system. There are two lines—the North (Northeast)/South line and the East/West line. These lines cross at a large central station in downtown Atlanta.

An aggressive construction program is currently underway to add an additional 10.6 miles of double track and 5 more stations. MARTA is currently spending more than $175,000,000 on this construction that includes several firsts for the MARTA system. It is the first construction on any branch from the mainline, it is the first time MARTA has crossed Atlanta's perimeter highway and it is the first time that MARTA has built trackway in the center of a highway. In addition to this construction an additional three miles of double track and four stations are in various stages of design.



MARTA system map

*Project Manager—Department of Transit System Development, MARTA
**Photographs by Dale Bass, MARTA

Proctor Creek Line

The first of the new expansions to be ready for revenue service is a branch to the north off the existing West Line. This branch will go to Bankhead Station on the Proctor Creek Line. This is a 1.1 mile segment that branches from the existing track in a tunnel (box) segment. This branch was anticipated when the original West Line was designed in the mid-1970's. The box structure was built so that one track was elevated over the other. Thus the turnouts on each mainline track can branch to two branch tracks without conflicting. In addition a portion of each level of the box was constructed when the West Line was built so that when the Proctor Creek Branch was constructed there would be as little disruption as possible to West Line operations.

The branch line and Station were designed by Parsons, Brinckerhoff/Tudor (PB/T), MARTA's General Engineering Consultant. Unlike the rest of the MARTA system this branch is designed for two car trains, totaling a length of 150 feet, with the capability to expand to four car operation. All other stations are designed for eight car operation. The station is two levels with the fare gates on the lower or concourse level and the platform on the upper level. Most of the station materials are cast-in-place and precast concrete elements with split face concrete blocks for both the exterior and interior walls. The concourse is enclosed in glass for weather protection. There is a bus loop on the lower level as well as a small kiss-ride parking lot.

The contractor for this construction is Ruby Collins, Inc. Construction began in August 1989, and revenue service is scheduled for June 1992. The approximate cost of this line and station is 14.4 million dollars.

New Bankhead Station on Proctor Creek line.

Northeast Line

In December 1992, the existing Northeast Line will be extended 1.9 miles to Doraville Station. As with all MARTA revenue service lines, this will be double track territory. With the exception of approximately 1000 feet of ballasted trackway, the line to Doraville is on aerial structure, with direct fixation fasteners anchoring the track to the deck. The structure is constructed with a concrete deck on

AASHTO girders and concrete piers. MARTA has frequently used aerial structures when adjacent to railroads, as we are in this area. This allows MARTA to get as close as possible to the railroad and not impact railroad operations.

The Doraville Station is located just inside Atlanta's perimeter highway, I-285, with tailtracks extending on a bridge across the ten lane expressway. In order to construct this bridge, traffic was diverted onto the emergency lanes so that a work area could be maintained in the middle of the highway during the construction of the center pier. Three sets of steel girders were placed in the early morning hours on weekends when traffic could be paced (stopped) during critical activities. Safety netting was then placed so that the deck could be completed during normal work hours.

The Doraville Station has two levels with entry on the lower level and the 600 foot center platform on the upper level. The main architectural feature is the pitched standing seam metal blue/green roof. The station is designed to have the appearance of a classic railroad station. Since this station will be an end of the line station, attention was paid to bus and car access. A bus loop is designed into the lower level so that barrier free transfer between bus and rail is afforded the patron.

Due to the site limitations, most of the 1120 parking spaces are in a four level parking deck adjacent to the station. Patron safety was of prime concern during the design of the parking structure. The deck has patron assist phones and surveillance cameras on every level near the elevator. The stairways are open and well lighted. Entrance and exit lanes are obvious and conveniently located.

The line was designed by PB/T and the station was designed by Devcon Design Group, Inc. The construction of both the line and station is being done by Underground Construction Company, Inc. at an estimated cost of 30 million dollars.

EAST LINE

The extension of MARTA's East Line began construction in September 1989, and is scheduled for revenue service in June 1993. The extension is 3.1 miles long and includes two stations. The line leaves the current end of the line station at Avondale and travels through MARTA's own Avondale Rail Yard which serves the East/West line. In order to minimize disruption to operations, yard construction, done in 1978, included an aerial structure that crossed the yard tracks. Unfortunately, due to unforeseen problems encountered during final design, a different alignment was selected which required about 300 feet of the previously built deck to be realigned. Close coordination with the transportation department was required while working in the yard so that a safe work area could be provided while rail operations continued.

Once the trackway leaves Avondale Yard, it then continues through business and residential areas, a departure from MARTA's usual location near heavy haul railroads. This meant that particular attention was paid to noise and vibration attenuation. Seventeen hundred feet of the at grade and aerial portions of the line have eight foot high acoustical barriers adjacent to the trackway. Three hundred feet of the track is supported with floating slab construction and 1500 feet is on resiliently supported ties (two block ties in rubber 'boots' embedded in concrete.) This is to prevent train vibration from being transmitted into the ground.

The portion of the East Line that stretches from Avondale Station to Kensington Station is a 2.1 mile segment that includes a 2400 foot long box structure constructed by cut and cover methods. The line was designed by PB/T and the low bidder for the construction at 18.4 million dollars was Green International, Inc., formerly Stolte Construction. The designer of Kensington Station was Post, Buckley, Schuh and Jernigan and the low bidder for construction was again Green International, Inc. for approximately 20.5 million dollars.

The station design calls for long concrete columns extending two floors from the trackway on the lower level to the roof. This gives the station a Greek appearance. Several different concrete form finishes were used on the walls and columns to provide interest and to give a rough finish to the concrete that helps to prevent vandalism. The roof on this station is also a standing seam metal blue roof accented with concrete ridges. The patrons enter the station at grade and drop down one level to the trackway. The station has a bus loop and a 900 car parking lot.

The next line section consists of a long cut section that will have ballasted track and a ballasted deck bridge. This line segment consisted primarily of cutting a valley for the track and moving the removed soil to the Indian Creek Station site. This line segment was also designed by PB/T and constructed by Gilbert Corporation of Delaware, Inc. for a cost of 5.1 million dollars.

East end of tunnels under and car bridge over I-285.

This leads to the most interesting and difficult portion of the current MARTA construction. That is the construction of twin trackway tunnels under I-285, Atlanta's perimeter highway, and a bridge over I-285. The tunnels will take trains to Indian Creek Station, the first MARTA station to be located outside I-285. The bridge provides car access to the expressway from the station.

Since this eight lane wide interstate is one of the busiest highways in Georgia, the Georgia Department of Transportation (Georgia DOT) would not allow MARTA to use cut and cover construction techniques, so the decision was made to tunnel two separate 180 foot long bores. Soil samples were taken in the shoulders and median of the highway. These borings indicated that the top one third of the tunnel cross section would have to go through fill material placed when the interstate was constructed. In addition the vertical geometry of the track was such that the top of the tunnel would be four and one half feet below the running surface of the highway. This required careful analysis of the tunneling method and many discussions with Georgia DOT.

The selected method of construction called for 21 inter-connected 30-inch diameter pipes to be driven beneath the road forming an arch. (Two arches are required, one for each track). Due to the critical placement of each one of these pipes, they were guided in place by lasers using a method called micro-tunneling. Once the pipes were in place then they were filled with lean concrete. The area under the arches was jet grouted for stability and then excavated. Steel pipe piles and steel rib sets were installed and the tunnel is finished with a reinforced concrete lining.

The tunnel was designed by PB/T and the prime contractor for the project is Archer-Western Contractors, Ltd. with Salgado Eastern Corp. the subcontractor for the micro-tunneling and jet grouting. The construction has progressed very well, is on schedule, and there has been very little disruption to the I-285 traffic.

The other portion of this contract requires that a curved steel girder bridge be built over this same interstate to carry car traffic from the adjacent Indian Creek Station onto the interstate. Although this bridge is curved, construction techniques and traffic control were similar to that used for the bridge beyond Doraville Station. The bid price for this contract which includes the tunnel and the bridge was 15.4 million dollars.

View of Indian Creek Station with glue laminated roof beams and sine wave wall in foreground.

The Indian Creek Station will become the end of the East Line. As with most MARTA stations, it is two levels. The concourse is at grade and patrons will descend to the 600 foot long center platform. The station's primary features are the curved glue laminated beams supporting a wood panel roof deck covered with a copper roof and a wall of the station follows a sine wave curve and is covered with a rock rubble finish. The station is open to the north and great care has been taken to preserve the natural area adjacent to the station.

The station is served by the usual bus loop and there will be a 2440 car parking lot with direct access to the interstate. The station was designed by Cooper Carry & Associates, Inc. and the contractor is Underground Construction Company, Inc. The bid for this facility was 19.7 million dollars, which includes approximately one mile of surface road improvements with two bridge widenings.

NORTH LINE

In addition to the work described above, 5.5 miles of trackway are under construction in conjunction with the building of a limited access road known as Georgia 400. MARTA's two tracks will run down the center of this highway. This branch was not originally designed into the MARTA system so locations for turnouts had to be found that would fit existing geometry. Work on the construction near the operating track was scheduled for weekends so that trains could single track around the work areas. Work requiring power to be off on both tracks was scheduled during the middle of the night on weekends.

Construction in the Georgia 400 corridor.

The base work for this 5.5 miles of ballasted trackway and Phase I of the Buckhead Station are being constructed by Georgia DOT contractors with supervision by MARTA field personnel. The estimated cost of the Marta portion of this work is 52.1 million dollars. Phase I of the station includes the foundations and all work that must be done before the road opens, scheduled for the summer of 1993. The MARTA line and Buckhead Station are scheduled to open with two additional stations, Medical Center Station and Dunwoody Station, in mid-1996, prior to the 1996 Olympic Games.

Phase II of Buckhead Station is currently in final design and bids will be taken in early 1992. This includes the completion of the structure, trackway and pedestrian access bridges. Medical Center Station is also in final design with construction scheduled to begin in early 1993. The line to Dunwoody Station and the station itself have completed preliminary design. Future expansions along this line are scheduled for the late 1990's.

It is evident that MARTA has become a critical part of the transportation system in the Atlanta area and the construction program will make the system an even more vital part of the city.

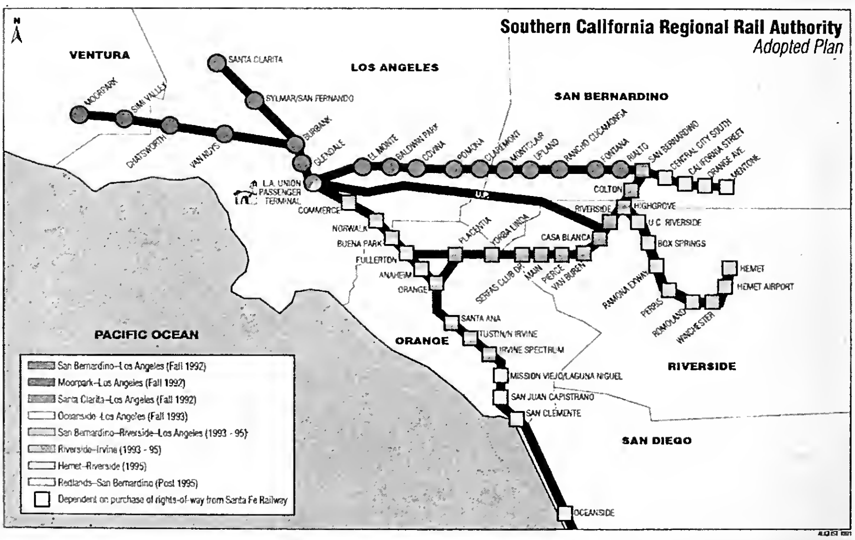
LOS ANGELES COMMUTER RAIL
A FAST TRACK PROJECT
IN A PUBLIC WORKS ENVIRONMENT

By: John L. Rinard, P.E.*

In September of 1991 five southern California counties formed the Southern California Regional Rail Authority (SCRRA). Adding a new and aggressive chapter to Southern California's transportation story, with representatives from Los Angeles, Orange, Riverside, San Bernardino, and Ventura counties.

Over the past 10 years alone, the population of California increased 25%. However, the number of licensed drivers increased 35%, the number of registered vehicles 40%, and the total vehicle-miles of travel 60%—all between 1980 and 1990. Yet the number of new roads increased only 2% during this period. The result was a large increase in congestion throughout the state, but especially in southern California.

In less than one year new service will be established on the first three out of an eventual eight commuter rail lines planned to serve the Los Angeles basin. As we speak, construction is now underway to convert 130 route miles of railroad, half of which is now FRA class 1 track without block signals to a modern 80 mph system. Work includes 50 miles of track and signals, seven bridges, one interstate overpass widening and a 3000 foot long viaduct and railroad flyover bridge, two layover facilities and a modern locomotive and coach maintenance facility.



SCRRA Adopted Plan—shows all routes planned to date.

The first three lines fall under two types of purchase and sale agreements. First the eastline, Los Angeles to San Bernardino agreement allows SPTC to retain the local freight rights but the Authority acquired all other responsibilities. It was thought that having unrestricted control would be necessary to provide the quality of service at an affordable price. The second type of agreement is to be shared use between SCRRA and the Southern Pacific Transportation Company (SPTC). SCRRA purchased

*Chief Engineer, Southern California Regional Rail Authority approximately half the width of SPTC's Coast and Saugus lines that terminate at Moorpark and Santa Clarita respectively. A shared use agreement was developed that allows commuter trains to have the priority operation during commute hours and share with freight at other times.

The initial lines will be diesel powered service with rolling stock consisting of 17 EMD FP59 locomotives and 70 bi-level passenger and cab cars for a value of approximately $108 million. The coaches will be handicapped accessible, set up for low-level platform loading. The start-up service will be one-way flow with all trains laying over at outlying points and proceeding into Los Angeles at regular intervals during the morning peak periods and returning in the evening. Future capital programs will accommodate growth to an ultimate full service system that will incorporate alternative fuels or electrification.

The outstanding feature of this project is not the technical difficulty of the work but the magnitude of the effort required to initiate full operating service a mere 18 months after the engineering work began. All of this in one of America's largest urban areas and within the guidelines of public projects. Design work for the majority of the $120 million worth of initial construction now underway was completed in less than four months after engineering began. This unprecedented achievement was accomplished by hard work, dedication and the close cooperation between SCRRA staff and the design consultants.

Service is expected to begin by October 1992 with three initial lines that are currently under construction. Strategy was to combine all work; signal, track and bridge within natural portions of the right-of-way into single bid packages. This was planned to eliminate the potential problems of follow-on contracts and to shorten the overall construction schedule. A team of consultants, headed by Frederic R. Harris, was selected to perform all design, with the exception of the maintenance facility. The team produced over 1000 plan sheets and specifications for the initial construction.

Operations planning was augmented by the DeLeuw, Cather & Company (DCC) team that consulted with the design group. Support was provided in the areas of track configuration and location, signals, dispatching and long term needs. In this fast-track engineering project the timely operations

Sample photo of equipment to be used, similar to GO service in Toronto.

planning of the DCC team was critical. The team paced the design efforts and were instrumental in providing quality input. Station location and design, and fare collection systems with ticket vending machine procurement are also included in their responsibilities. Their further work in construction will include change control process, value engineering safety and quality assurance oversight.

Sample photo of station, similar to Toronto Transit's.

Bridges

The bridge designs ranged from complete design to major retrofit. However, again due to the time constraints standard bridge designs that were familiar on railroads and that were familiar to contractors in the region were used.

LuBono, Armstrong and Associates, a wholly owned subsidiary of F. R. Harris assembled an incredible team that produced all bridge designs under the same tough schedule. The challenge was the 3000 foot long viaduct and flyover that crossed over the SPTC with the alignments running parallel. The new 3000 foot structure crosses the SPTC on 900 feet of bridge and the San Gabriel River on an additional 600 feet as it descends to grade.

Original plans called for final designs of the sub-structure only with the super-structure to follow later. The LuBono team completed designs of the entire structure in the time planned for sub-structure only.

Maintenance Facility

Servicing will be performed at a new maintenance facility in Los Angeles during the mid-day hours. All servicing, cleaning, and inspecting will be performed at this hub facility with only limited and emergency work being performed at the outlying layover points. A progressive maintenance program to be incorporated into the facility was designed by the firm of STV/Seelye Stevenson Value & Knecht. STV also performed heroics by completing designs for the $32 million facility in under the same four month schedule. The Government of Ontario (GO) facility at Toronto was used as a prototype and modifications were analyzed and incorporated. Our primary concern was to not start from scratch but use a proven design and capitalize on it's functionality as well as to save time. High property values, environmental concerns, accessibility were but three of the difficult issues incorporated into the facility.

The facility will have four servicing tracks, locomotive shop, coach shop, welfare offices, progressive maintenance shed and storage for over 180 coaches. This facility is located on land purchased from Southern Pacific Transportation Company and they have agreed, within the purchase agreement, to perform the necessary environmental clean up. SPTC has responded to the cleanup challenge and are endeavoring to stay ahead of the new construction schedule.

Maintenance and layover facilities as located.

Plan Preparation

It was decided to utilize the benefits of aerial photogrammetry combined with EDMI-theodolite based line surveys. The aerial survey was used to identify the topographic features and as a means of developing the actual corridor of the rail line. A digital terrain model was developed for the aerial survey. Existing contours were digitized from the aerials and through software a TIN model was created. The TIN allowed the design engineers to study the affects of horizontal and vertical alignment changes on both earthwork quantities and the surrounding facilities. It helped establish the needs for retaining structures, avoided the need for easement acquisition and allowed the designers to develop the final earthwork software program.

Once the designers completed their analysis of the existing right-of-way and the desired alignment decided upon, the next step was to describe the alignment mathematically. These newly integrated software packages allow the designer to view the computer monitor and determine how the proposed alignment looks in relation to the right-of-way. This allows the designer the advantage of making minor adjustments to the design and to instantly view the effect on topographic elements. The WYSWYG, (what you see is what you get) aspect of design was very important in this project. Due to the restricted right-of-way, existing utilities, and existing industry tracks and the prime concern of delivering the schedule for start-up required the designers to not create obstacles but work around them.

The computer allowed the designer to concentrate on the most important task, that of fitting the proposed track to best serve the needs of all while freeing him/her with the burden of performing a multitude of routine calculations needed to finalize design.

Drainage, Drainage, Drainage Design

While the railroad right-of-way was the same for nearly the last century the surrounding area had been developed to the point where a great deal of the land had been paved. As is the custom in so many other locations, the railroad right-of-way serves as a major storm water collection conduit.

The designers were faced with two problems:

- Determine the actual amount of surrounding runoff entering the existing right-of-way
- Analyzing the existing drainage system to determine its capacity, and design to carry the excess

Once again computer modeling came into the picture. Models along the length of the project were developed for the design storm. The surrounding areas were reviewed to establish the present day drainage patterns. A detailed estimate of runoff factors were developed and incorporated into the model. The analysis showed that an open ditch drainage system was best. Where this system did not allow continuous drainage a positive longitudinal drainage system was incorporated. This positive system drained into the local storm system.

In order to obtain approval for positive connections to an existing system, the designers had to demonstrate that added drainage from the right-of-way would not over burden the local system. This was a strange paradox due to the fact the railroad was there first and any additional drainage coming from the new right-of-way design actually came from the surrounding land development.

Signals

Upgrading the San Bernardino to Los Angeles eastline signaling involved the installation of a CTC controlled block signal system and improving the controls and warning signals at approximately 35 highway grade crossings.

Since time was of the essence it was decided to apply well established practices, using readily available hardware, to the wayside signal system. The decision was made to use center fed and end fed direct current track circuits for train detection, in conjunction with block circuits carried in underground cable. Influencing this decision was the great number of grade crossings involved, all of which would be controlled by state-of-the-art micro processor constant warning type units. DC track circuits simplify the compatibility issues that would be faced if electronic coded track circuits were used. However, the specifications allowed this to be an alternate in order to achieve competitive bids. The Authority knew the risk of not having system-wide continuity but due to the packaging of contracts this risk was accepted. In addition, a fiber optic cable was planned for the line, so the trenching required for the underground signal cable would be provided by that installation. The interlockings are either single switch end of sidings or holding signal pairs and are all relay. Wayside signals will be Safetran Unilens signals which utilize the best attributes of the single lens searchlight signal and the unit lens colorlight signal.

Train operations on the route will be controlled from a dispatching office utilizing distributed processing provided by MS-DOS computers driving color VDU's displaying the track model and providing train tracking, entrance-exit operation, and event recording that permits an "instant replay" like feature. The link from the control office to the field control points will be via a high-speed optic cable. The system is readily expandable to incorporate additional territory as the system expands.

REVIEW OF RAIL CAPITAL PROJECTS IN NORTHEASTERN ILLINOIS

By: Paul Muldoon*

1. INTRODUCTION

A combination of events has lead to a significant increase in rail capital investment in Northeastern Illinois. Major capital investments are currently underway to renew the Chicago Transit Authority's aging elevated structure, renew Metra's commuter railroad bridges, and to add new facilities such as the CTA's Southwest Line currently under construction. This paper provides an overview of track, structure, and facilities projects in Northeastern Illinois.

1.1 Overview of Transit Interests in Northeastern Illinois

Frequently it is difficult to understand the inner workings of a capital program without first understanding what role government agencies play in the program. This is particularly true in Northeastern Illinois where a multitude of government bodies have the potential to directly impact the regions transit capital investment. Key players in the region are identified below:

Regional Transportation Authority: Created by the state legislature in 1974 to provide public transit service to the six county region. The RTA was reorganized by the state legislature in 1983 to act as a funding and oversight agency. The RTA has a 13 member board of regional officials appointed by the City of Chicago and the six county governments. Three operating agencies are funded by the RTA: Chicago Transit Authority (CTA) which operates public transit services (rail and bus) in the City of Chicago and surrounding suburbs; Metra, responsible for the operation of commuter rail service in the six county region, and Pace, responsible for the operation of bus service in the six counties excluding the City of Chicago. Each Service Board is responsible for day to day operating decisions, as well as implementing capital improvements to their system.

The RTA levies a regional sales tax which, under the RTA Act, is supplemented by a 25% direct matching funds from the State of Illinois general fund. While the majority of these funds goes toward operating subsidy, a certain amount is reserved to cover debt service on $500 million of RTA's bonding capacity, and to directly fund a small number of capital projects. The RTA receives an indirect reimbursement from the State of Illinois for an additional $500 million in bonding capacity.

City of Chicago: In the past the City of Chicago has been responsible for major construction of new rail systems within the City of Chicago.

Illinois Department of Transportation: Supplies approximately 10% of the capital funding for the region.

Urban Mass Transportation Administration (UMTA): Excluding Interstate Transfer funds the federal government through UMTA supplies approximately 50% of the capital funding for the region, and 5% of the operating funding.

1.2 Scope of Public Transit Services in Northeastern Illinois

Northeastern Illinois' investment in public transit service is second only to New York. The value of the investment is placed at over $16 billion, and the annual operating budget is slightly greater than $1.0 billion. CTA services 570 million riders a year, while Metra's rail service carries 72 million annual riders, and Pace suburban bus services 40 million passengers a year.

On the rail side, CTA has 249 miles of track and 143 stations serviced by 1216 railcars. Metra has 1200 miles of track and 233 stations serviced by 890 passenger cars and 135 locomotives.

2. PLANNING FOR THE CAPITAL PROGRAM

While the investment in the Southwest Line was committeed to in the late 1970s, much of the RTA's transit system was falling into a state of poor condition, primarily due to age. In 1987, after the reorganization of the RTA, an effort was made to begin to better understand the overall condition of the

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*Manager of Technology, Regional Transit Authority, Chicago

system and to develop a plan to address the investment requirements. As part of its strategic planning effort the RTA undertook a study to review the status of its rail lines and facilities. The study was a survey of the overall age of different elements of the system and an evaluation of their general condition. From this information a macro analysis was completed of the replacement costs for the system, and broad projections were made on the annual financial requirements to renew the system. The findings indicated that the RTA had a shortfall of required funding of more than $6 billion. In order to further refine this information the RTA requested that the Service Boards undertake a detailed engineering analysis of key elements of their system.

Because of its overall age and apparent condition the CTA was requested to undertake an engineering assessment of it's complete subway and elevated system. The engineering assessment is a comprehensive look at all elements including: power, communications, track, structure, and stations. The two and a half year effort will be concluded in mid 1992. The results of the engineering assessment will provide the basis for CTA's future capital program decisions. The assessment has already highlighted capital renewal priorities in certain areas.

Because the strategic planning effort indicated that Metra's bridges would require a major investment in the near future, RTA requested that Metra undertake a detailed engineering assessment of a specific subset of it's bridges. This assessment was completed in 1989, and has become the basis for Metra's bridge renewal program.

Photo 1. Metra Bridge Renewal in progress. More than 35 bridges slated for renewal on Metra's north and northwest lines.

3. REVIEW OF MAJOR PROJECTS

3.1 CTA Elevated Structure Renewal

The CTA's rail system is composed of at grade, subway, and elevated open steel deck structure. The elevated portion constitutes approximately 47 miles of the 215 route miles of track in the system. The first phase of the engineering assessment highlighted a specific area of concern with column foundations.

3.1.1 Renewal of Foundations

A limited analysis of the elevated system during the first phase of CTA's engineering assessment indicated that foundation deterioration was contributing to pumping of columns and consequent damage to the structure. This was particularly true of CTA's Lake Street Line and the Southside Mainline. Both lines were built prior to 1900, and had received only limited foundation maintenance over the last 90 years. In the case of the Southside Mainline it was found that stray currents combined with sandy soil conditions was causing deterioration of the foundations and corrosion of the column. In the case of the Lake Street Line, column footings are located in the roadway below pavement. Based on excavation it was felt that a number of the footings on the western end of the elevated structure required replacement. In 1990 the CTA undertook a program of replacing column foundations on the Lake and South Side Mainlines. At the completion of the $17 million project a total of 1,069 foundations (470 Southside Mainline, 599 Lake Street) will have been replaced. In the case of Lake Street the footings have been redesigned so that column footing connections are above the street surface and the footing is of sufficient height to protect the column from vehicle traffic.

3.1.2 Renewal of Structure

While the engineering assessment mentioned previously will develop the basis for CTA's future structure renewal program, in the early 80's the CTA undertook a study to evaluate structure condition of the Southside Mainline. That study indicated that a significant number of flange angles were in need of replacement on the Southside Mainline. This $40 million multi-year project is now nearing its conclusion.

Photo 2. View of Howard Yard expansion project.

3.2 Renewal of Ballasted Track

In early 1991, CTA initiated a $30 million project to replace ballasted track on three lines: Skokie, Ravenswood, and Douglas. This project called for the replacement of 14 miles of ballasted track. The CTA closed the ballasted track portions of these three rail lines on selected weekends to facilitate completion of this work within the year.

3.3 Renewal of the Elevated Downtown Loop and Subway Stations

Utilizing Interstate Transfer, and local funding the City and the CTA over the last ten years have embarked on a program which has resulted in the renewal of CTA's loop elevated structure and stations, subway mezzanines, and Jackson Park elevated structure and stations.

3.3.1 Loop Elevated Rehabilitation

This project has included the renewal of seven stations in downtown Chicago, and the addition of one new station at the City's new Harold Washington Library, at a cost of $37 million. It also includes $91 million of work on the loop structure as well as the connecting portions of the Lake, Ravenswood and Southside Mainline.

3.3.2 Subway Station Renewal

The City of Chicago and CTA renewal of the subway mezzanines includes ten downtown subway stations at a cost of $27 million. This ongoing project also includes installation of accessibility to station platforms, installation of acoustical panels and waterproofing in the subway tunnel, and installation of emergency power.

3.3.3 Jackson Park Elevated Rehabilitation

The Jackson Park Line is a spur of the Southside Mainline. This City of Chicago and CTA project cost $31 million and included the renewal of three stations and the refurbishment of two more. The project also included elevated structure work totaling $7 million.

3.4 CTA Renewal of the State Street Subway Track

CTA has approximately 22 miles of subway track of which nine miles are in the State Street Subway. The State Street Subway was completed in the 1940's. The ties and rail in the tunnel had not been replaced since the original construction. In 1991 the CTA initiated a $27 million project to renew the ties and track in the subway. All running and power rail was replaced and 85% of the ties were replaced. In order to facilitate the rapid completion of the project, the CTA turned the tunnel over to the contractor during 22 consecutive weekends. For the most part all work was accomplished during the weekends with the contractor turning the tunnel back over to CTA early Monday morning.

3.5 Metra Bridge Program

The Metra system operates approximately 500 route miles, encompassing 1200 miles of track and 796 bridges. The average age of the structures is 75 years. Metra's Bridge Assessment Study, completed in 1989, examined 91 of 796 bridges considered most in need of repair or replacement. Of the 91 bridges, 66 were defined as high priority and 25 as non-critical. The 66 high priority bridges were divided into 16 groups based on geographical location, operational constraints, and limitations on street closures imposed by the City of Chicago. Each group will have three contracts consisting of engineering and design, construction management, and construction. Contracts for engineering and design have been executed for nine of these groups. By the end of 1990 three of the studies had been completed. The rest are expected to be completed in 1991 and 1992. Based on these studies $69 million has been programmed between 1991 and 1995 for replacement of bridges.

3.6 Metra Downtown Station Renewal

In the early 80's Metra initiated a program for the renewal of its downtown passenger terminals. Work has either been initiated or completed on all five downtown terminals, which handle 70 million passengers per year. The following summarizes the status of work on each station.

3.6.1 LaSalle Street Station

This project will completely renew platforms, track, structure and signal systems. The first phase of a three phase renewal has been completed.

Photo 3. LaSalle Street Station, a three phase project which will completely renew the track, structure and train control system for the station.

3.6.2 Chicago Passenger Terminal

Award was recently made for the renewal of the trainshed, platforms, track, structure and signal systems. This $135 million project follows the completion of the terminal under a joint development effort.

3.6.3 Van Buren Station/Randolph Street Station

Renewal of these two stations which service Metra's electric service to the southside of Chicago will be completed in 1992.

3.6.4 Union Station

A major renewal of this historic structure which provides service for approximately 20% of Metra's passengers, is underway. This $33 million project is funded by the RTA, Amtrak, and Chicago Union Station.

3.7 Rail Support Facilities Projects

3.7.1 CTA Facilities

CTA is in the proces of completing the engineering on the replacement of Skokie Shops, its main heavy maintenance facility which services CTA's 1200 car fleet. This $80 million dollar construction project will consolidate the operation under one roof and rationalize the operation of CTA's heavy repairs and component overhauls.

Additionally, the CTA will have completed by the summer of 1993 renewal efforts on five terminals funded at $67 million.

3.7.2 Metra Commuter Rail Facilities

Metra is completing work on Western Avenue Yard, its primary yard for their northwest commuter rail service. This $50 million project is scheduled for completion by the end of 1992.

Metra has also undertaken construction of a new rail yard for their Metra Electric service on the southside of Chicago. This $25 million project will provide for the construction of a maintenance of way facility, and a heavy maintenance facility.

3.8 CTA's Southwest Line Project

By far the most significant public transportation project occurring in the Chicago region in the last decade is the construction of the Southwest Line. This line will provide service to Chicago's southwest side with a terminus at Midway Airport.

The Southwest Rail Line is actually two projects. The first, the line itself, is a $500 million project (construction $410 million, 90 rapid transit cars $90 million) to the southwest side of Chicago. The rail line will have seven stations, require 90 rapid transit cars, and is expected to carry 50,000 passengers each weekday.

In the downtown the Southwest is programmed to operate on the Loop elevated structure. The Loop cannot effectively handle the additional traffic created by the Southwest without rerouting some of the current system. In order to integrate the Southwest with the rest of the CTA system, a second project, the Howard/Dan Ryan linkup, was required. This project totals $164 million and involves the rerouting of the Southside Mainline to link with the Lake Street line, and the rerouting of the Dan Ryan Line to permit a linkage with the Howard Line. The construction includes a new portal for the subway on the southside of downtown to accommodate the Dan Ryan/Howard connection, and reconstruction of Howard Yard on the north side of Chicago to accommodate the increased number of vehicles on that line. The result is a balancing of railcar assignments with ridership. It essentially is a realignment of 40% of CTA's system. The realignment will permit CTA to save 91 railcars, thereby permitting the addition of the Southwest Line without any additional increase in the railcar fleet. Both projects are on schedule for completion in late 1992.

Photo 4. Work nearing completion on CTA's Southwest Rail Line which will service southwest Chicago including Midway Airport.

4. FUTURE INVESTMENTS

A number of public transit proposals are currently being considered by local government officials. Two of the more unique proposals are recapped below:

4.1 Downtown Circulator

In late 1987 the RTA commissioned a study to look at alternatives for improving downtown access. The study and subsequent efforts by the City of Chicago has led to the development of a proposal for a downtown light rail system. The proposed at grade system would connect the expanding northeastern portions of downtown, and the McCormick Place Convention Center on the southeast portion of downtown with Chicago's downtown loop and commuter rail stations. Although specific alignments have not yet been agreed on, the general alignment would provide service from the west loop through downtown to the lakefront where north/south service would be supplied. A second line would operate from the west loop along the Chicago River to the North Michigan Avenue merchants district. Currently, this project has received favorable reception by the Chicago business community, and the City Council has created a tax increment financing district to provide a one-third share of the estimated $750 million project cost. If all goes according to schedule the City of Chicago's downtown will have a new light rail system by the end of 1996.

4.2 Personal Rapid Transit

The RTA has provided $3 million to two contractors to develop competing system designs for Personal Rapid Transit (PRT). PRT, as defined by the RTA, is a fixed guideway system with off line stations utilizing three to five passenger vehicles. Four communities are now being considered as potential sites for PRT. At this point the contractors are finishing their system design proposals and RTA's Board will consider whether to move forward with PRT during 1992.

5. Conclusion

As indicated above, significant investments are being made in rail systems for Northeastern Illinois. However, as outlined by RTA's Strategic Plan, if public transportation is to continue to grow a considerable investment needs to be made in the Region's aging facilities. The ten year capital need is judged to be approximately $8 billion (1990 dollars). The RTA's future capital funding is currently projected to provide roughly $250 million on an annual basis, obviously this will not be sufficient to meet the RTA's long term capital needs.

NEW TRAIN CONTROL TECHNOLOGY APPLICATIONS IN RAILROAD AND TRANSIT OPERATIONS

By: Alex P. Goff* and David Weiss**

Overview

Safety is the prime ingredient which any railroader values above all other concerns; hence the industry accepted phrase "Safety First." New generations of train control equipment are providing a significant improvement in overall safety for railroad and transit operations.

Many new high-technology train control systems are being installed or proposed on railroad and transit properties. This presentation will address some of the important new aspects of traditional signalling technical issues and their impacts on existing and proposed train control system areas. Several advancements related to recent developments in track design methods are discussed in an effort to place the signal engineer and the track engineer on common ground, in lieu of a perceived adversarial past.

In addition, criteria to assist in choosing among several widely different train control technologies has been included to aid in specifying or accepting a bid. Some representative systems are mentioned as information only.

Utilization of tangible gains made in the electronics industry has allowed train control or signalling technology to keep pace with changes in operations requirements and track design, each of which historically has been a driving force behind changes in signalling. Advancements in electronics and systems integration technology have allowed us to get closer to the intended goal of preventing, through automatic notification or intervention, unsafe operational acts from happening.

Increased safety, enhanced operational flexibility, and reduced cost are some of the gains realized by the new technology. Reduction in the incidence of accidents, which can occur whenever people and equipment regularly interact, continues to be a long term goal of the signal engineer. Computerization has added improved overall system capabilities and performance by providing a reasonable means to constantly monitor changing characteristics of all safety related systems and sub-systems.

Other cost benefits of the new technology are realized in the construction and long term maintenance cost savings. Space requirements are generally much less, compared to traditional space requirements for relay equipment. Environmental needs are in some cases more critical, however a single bungalow can house vital and non-vital interlocking and control equipment, and associated heating and cooling equipment.

Microprocessor control of integrated circuit (IC) based vital and non-vital equipment is largely replacing many of the traditional components of relay based signalling, thereby reducing substantially the system installation and maintenance costs. Utilization of the existing fixed plant signalling equipment is possible in many instances to maximize cost benefits in resignalization.

Initially, many railroad lines could not warrant automatic block or a similar form of wayside signal system due to relatively light traffic levels and high installation and maintenance costs associated with traditional signalling. The installation of new "black box" cab signal system equipment will allow more existing dark territory or unsignalled trackage to be cost-effectively signalled, with dramatically reduced installation and associated maintenance costs due to reduced numbers of mechanical components requiring testing and repair. It should be noted that the new equipment requires additional safeguards during installation, repair and maintenance which must be followed such as improved surge and lightening protection, equipment isolation and grounding, and in some cases environmental control—heating and a/c.

The Vital circuit requirements of steel-wheel-on-steel-rail train detection have traditionally relied on consistent and predictable track circuit occupancy or shunting. It is this particular issue of shunting

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which has received much attention, and benefitted from recent technical improvements. Traditional design track circuit equipment provided shunting sensitivity levels of slightly better than .06 ohms, which was generally adequate in moderate to heavy traffic areas due to conditions relative to the actual condition of the railhead. Heavier traffic areas tend to maintain a cleaner wheel/railhead contact area, which allows for relatively predictable shunting.

New increased sensitively or "hot-shunting" track circuit equipment, currently being used on many heavy rail and transit properties, has performed extremely well particularly in those areas formerly experiencing inconsistent shunting. New hot-shunting track circuits routinely provide consistent shunting sensitivity levels of .2 ohms in non-electrified areas, and even higher levels in electrified areas. This increased vehicle detection capability through advanced electronics allows improved track circuit operation on lighter density railroads which had earlier experienced unpredictable or inconsistent shunting due to slightly rusty or otherwise impaired railhead conditions. The term "otherwise impaired" refers to a condition in which non-conductive material is present on the top of the rail.

The presence of foreign material substantially increases the electrical resistance at the wheel/rail point-of-contact. Extensive railhead residue present throughout portions of a track circuit will cause temporary loss-of-shunt conditions. Examples of foreign material which have caused loss-of-shunt situations, and which are commonly encountered along the right-of-way are oil or chemicals such as experienced with right-of-way weed spraying, mill scale on new rail, fallen leaves, locomotive and trackside-applied curve lubricant, excessive sand by on-board sanders, or other similar materials which when compressed, forms a hard coating on the railhead.

Improved track circuit shunting sensitivity levels are important not only on railroads in signalled territory, but also for unsignalled lines employing grade crossing protection equipment. On many carriers, consistent loss-of-shunt at grade crossings requires operating rulebook special instructions requiring all moves to Stop-And-Protect unless it is known that the grade crossing protection is operating properly. Although the new equipment will not fully solve the problem, it is designed to reduce the occurrence of loss-of-shunt, thereby minimizing the incidence of manual train crew protection, or worse, the liability of inoperative grade crossing protection.

On many carriers the use of insulated joints, a known weak link in the track structure, has been minimized at grade crossings and other specific areas on railroads, and in most areas except special trackwork on transit properties through the use of audio-frequency overlay (AFO) track circuits.

Improvements in motion sensor and grade crossing predictor design, in conjunction with new processor controlled track circuits have enabled mixed passenger and freight operation to utilize the same track at differing speeds due to calculated speed/distance warning times. The basis for accurate train speed detection for either of these is consistent shunting throughout the limits of track circuit.

Signal system pole lines on traditional CTC systems have been successfully retired with the use of micro-processor based track and signal circuits, which convey consistent and accurate track condition and signal system information through the rail. By employing extensive fail-safe design practices, such as continual fault tolerance and information transfer review, ballast resistance measurement and comparison to acceptable levels, and stray current detection, superior protection from track component failures is available with low occurrence contingency failures included.

Many modern rapid transit systems have improved on their existing train control systems by providing interactive digitally-based wayside and vehicle equipment. Figure 1 depicts a typical Train Control Communications System block diagram, such as used on the Washington Metro (WMATA) System. The diagram depicts transmission of the field train control data through a redundant 24 channel data terminal to the central control facility terminal, to the processing equipment where it is sorted and verified before transfer to the main computer system.

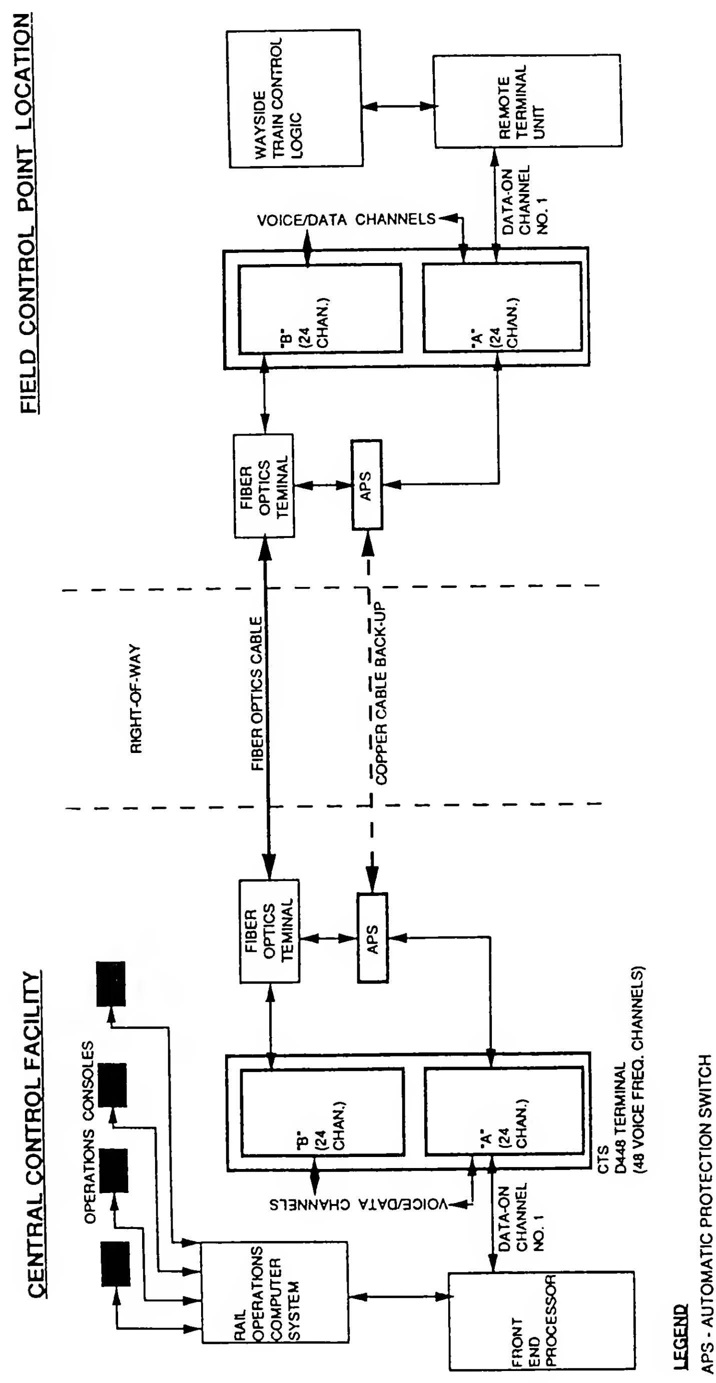

Figure 1.

Typical Train Control Communications System Block Diagram

New field CTC code system equipment for automatic train control systems consisting of vital wayside train control logic, non-vital signal indication logic, microprocessor-based code system and application logic are generally connected to a Remote Terminal Unit (RTU) for data transmission to the central control facility. Interface between the central control facility and the field control point, typically an interlocking or other facility is accomplished through fiber optic cable, with a redundant fiber and/or copper cable as a contingency.

Improvements in the utilization of Vital-Processor Interlocking equipment serve to increase operational flexibility and reduce initial and long-term costs of interlocking construction. Associated technical improvements in communication technology have enabled new custom configured train control systems to be designed for virtually any level of operation. Changes or modifications to the system can be easily handled at the site with the aid of a properly outfitted laptop computer for programming. Grand Central Terminal in New York is currently undergoing renovation with a Vital microprocessor-based interlocking control system.

Each Vital-Processor Interlocking function is based upon the same vital logic as it's relay interlocking relative. Both are dependent on traditional Boolean Algebra derived relay logic circuits. A signal engineer provides equivalent circuits to the software programmer, which can be checked by traditional means. The programmer inputs a series of instructions to the micro-processor, which is supervised internally as it performs predetermined tasks. Much of the micro-processor time and effort is spent checking and rechecking it's own work. It is in this manner, and through redundant internal circuitry, that the software is written in a realm of "certainty" (i.e.—within an acceptable level of probability), and that the repetitive operations required by the software will be accurately performed. Of particular importance in acceptance of processor controlled vital-circuitry is the correct evaluation of each input, and that non-permissive or incorrect outputs are not deemed permissive.

The vital input data is transferred via a secure communications system to a central control facility for processing. Figure 2 depicts a Typical Computer System Architecture within a central control facility. System redundancy is accomplished through the utilization of identical interconnected computers. After several levels of verification, the data is transmitted to the main processors for distribution and display. Verifiable backup is available with disk or cartridge tapes.

The ever-growing speed and capacity of computers, reductions in size and cost, and the ease of networking them to create hierarchial layers have been harnessed for modern transit application. New train control systems, which utilize high capacity wideband communications channels have been deployed primarily on Automated Guideway Transit (AGT) Systems such as in Vancouver, Detroit, and Toronto.

The designer or owner of a new or existing transit system or railroad can choose between several widely differing technologies. Some important questions to ask before specifying or selecting a bid for a particular systems are:

1. Cost—capital, operating life-cycle
2. Service history—What types of installations are currently installed? How has the performance been since inception?
3. Reliability—In-service, predicted versus actual
4. Ease of installation (especially important for replacing older systems, and determine value of existing system infrastructure)
5. Capacity and speed—What headways and running speeds are permitted? How many trains are handled simultaneously?
6. Failure mode and effects—Can impacts be limited or will they create global shutdown? What is required for system restart?

7. Availability of spare parts and second source—Important for proprietary technologies
8. Need for regulation approvals—such as radio frequency assignment
9. Expandability—for future changes, modifications, improvements

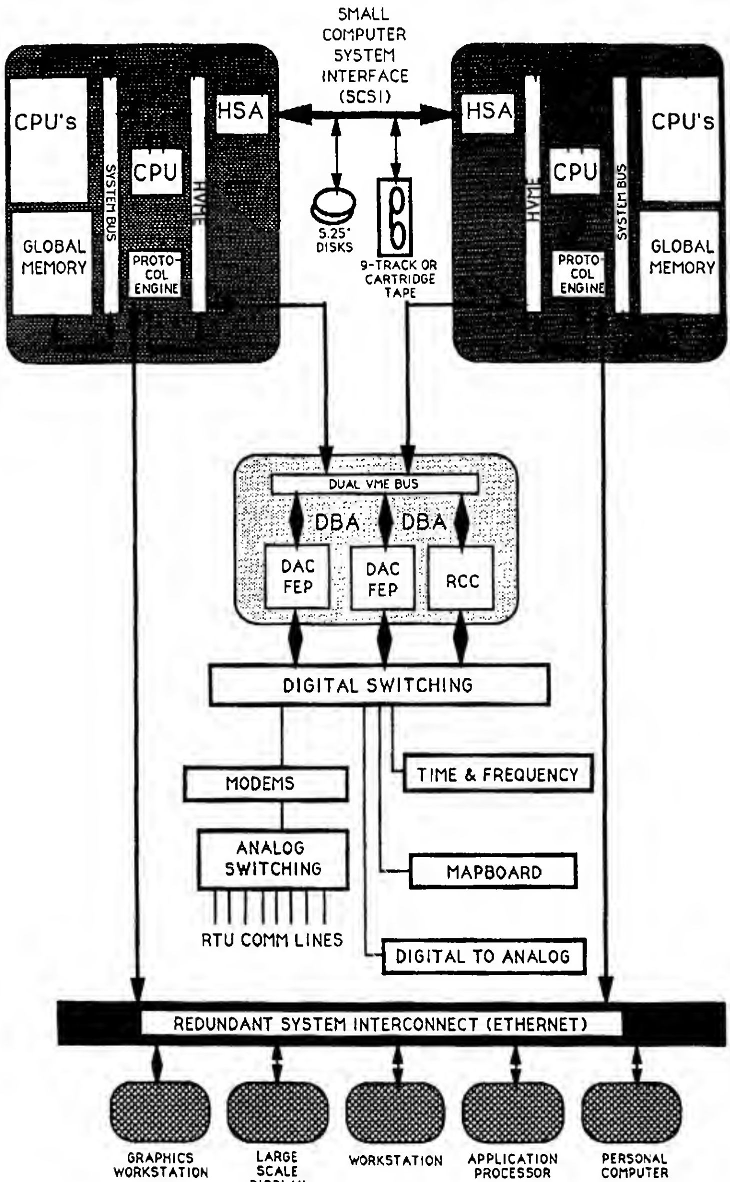

Figure 2.

Typical Computer System Architecture Block Diagram

Computer based moving block systems have been installed on moderate capacity AGT systems in the last ten years. While AGT trains are generally half the size of rapid transit trains, this is not required by or limited by the technology.

These systems are claiming to enable 60 second headways, however, close headways have not been implemented. The Vancouver and Toronto systems operate on just over two minute headways.

A computer based system can result in globalizing failures impacts, if the central processors are not designed to contain the impacts to the specific area which has failed. Contingency planning is essential to any operation. Smaller computer systems which control definite system areas while being controlled by the central processor may provide additional back-up.

A major risk which must be addressed early is the possibility of completely proprietary technology. Second sourcing for most critical path items is advantageous to the owner of a new system. As more similarly configured advanced train control systems are installed, second sourcing won't be as much of a problem due to availability of repair and modification parts and acceptance of the technology.

The centralized nature of the computer-based systems can also limit the total number trains that can be handled successfully. An operational bottle-neck could occur as a result of the communication channel capacity (each train can receive and transmit every second) or in the size of a computer. If special purpose processing computers are used in lieu of a standard format, it may be difficult to simply replace an existing computer with the next later or improved model when system expansion is needed. Contingency planning for system expansion needs is necessary to minimize the changes of problems similar to these occurring.

Special trackwork for railroad and transit needs has again driven changes in new train control system signal design. Examples of trackwork which requires customized signal circuits include increased use and re-design of double slip switches, movable point frogs and new high-speed crossovers. In most cases, multiple switch and lock movements (switch machines) are required to operate the trackwork. Equally complex signal circuits are necessary to regulate the operation and ascertain accurately if and where all of the affected switch parts have moved. Special track circuit design and, if necessary, traction return must be provided throughout these special trackwork areas.

On a recent Amtrak high-speed crossover installation at Grove Interlocking requiring ten switch machines, only five (three switch point, two movable point frog) were designed to be thrown initially due to power constraints. When the first five machines have thrown and properly indicate that condition, the remaining five are allowed to operate. All ten machines must indicate that the crossover is properly lined and electrically locked before a route is allowed over it.

The continued acceptance of new train control technology requires a well trained work force. The traditional signal maintainer with bonding equipment, and a Simpson meter is being replaced with a hybrid maintainer/electronic technician. Another level of electronic specialist is required for the programming functions and maintenance of the control system equipment.

A quiet, yet important benefit of the new technology may just be that the traditional adversarial relationship; between the signal engineer, the Engineer of Track, and operations personnel is also being replaced with the equipment. The back-to-basics approach wherein required improvements in one area will drive the technical improvements in another will always be prevalent in railroading. Inter-discipline communication is the key to continued progress in safety areas.

PUBLISHED AS INFORMATION

COMMITTEE 1—ROADWAY AND BALLAST

Chairman: Walter L. Heide

Comparing the Long Term Effects of Chemical and Mechanical Brush Control

By: David A. Breedlove, Harvey A. Holt, George R. Parker, T. F. Sheahan

Introduction

In much of Eastern North America, railroads are built in what would be forests. This tendency of nature to reclaim rights-of-way with woody vegetation forces us to resort to manual or mechanical cutting to achieve proper visibility and clearance on both sides of the track. This clearance is not achieved cheaply. Moreover, no sooner has a brush cutting machine completed its assignment, than the cut stumps, stems, or twigs of deciduous trees are already resprouting below the cut. In some cases eight to ten feet of regrowth is possible in the first season. The appearance in the third season may be as bad or worse than the condition that originally warranted cutting.

To those familiar with the effects of brush-active herbicides, it has long been obvious that treatment of cut brush (by manual stump treatment, or delayed broadcast spray) will dramatically reduce the degree of regrowth. An ongoing study by the Purdue University Department of Forestry and Natural Resources with monitoring by A.R.E.A. Committee 1. Subcommittee 9, is helping to quantify such reduction. This article draws attention to the findings, and evaluates the implications for railroad management.

The test site located west of Bloomington, (MP 66-75) in south central Indiana, was provided by the Indiana Rail Road Company, Indianapolis, Indiana. The railroad was acquired from the Illinois Central Railroad in March, 1986. Until that time the right-of-way had been treated with standard practices of the Illinois Central Railroad, which included herbicides for controlling woody plants. The entire railroad was mechanically cut with a Kershaw double rotary head mower December, 1987 to April 1988 by personnel of the Indiana Rail Road Company. The mower reached a distance of 25 feet from center of track. This study was concerned with vegetation occurring in the zone 9 to 25 feet from center.

Methods and Materials

Test plots were 16 feet wide and one mile long (2 acres/mile) with treatments randomly assigned to these mile-long plots. Each treatment was applied to four plots, two on each side of what generally is the north and south side of the right-of-way. Before the herbicide treatments were applied, a set of 20 permanent sample plots, 3.3 feet wide and 13.2 feet long (0.001 acre each), were established perpendicular to the rail in each test mile.

Sample plots were established systematically along the right-of-way, 264 feet apart and inventoried in July/August, 1988 when the cut vegetation had resprouted for one growing season. The percent cover of bare ground and plant species was determined for all sample plots. Woody plant data also includes species, frequency, and height. This inventory was repeated in July/August, 1989 and 1990.

Treatments

1. Mechanical cutting only: Track mounted brush mower applied December, 1987 to April, 1988.
2. Selective herbicide with residual soil activity: Tordon K + Garlon 3A (3 pints + 4 pints/acre) applied June 9, 1989.

3. Nonselective herbicide without residual soil activity: Roundup (5 quarts/acre) applied September 4 and 22, 1988.
4. Nonselective herbicide with residual soil activity: Arsenal (3 pints/acre) applied September 22, 1988.

The mechanical cutting was done by the Indiana Rail Road as previously described. The herbicide treatments were applied by Purdue University to vegetation which had been cut during the winter of 1987-88. Herbicide treatments were applied with a Radiarc Sprayer in a total volume of 40 gallons per acre. The Radiarc Sprayer was mounted to produce a vertical spray pattern.

Results

The response of woody vegetation to the three herbicide treatments was very similar, and very different from the mechanical cutting treatment, as measured by stem density (Table 1, Figure 1) and average stem height (Table 2).

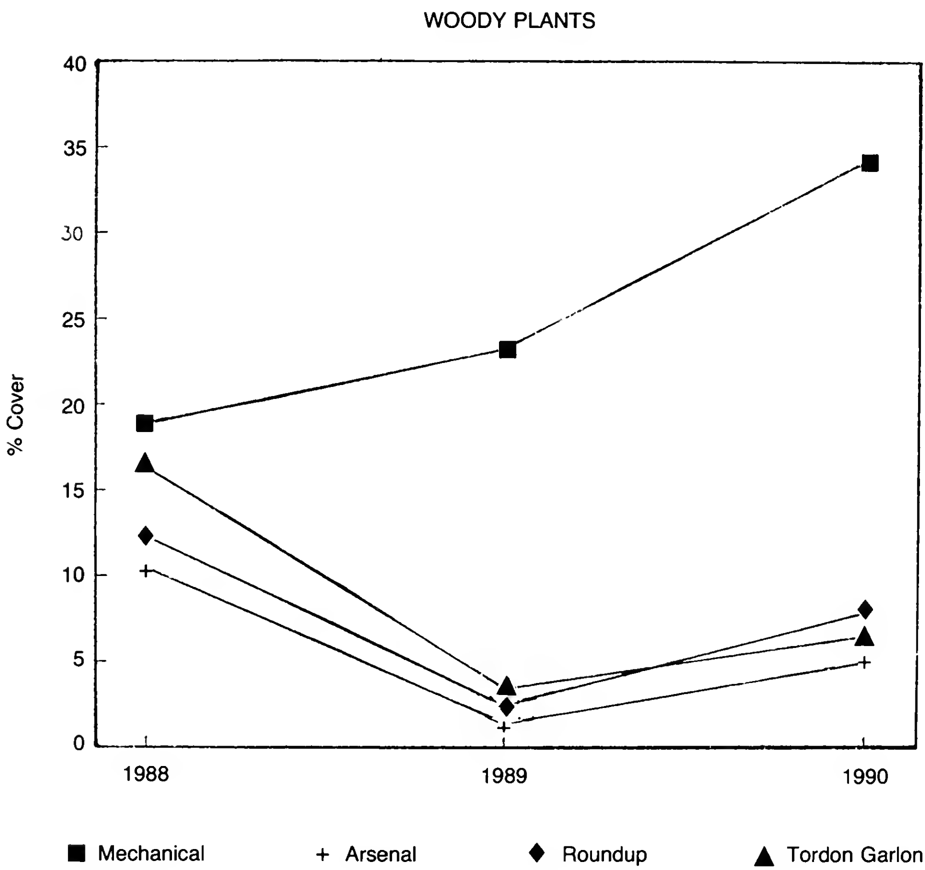

Figure 1

Table 1
Woody Plants: Stems/Acre

	1988	1990	% Change
Mechanical	4,621	4,930	6
Arsenal	2,303	1,376	-40
Roundup	3,075	2,011	-35
Tordon/Garlon	3,714	1,667	-55

Table 2
Woody Plants: Height (ft)

	1988	1990	% Change
Mechanical	4.6	5.1	12
Arsenal	5.1	4.2	-17
Roundup	4.6	3.9	-16
Tordon/Garlon	4.6	3.4	-28

Discussion

It is difficult for a photograph to do justice to the actual difference in appearance between the treated and untreated cut brush plots in this study. After three years, the untreated areas are dense enough to obscure visibility of the ground beneath them. The treated areas are still open with plenty of herbaceous growth, and occasional leafless branches and stems remaining from the herbicide treatment a year and a half before. Interestingly, there is little difference between the three herbicide treatments, Roundup, Arsenal, and Tordon/Garlon. All were used at recommended rates and at roughly similar costs per acre. All achieved an impressive reduction in regrowth.

Table 1 and Figure 1 show that the number of stems per unit area for all three treatments were less than one-half of what they would have been had they remained untreated. Moreover, Table 2 shows that the average stem heights were also reduced by about one-third.

It seems reasonable to suppose, then, that the total reduction of growth in the treated plots must be greater than either of the two measurements would indicate. This substantiates the visual impression that the quantity of woody material is only a fraction as great in the treated plots. It seems reasonable to further suppose that the eventual interference with rolling stock will be much sooner and more extensive in the untreated areas.

The above figures suggest that it will take two or more years for the treated plots to approach the density and height of the untreated brush in 1990. Only further measurement will determine just how much time and savings have been obtained by this rather inexpensive follow-up to a cutting program.

In the meantime the savings could be estimated in the following way. If the 1990 per mile cutting cost is $1500, (CSX estimates) and the effects last through three years, the average cost would be $500 per year. If a chemical treatment costs an additional $300 but adds two years to the control-life, a total of $1800 would be spent over 5 years for an average of $360 per year. This results in a savings per mile per year of $140. For every thousand mile cut, a railroad might realize $140,000 per year!

In this era of reduced maintenance budgets, one would think that railroads would be quick to notice and spend one dollar so that they could save three or four dollars two years from now. An informal poll of subcommittee members suggests that this sequencing of methods is by far the exception rather than the rule. One can only wonder at how many millions of dollars are being spent needlessly because the brush spray program has not been coordinated with cutting, or simply been underfunded.

1. Sheahan, T. F., "The Cost of Brush Clearance." Proceedings of the 100th Annual Conference of the Roadmasters and Maintenance of Way Association of America, 1988, pp. 145-6.

COMMITTEE 16—ECONOMICS OF PLANT, EQUIPMENT & OPERATIONS

Chairman: M. W. Franke

FACTORS TO BE CONSIDERED IN DISPATCHING OFFICE CONSOLIDATION

Subcommittee Chairman: R. W. McKnight

The factors to be considered would include those in the following broad areas: Human, physical, operational, technical and economic.

HUMAN FACTORS would, of course, be the people involved: dispatchers, operating personnel, such as train crews, trainmasters and superintendents. Others in this category would be signal department, maintenance-of-way and communications department personnel; and others who might have need to be on the right-of-way or track.

PHYSICAL FACTORS would include the buildings housing the dispatchers; the railroad territory itself including number of main and branch line tracks, number and severity of grades and curves; and bridges and tunnels.

OPERATIONAL FACTORS would include number of trains operating in a dispatcher's territory in a given period of time, say an 8-hour shift or trick; the type of trains, such as through, local, industry runs, yard transfers, passenger trains; the types of commodities carried (including hazardous materials) and high, wide or special loads. Also to be considered is the type of operation, such as manual block, timetable and train orders, centralized traffic control, and track warrant system, for example.

TECHNICAL FACTORS should include items of safety and security for the dispatchers' headquarters. On the communications side, one should consider fiber optic cable, radio and microwave, for voice and data transmission between the dispatcher and control points, moving trains and personnel on the right-of-way. Also included would be the alternative communications required in case of failure of the main systems. Additionally, one should include signal systems and safety detectors in the movement of trains over the territory; for example, automatic block signaling, centralized traffic control and interlockings. Safety detectors that inspect moving trains and wayside condition detectors should be included. And, last but not least, are the myriad computers used in today's railroad operations, not only at the dispatching headquarters but those associated with signal systems in the field.

Communications

The major item in dispatching is communications, not only for the transmission of controls and indications for centralized traffic control, also interlockings or other signal facilities, but also the voice and data communications to and from train crews, m/w forces, signal maintainers and supervisors out in the field and on the line of road. Whether centralized or decentralized, communications is the most important factor in the successful operation of a railroad. However, when communications fail, the impact on the system operation might well be less if decentralized dispatching were in operation.

One factor to be considered with alternative or fall-back communications routes is to have adequate capacity to handle the traffic volume (data and voice) on these alternative or fall back routes. This is important to determine especially if a communications common carrier which has other demands on its capacity, is one of the alternative routes. Also, one must determine the minimum acceptable level of communication to be available when the main system fails.

ECONOMIC FACTORS cover all of the above as to costs to install and maintain equipment, buildings, communications and signal systems and facilities, as well as payroll costs of the people involved. Also to be considered are delays to trains, maintenance-of-way and signal personnel when attempting to call the dispatcher.

The revenue aspect, although it is the most difficult to quantify, deserves particular emphasis. Recently "just-in-time" management of materials has received much publicity. Of course, "just-in-time" operation is nothing new, as the railroads moving automobile parts well know.

If railroads are to keep and expand their participation in the "just-in-time" operations of manufacturing, they must provide reliable, scheduled service.

From the discussion so far, it can be seen that it will take careful observation and judgement to determine with reasonable confidence how to divide the railroad into dispatching territories each of which a dispatcher can most efficiently handle in periods of high activity and how to combine these territories for control by fewer dispatchers in periods of less intense activity.

Centralized or Decentralized Dispatching Offices

Do we locate the control of all these territories, and the dispatchers, in one central office, or in a few offices around the system, or in separate offices for each territory? Are there even territories smaller than the maximum which can be efficiently controlled by one dispatcher which warrants local dispatching control?

Except for this last situation, the matter of dispatching office location does not affect the number of dispatching positions, and it will only rarely be desirable to designate a dispatcher's territory smaller than maximum efficiency demands.

In times past, it may have been desirable to locate each dispatcher's office in the territory he controlled. With today's improved communications capabilities such dispersal of dispatching points aren't as necessary. Modern communications makes it more feasible to consolidate dispatching at a few locations or even one (with telegraph and telephone it has always been possible to do this but years ago it was probably inconvenient, expensive and even unreliable).

At least some degree of consolidation of dispatching points offers advantages although the expense and the impairment of reliability, while less than in the past, must still be considered. Communications facilities cost money and still are subject to interruptions. Microwave towers may be blown over or hit by airplanes. Fiber-optic cables may be cut. At least some degree of consolidation permits reduction in duplication of apparatus, no small matter when computers are installed. Some degree of consolidation also facilitates contact between dispatchers of adjacent territories. Dispatchers sitting next to each other even overhear their 'neighbors' reports and orders. One dispatcher can be the relief for more than one territory. This can be done without consolidation but requires travel on the part of the relief dispatcher.

Committee Surveys Railroads

In a survey of railroads ranging from small to medium and large, it was found that about half of them have centralized dispatching at a headquarters location. It should be noted that a railroad with centralized dispatching may have separate dispatching offices covering large terminal areas or joint facility operations with another railroad.

As for the physical facilities at the dispatching center, there are several items on which those who centralized and those who decentralized have found agreement.

In general, the dispatching center building will have the following:

—Security system
—Sprinklers
—Smoke detectors
—Halon spray for fire in computer room
—Standby or alternative power sources
—Communications in general
—Adequate water supply
—Air conditioning
—Computers for communications, signaling (ctc or interlockings), train movement (train orders, manual block or track warrants), record keeping, standby computers for the above functions, and

safety storage for computer information. Survey respondents also said they have data storage remote from the dispatching center building.

As to the location of the dispatching center in the same building as the operations headquarters of the railroad, practice is almost equally divided as between being in the same building or not. If not in the same building, then direct communications is provided between the dispatching center and the operational headquarters. The above applies equally to centralized and decentralized dispatching, according to the survey.

Optimum Size of Territory

A determination is to be made is the optimum size of a dispatcher's territory. But that size varies with conditions. Not only can more trains be run on two tracks than on a single track, but the demands on the dispatcher are less, especially where there are few overtaking movements. In some places the dispatcher controls train movements by signal indications through oral instructions to interlocking operators; in others the dispatcher controls the switches and signals directly. There is still a great mileage of single track with automatic block signals but without centralized traffic control, or single track with no signals at all, sometimes known as "dark territory." In the case of single track automatic block signaling of dark territory, use is made of train orders or some form of radio control of train movements which make substantial demand on the dispatcher's time and attention. Thus, trackage alone is not the only criteria for determining size of dispatcher's territories.

With any of the foregoing systems, the burden on the dispatcher can presumably be lightened through the assistance of computers, but it cannot be eliminated.

If a dispatcher's attention is spread over the largest feasible territory, maintenance forces and trains will have to wait their turn; he can only note one happening, hear one request, or give one order at a time. On some railroads today, a train crew or a maintenance foreman may have to wait as much as 15 minutes to speak to the dispatcher. A 15-minute delay may have a multiple effect. If a signal maintainer inspecting a switch finds the need to keep it out of service longer than expected, the dispatcher if promptly notified, may switch an approaching train to another track. Without prompt notification, because he is busy with other parts of his territory, the dispatcher lets the train be delayed, perhaps an hour or more until the maintainer can get the switch back in service.

Delays to maintenance and inspection forces cost time of employees and equipment. Delays to trains cost crew time, locomotive time and car time and track capacity. All of these are money costs and increases in operating expenses. Less measurable, but worse is the impairment of service which costs shippers money. If service is slow or irregular, new shippers will not be won and old shippers will be lost. Even ignoring the most important consideration, the effect on revenue, it doesn't take much crew and maintenance overtime and equipment rental and car hire to pay a dispatcher's wages and fringe benefits.

Dispatchers and Territories

Concerning the number of dispatchers employed, survey information varied by some general principles applied to both centralized and decentralized dispatching. All railroads except one reported the first trick as having the heaviest work load per dispatcher. Along with this, the greater number of dispatchers were employed on first trick under the centralized and decentralized dispatching function. The railroad reporting third trick as having the heaviest work load per dispatcher had more dispatchers on duty then than for the first and second tricks.

In large consolidations, generally speaking, the territory covered by a third trick dispatcher is greater than that covered by either first or second trick (with that one railroad exception noted above). At some of the regional or district dispatching centers, not all third trick dispatchers have more territory to cover than do first or second trick dispatchers.

All reporting railroads have relief and chief dispatchers, although one road has the chief dispatcher function handled by an individual with a different title.

Concerning the individual dispatching function for one dispatcher for 8 hours, there was general agreement by both centralized and de-centralized dispatching railroads. A dispatcher's territory ranges from 100 to 400 miles of road, predominantly single track. Some dispatchers have a yard within their territory. Trains range from 50 to 25 per 8 hours, with one railroad handling up to 100 trains in 8 hours over equal portions of single and double track.

As might be expected, when it comes to determining the number and types of trains handled by a dispatcher, the informaion varies widely by railroad, its traffic mix and dispatchers' territory. Survey results are not specific except that three types of trains predominated, namely, through, local and unit trains.

On-Track Time and Limits

For protecting track work and on-track equipment, there was agreement of centralized and decentralized railroads. They all use train orders, manual block, direct traffic control or track warrants, and centralized traffic control. No one has, as yet, used advanced train control for protection of the track work function.

As for type of dispatcher communications, all railroads surveyed agreed regardless of having one or more dispatching centers that essential communications must include voice radio, telephone, intercommunications (voice intercom), and facsimile. Also, they agreed that telegraph and teletypewriter (with one exception) are no longer used for dispatching purposes.

Railroads are using computers at all centralized dispatching centers and at most regional or district dispatching centers.

All agreed that the dispatcher should issue line-ups of train movements. One railroad reported that this function is handled by the chief train dispatcher.

As for issuing all line-ups, all railroads surveyed said the dispatcher uses voice; some use facsimile transmission to send the information to connecting railroads. In most dispatching centers, a computer may be used by the dispatcher to generate and transmit line-ups.

All railroads replied that the dispatcher handles calls from train crews. On one railroad, a communications coordinator may receive calls from train crews.

Also, all railroads replied that requests for on-track time and limits are received by the dispatcher who also issues them. This function involves m/w forces, signal forces, operating personnel, mechanical personnel and any type of on-track operation.

Dispatcher's Work Load/Time

As for the amount of time or percentage of a dispatcher's time spent on specific functions, there are variations due to train volumes, m/w activities, territory and the trick he is working. Railroads answering the survey were in general agreement that m/w activity is heaviest on the first trick. While not giving any percentage figures on time spent answering calls, one railroad reported that a typical dispatcher handles 10-20 calls per hour in an 8-hour day.

Here are survey results of the percentage of time dispatchers spend handling the following:

Function	Centralized	Decentralized
Line-ups	5	10
On-track time and limit requests	15	15
CTC operations	15	15
Issuing train orders	10	5
Issuing track warrants or equivalent	20	20
Train sheet recording	5	5
Other record keeping	5	5
Calls from other dispatchers	5	5
Calls from train crews	10	10
Other calls	10	10

The only variations shown above are in more time spent handling line-up calls in decentralized dispatching centers, due one road said to handling of m/w activities on a regional rather than system basis. On the train order side, one centralized road said it had no train order territory in one of its regional dispatch centers, but on centralization such territories came into the one central location.

In both centralized and decentralized dispatching, considerable use is made of telephone, facsimile, radio and intercom communications.

Centralization

Proponents of centralization point to the economics that favor such action. They cite that facilities are constructed at only one location, hence no need for two or three sets of equipment or facilities. For example, buildings including power sources and security and computers to operate displays, provide work stations, process data and handle communications are needed at only one location.

All communications lines can come to one location, which can make it easier to provide redundant or alternative feeds.

The biggest savings usually comes from a reduction in the number of dispatchers required to handle the work load, although carefully chosen regional dispatching offices should ideally require no more dispatchers than one central office.

Centralization can also bring closer coordination with the operating and other departments of the railroad, especially if the dispatching center is located at the railroad's headquarters.

A major reason for consolidating all the dispatching of a large railroad in one office seems to be philosophical: the trend toward centralized management. Centralized management does offer consistency and closer control of operations. It is, however, contrary to modern management theory, which favors decentralization, giving local managers more authority and judging them by results, not telling them in detail what to do or "micromanage" them.

Concerning other functions handled at the dispatching center, survey results indicated that those having centralized dispatching are in agreement. They have crew calling, locomotive dispatching and train and engine payroll in the same location as dispatching.

One railroad with centralized dispatching also handles timekeeping for mechanical and maintenance-of-way forces at the dispatching center.

For the centralized dispatching function, the same number of dispatchers were employed both daily and on weekends.

The survey also showed that for centralized dispatching, direct traffic control, ctc or a form of manual block are used. One railroad with centralized dispatching still has some timetable and train order territory in service.

Only one railroad reported developing an advanced train control system.

Concerning keeping operations headquarters fully informed about dispatching, those with centralized dispatching centers reported that in most cases operations and dispatching are in the same building, sometimes in the same room or on the same floor. Where they are in different buildings in the same city, computers and communications provide direct links between dispatching and operations headquarters.

Decentralization

For some railroads, decentralized management is especially appropriate. Division officers and employees know the local shippers and potential shippers and their needs can tailor service to meet those needs. This, of course, is one of the touted advantages of short lines, but large railroads can exploit it too. A dispatching office at division headquarters is an important tool helping the superintendent and his entire "team" provide service tailored to the needs and desires of the customers.

Those in favor of decentralization point out that in case of failures, the loss of the dispatching function does not knock out the entire railroad.

Much of the advantage of consolidation can be achieved, on a large railroad, by grouping dispatching offices into a few strategic points without pulling them all into one central office. The advantages of computer-aided dispatching lead to the thought that several dispatching points require several computers instead of one. Since each of the several computers can be of lower capacity than one central computer, the economy of concentration may not be as great as would first appear.

The single central dispatching computer can be linked to the railroad's main computer or management information system to feed in train performance data, car location and waybill data, for example. But a computer at each of several dispatching centers can also be linked to the main computer or MIS system with lower capacity communications requirements than with centralized dispatching. Dispersed dispatching offices and computers may actually facilitate passing train information to the yards that receive the trains.

A major advantage of having several dispatching offices is that they can be placed at regional, district or division headquarters. The regional, district or division officer has direct knowledge and control of the operations for which he is responsible. His subordinates, the trainmasters, can readily check with the dispatchers before going out on the road or while they are out. The people whose work must be coordinated will know each other. Dispatchers will have the opportunity to become familiar with their territories without excessive travel time. Indeed, the requirement that each dispatcher ride over his territory in a locomotive cab on a regular basis can actually be implemented, and probably at less cost compared to having all dispatchers at a central location.

According to the survey, the railroads choosing decentralized dispatching had from 4 to 10 dispatching centers at regional, district or divisional headquarters. Also, it was reported that some regional dispatching center handle as much or more territory than a centralized center of a smaller railroad. The survey also showed that for decentralized dispatching, fewer dispatchers were employed on the weekends than for the daily operation.

Those having decentralized dispatching generally have crew calling at the dispatching center. Most decentralized dispatching railroads handle locomotive dispatching and train and engine payroll at another location, each at the railroad's operational headquarters. At some regional or district dispatching center, car control may be handled at this location.

Concerning the type of train control or movement authority, decentralized dispatching railroads report using all of the below mentioned types of authority at some dispatching centers:

- Timetable and train orders with or without block signals; manual block; direct traffic control or track warrants; centralized traffic control; interlockings or advanced train control.

- Decentralized dispatching centers are usually connected via computer and communications networks to the operational headquarters computers, and in many instances, the dispatching center information is fed directly into the railroad's management information system.
- At regional or district dispatching centers, someone, usually the director or officer in charge is responsible for keeping operational headquarters informed about the dispatching function and operations.

COMMITTEE 24—ENGINEERING EDUCATION

Chairman: J. W. Orrison

Report of Subcommittee C1-1-82: Recruiting

Subcommittee Chairman: L. J. Hoffman

A survey of MW&S Chief Engineers concerning college graduates hired in 1989, 1990 and 1991 has been completed. Replies were received from 9 of the 18 railroads requested to furnish information.

During 1989 there were nine graduates employed. During 1990 there were four graduates employed. During 1991 there was one graduate employed.

Table 1 summarizes the type of degree and major course of study for the employed graduates.

Table 2 is a summary of schools represented by the graduates employed.

During 1989, five of nine responding railroads employed at least one graduate. One graduate was employed by each of four railroads, and five graduates were employed by one railroad. The average number employed by hiring railroads was 1.8. One of the graduates hired had prior railroad experience.

During 1990, three of nine responding railroads employed at least one graduate. One graduate was employed by each of two railroads, and two graduates were employed by one railroad. The average number employed by hiring railroads was 1.3. One of the graduates hired had prior railroad experience.

During 1991, one of nine responding railroads employed a graduate. The hired graduate had no prior railroad experience.

Employment of Electrical Engineers decreased from a previous high in 1986 of 12, to three in 1989, three in 1990 and none in 1991. Civil Engineer employment decreased from a recent high in 1988 of 13, to five in 1989, three in 1990 and one in 1991.

The average monthly salary of the graduates employed is provided in Table 3. Salaries reported by U.S. railroads included a high of $3,000 and a low of $2,250 per month for 1989; a high of $2,540 and a low of $2,250 per month for 1990; and $2,625 per month for the 1991 graduate.

A Co-op program was provided by one railroad in 1989 with the company sponsoring four students. The sponsoring railroad paid a salary of $2,000 per month. The railroad sponsored Co-op students selected from two universities. Salary information is shown in Table 3. There were no Co-op student programs reported by the responding railroads in 1990 and 1991.

Table 4 is a summary of schools represented by the Co-op students employed.

Summer employment was not provided by any of the responding railroads in 1989, 1990, and 1991.

Table 1

Degrees and Major Courses of College Graduates Employed by Railroads

	Number of Graduates									Distribution					
										1989		1990		1991	
Degree	'83	'84	'85	'86	'87	'88	'89	'90	'91	U.S.	Can.	U.S.	Can.	U.S.	Can.
B.S.	30	84	45	43	7	17	9	4	1	9	0	4	0	1	0
M.S.	1	5	4	0	0	0	0	0	0	0	0	0	0	0	0
B.A.	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
A.S.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Total	31	90	50	44	8	18	9	4	1	9	0	4	0	1	0

Major Courses of Study

Degree	Number of Graduates '83	'84	'85	'86	'87	'88	'89	'90	'91	Distribution 1989 U.S.	1989 Can.	1990 U.S.	1990 Can.	1991 U.S.	1991 Can.
Civil Engr.	22	57	45	23	1	13	5	3	1	5	0	3	0	1	0
Elec. Engr.	3	15	1	12	6	3	3	0	0	3	0	0	0	0	0
Business	0	4	1	1	0	0	0	0	0	0	0	0	0	0	0
Engr. Tech	1	3	1	1	1	0	0	1	0	0	0	1	0	0	0
Constr. Engr.	2	3	1	3	0	0	1	0	0	1	0	0	0	0	0
Transportation	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Engr. Physics	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Computer Science	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Other	3	7	0	3	0	0	0	0	0	0	0	0	0	0	0
Total	31	90	50	44	8	18	9	4	1	9	0	4	0	1	0

Table 2
Schools of College Graduates Employed by Railroads

	1989	1990	1991
University of Arizona	1		
Syracuse University	1		
Kentucky State University	1		
Morgan State University	1		
West Virginia Institute of Technology	1		
Virginia Polytechnic Institute and State University	1	1	
Florida A & M University	1	1	
Pennsylvania State University	1		
Lehigh University	1		
Clemson University		1	
Drexel University		1	
Purdue University			1
Total	9	4	1

Table 3

Average Monthly Salaries

Categories	American - U.S. $ '86	'87	'88	'89	'90	'91	Canada - Canadian $ '86	'87	'88	'89	'90	'91
College Graduates												
Overall Average	2223	2231	2487	2717	2432	2625	2447	2387	—	—	—	—
Bachelor												
—w/Prior Experience	2297	—	2713	3000	2250	—	2387	2387	—	—	—	—
—w/No Experience	2220	2231	2400	2681	2492	2625	2573	2387	—	—	—	—
—Civil Engineer	2137	2100	2447	2671	2402	2625	3153	—	—	—	—	—
—Electrical Engineer	2380	2301	2500	2887	—	—	—	2387	—	—	—	—
Co-op Students												
Overall Average			1701	2000	—	—						
—Civil Engineer			1662	2000	—	—						
—Electrical Engineer			1795	2000	—	—						
Summer Students												
Overall Average			1569	—	—	—						
—Civil Engineer			1569	—	—	—						
—Electrical Engineer			1569	—	—	—						

Table 4

Schools of Co-op and Summer Students Sponsored by Railroads

School	1989 Co-op	1989 Sum.	1990 Co-op	1990 Sum.	1991 Co-op	1991 Sum.
Texas A & M University	1					
University of Houston	3					
Total	4	—	—	—	—	—

THE EFFECT OF IMPROVED RAIL MANUFACTURING PROCESS ON RAIL FATIGUE LIFE

By: Allan M. Zarembski Ph.D., P.E.*, Joseph W. Palese M.C.E.*, John H. Martens**

Introduction

The recent trend in rail manufacturing has focused on the development and manufacture of "clean steel," which has been defined as steel with a significantly reduced level of inclusions. This trend has been in response to the increasingly severe loading environment that today's rail is subject to, together with an increasing emphasis on reduction in rail failures (defects), and a corresponding increase in the rail's service life, particularly under conditions where fatigue is the dominant mode of service failure. As a direct result of this, steel manufacturers have been upgrading their steel making process to eliminate inclusions and impurities that could result in rail defects.

This trend has been accentuated by recent indications of a relationship between increased rail cleanliness and a reduction in the development of fatigue defects in the rail [1, 2]. However, this relationship appears to be quite complex, depending on the definition of rail cleanliness (using such techniques as the ASTM-volume fraction of oxide inclusions or the total length of oxide stringers [3]), the type of inclusions, as well as other metallurgical properties such as rail hardness [2].

However, data showing a direct correlation between changes ("improvements") in manufacturing process, aimed at increasing the level of cleanliness, and reduction in the level of rail fatigue defects in service, has been extremely limited. The purpose of this report is to present two such sets of data relating the in service performance of rail, made by one rail manufacturer, Bethlehem Steel Corporation, to changes in the rail steel making process. These two sets of data represent actual fatigue defect histories on two major U.S. railroads under a broad mix of traffic.

The objective of this activity was to analyze the performance and behavior of standard carbon rail and fully heat treated rail produced by Bethlehem Steel Corp. and to define the relationships between performance, specifically development of fatigue defects, and manufacturing process and practice as defined by the time period of rail manufacture.

Collection of Defect and Rail Manufacturing Data

The emphasis of this activity was on the evaluation of specific railroad performance data for rail steels in representative U.S. freight railroad service. In order to achieve these results, two major Class 1 railroads were asked to participate in this study:

Burlington Northern Railroad
CSX Transportation

Each of these two railroads was asked to provide rail performance data, to include rail defect histories, for a defined set of time periods, corresponding to distinct manufacturing process changes. Table 1 is a listing of the specific rail defect and performance data requested from each railroad.

Table 1

Failure History:	Railroad Track and Traffic Information:	Rail Information:
Detected defects	Tonnage (annual, cumulative)	Manufacturer
Service break	Location	Rail section
Derailment	Curvature	Roll date/Install date
Other	Other	Date found
		Rail metallurgy
		Other

*Zeta Tech Associates
**Bethlehem Steel Corporation

Selection of the study time frames was a key issue, in that the study time frames had to be long enough to allow for a significant population of rails to be manufactured and placed in service, yet recent enough to reflect the most modern generation of rail manufacturing practices. After a careful evaluation of these manufacturing processes, a base period and three process change periods were defined by Bethlehem Steel, as shown in Table 2. These selected study periods encompassed the time period 1987 to 1990.

Appendix A presents an overview and a detailed description of the manufacturing process changes corresponding to these four study periods. Appendix B presents a comparison of micro cleanliness results (type B Alumina inclusions), for the Before and After period.

Table 2. Bethlehem Steel Corp. Manufacturing Process Changes

Process Period	Time Frame
Base Period	1987
	1988 (1-8)*
Transition Period	1988 (9-12)
	1989 (1)
Process Change Period #1	1989 (2-8)
Process Change Period #2	1989 (9-12)
Process Change Period #3	1990 (1-3)

*(1-8) refers to months January (1) through August (8).

Upon receipt of the railroad data corresponding to the above time periods, it was decided that these periods should be consolidated into two distinct periods, in order to provide for a sufficient sample of rail data, and to allow for time, in service, to develop defects. The resulting two periods are referred to as the "Before" and "After" periods and are illustrated in Table 3.

Note; it was assumed, for the purpose of this study, that any rail produced during the transition period 1988 (9-12) would not be laid until 1989 therefore resulting in no defects occurring in 1988. Therefore the analysis was performed for the following periods:

Before (1987/88):	Base period
After (1989/90):	Process change

These periods will be referred in the above manner throughout the remainder of this paper.

Table 3. Bethlehem Steel Corp. "Before" and "After" Periods

	Process Period	Time Frame
Before	Base Period	1987
		1988 (1-8)*
	Transition Period	1988 (9-12)
		1989 (1)
After	Process Change Period #1	1989 (2-8)
	Process Change Period #2	1989 (9-12)
	Process Change Period #3	1990 (1-3)

*(1-8) refers to months January (1) through August (8).

After collection, sorting, and preliminary evaluation of the defect data, it was decided that a Weibull analysis of the defect data, by railroad and process period (Before/After) would provide the most effective means of evaluating the defect data, and of projecting that defect data to determine the long term fatigue (and thus rail life based on fatigue) performance of the rails. The specific analysis procedure used is presented in the following section.

Analysis Procedure

In order to analyze the performance and behavior of Bethlehem Rail on the Burlington Northern Railroad and CSX Transportation, the following procedure was developed and implemented:

(1) Collect defect (rail fatigue failure) data for the time period 1987 to 1990.
(2) Sort defect data by manufacturer.
(3) Sort defect data by year installed.
(4) Sort Bethlehem data by metallurgy
(5) Perform cluster analysis on each metallurgy type.
(6) Obtain cumulative tonnage data for defects.
(7) Perform defect data analysis.

Specifically, the following activities were performed:

(1) Collect defect data for the study period

Defect data in the form of rail fatigue defects, occurring during the time period 1987 through 1990, and corresponding to the manufacturing (study) periods noted above, was collected from the two study railroads. Using the full set of defect data and information obtained from the two railroads, a defect data base was compiled, containing the data shown in Table 4. Note; differences between the two sets of databases correspond to differences in the data records maintained by the railroads.

Table 4. Defect Database For Each Railroad

Burlington Northern	CSX Transportation
Line segment number	Division
Mile post	Subdivision
Defect type	Prefix
Rail manufacturer	Mile post
Rail steel	Class (main, siding, other)
Year rolled	Track (single, East,...)
Date found	Direction
Annual MGT	Curve (high or low rail)
Amt. steel purchased	Detection car/Service
	Defect type
	Rail manufacturer
	Rail steel
	Year laid
	Date found
	Date changed
	Annual MGT
	Amt. steel purchased

Since the intent of the study was to focus on defects associated with the rail manufacturing process, the defects used in the study were limited to fatigue defects only. Non-fatigue defects, such as bolt hole breaks, engine burn fractures, and weld defects were not included in the analysis.

(2) Sort defect data by manufacturer.

Since the study was limited to Bethlehem rail manufactured during the study period, the defect database for each railroad was sorted by manufacturer, and only Bethlehem steel data was retained.

(3) Sort defect data by year installed.

In order to establish tonnage and time history, the installation date was required for each defect rail. In the case of CSX, this was straightforward since the data was available directly. However, this information was not available for the Burlington Northern Railroad, although, the roll year was available. Therefore, it was assumed that the rail was installed within six months of the year rolled.

(4) Sort Bethlehem data by metallurgy.

In order to correctly represent the difference in manufacturing processes, the analysis had to be performed separately for standard carbon and premium rails. Therefore, the databases were sorted into rails that are of standard carbon metallurgy and "premium" rails, where premium refers to heat treated rail.

(5) Perform cluster analysis on each metallurgy type.

The original intent of the analysis was to find "clusters" of defects (a grouping of defects occurring within a defined geographic proximity to each other) containing a statistically significant defect count, and to perform the defect analysis for the clusters. However, analysis of the data showed only a very limited number of cluster locations, as shown in Table 5.

Table 5. Defect Clusters for Bethlehem Steel Corp.

Defect Clusters	BN	CSX
Segments with >5 defects	2	1
Segments with 2-5 defects	1	1
Segments with 1-2 defects	9	1

Since the defects did not occur on specific segments with sufficient frequency to perform the defect analysis on a segment or cluster basis, the analysis approach was modified, and the defect data analysis was done on a system wide basis for each railroad, using all of the defect data available from each railroad, from the manufacturing periods under study.

(6) Obtain cumulative tonnage data for defects.

Using the known location of each defect, and the railroad tonnage histories for the study time periods, tonnage data for each railroad was determined for each defect location and the corresponding cumulative tonnage was calculated. If the month of the rail laid was not known, it was assumed that the rail was laid in midyear and the cumulative tonnage was calculated accordingly.

(7) Perform defect data analysis.

After reviewing the data set resulting from the above defined data development process, it was determined that a Weibull type of analysis [4, 5] was most appropriate for this study. This was particularly true since the time periods under study had no significant changes in maintenance practices occurring on the two study railroads, i.e., rail installation, grinding, lubrication, and general maintenance practices remained constant throughout the period. [Note; Burlington Northern was undergoing a major concrete tie program, however, this was limited to very sharp curves in limited locations. Since the majority of the rail studied was standard carbon rail, which was laid on tangents and shallow curves where conventional wood ties were used, it was felt that this effect was not significant in the analysis].

The statistical analysis technique used was a two parameter Weibull distribution [4, 5]. This analysis technique relates the probability of a rail defect occurrence to the cumulative traffic tonnage occurring on that rail.

The statistical Weibull distribution is expressed as:

$$PD\,(MGT) = 1 - e^{[-(MGT/\beta)^{\alpha}]} \qquad MGT,\ \alpha,\ \beta \geq 0 \tag{1}$$

where:

PD (MGT) = The probability that a defect will occur on a rail before reaching the specified MGT level.

α = The slope of the Weibull line that best fits the data, which determines the shape of the distribution.

β = The corresponding MGT value at which .632 or 63.2% of the rails will contain a defect. β is termed the characteristic life.

For a detailed description of the Weibull analysis technique and its application to rail data, see References 4 and 5.

Results of Defect Data Analysis

In order to analyze the performance and behavior of the study rail, the corresponding defects were defined according to the Before/After time frames presented in Table 3. To determine the Weibull distribution parameters, and show the differences in rail manufacture, the appropriate structural unit, i.e., the number of rails, was first determined for each category. This was done for each railroad by determining the amount of steel that was purchased from each manufacturer for the years 1987 through 1990. The number of rails used for the Before Analysis was 90% of the sum of the rails purchased in years 1987 and 1988. The number of rails used for the After analysis was 90% of the sum of the rails purchased in 1989 and 1990.

As part of the defect analysis, the data was tabulated in a defect rate format in order to gain a general understanding of the defect behavior. The format used was cumulative defects per 1000 tons of steel for each railroad.

The cumulative defects per 1000 tons of steel for the Burlington Northern Railroad and CSX Transportation are given in Table 6 for defined tonnage levels. Note; the tonnage levels shown are cumulative MGT calculated from the rail installation dates and the annual tonnage levels. In the case of CSX Transportation, tonnage levels may not have been sufficiently high to reach the highest tonnage categories.

Table 6. Cumulative Defects/1000 Tons of Steel

			Cum. Def./1000 Tons of Steel				
			MGT				
RR	**Time Period**	**Rail**	**20**	**50**	**100**	**200**	**>200**
BN	Before	SC	0.00	0.00	0.48	1.48	2.16
	After	SC	0.10	0.15	0.30	0.40	0.40
	Before	HT	0.00	0.00	0.10	0.30	0.60
	After	HT	0.14	0.21	0.21	0.21	0.21
CSX	Before	SC	0.14	0.16	0.26	**	**
	After	SC	0.09	0.09	0.09	**	**
	Before	HT	0.00	0.00	0.24	**	**
	After	HT	0.00	0.07	0.07	**	**

**MGT value may not have been reached.

Analysis of the data presented in Table 6 shows a reduction in the defect occurrence data (defects per 1000 tons of steel installed), in the After category as compared to the Before category. This trend appears to hold for both BN and CSX data and for Standard Carbon and Heat Treated Rail. Note however that the absolute level of defects for the Heat Treated (Premium) rail is quite low and as such the results may not be as statistically valid as those for Standard Carbon rails where the defect count was significantly higher.

As can be seen in Table 6, at the higher tonnage levels the defect occurrence (defects/1000 tons of rails) is 3 to 5 times greater in the Before category than in the After category.

A Weibull analysis of the full set of defects was also performed using the full set of fatigue defects for each manufacturing time period for each railroad. The defect probability (PD) values were determined using 90 percent of the total rails, assuming that the remainder of the rails would be used for turnouts and other applications. Figures 1 through 4 present these Weibull results for BN Standard Carbon rail (Figure 1), BN Heat Treated Rail (Figure 2), CSX Standard Carbon Rail (Figure 3) and CSX Heat Treated Rail (Figure 4).

Examination of the BN standard carbon rail data presented in Figure 1 shows a distinct improvement in Weibull characteristics (slope, intercept) in going from the Before to After defect data. While the number of defects in the After sample was significantly less than the Before, there was still sufficient data to perform the defect analysis. Noting that the railroad's maintenance practices, particularly lubrication, remained the same for the time periods under study, it can be inferred from this Figure that a distinct benefit occurred from the improvement in the steel manufacturing process occurring between the two study periods.

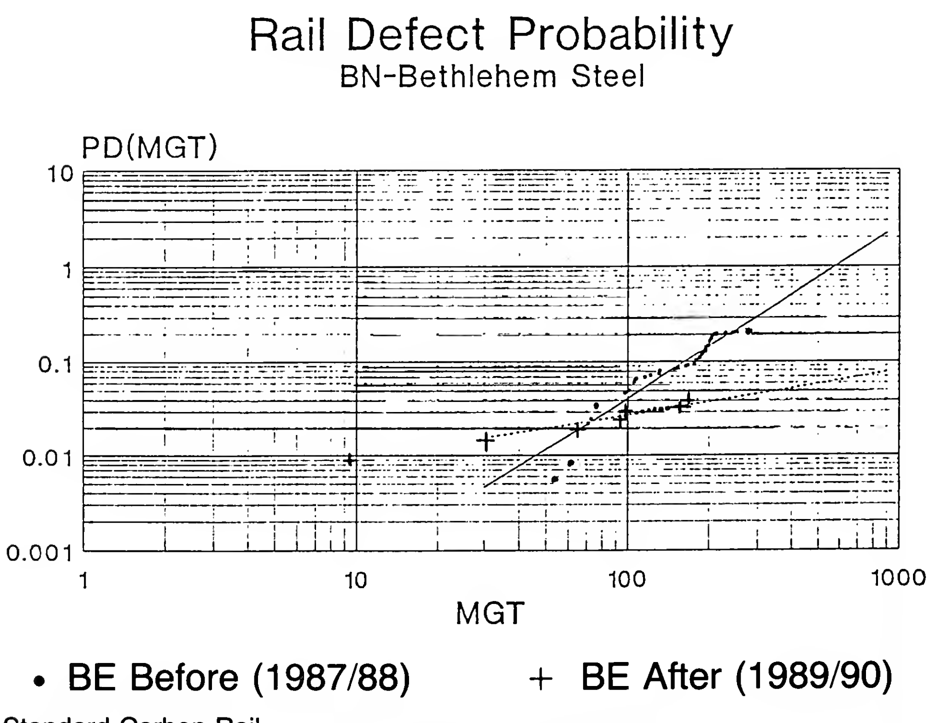

Figure 1. BN Standard Carbon Rail

Examination of the BN Heat Treated Rail shown in Figure 2 shows a similar trend. However, this data should be used with caution since there are only a very limited number of defect data points available in the samples, particularly the After sample.

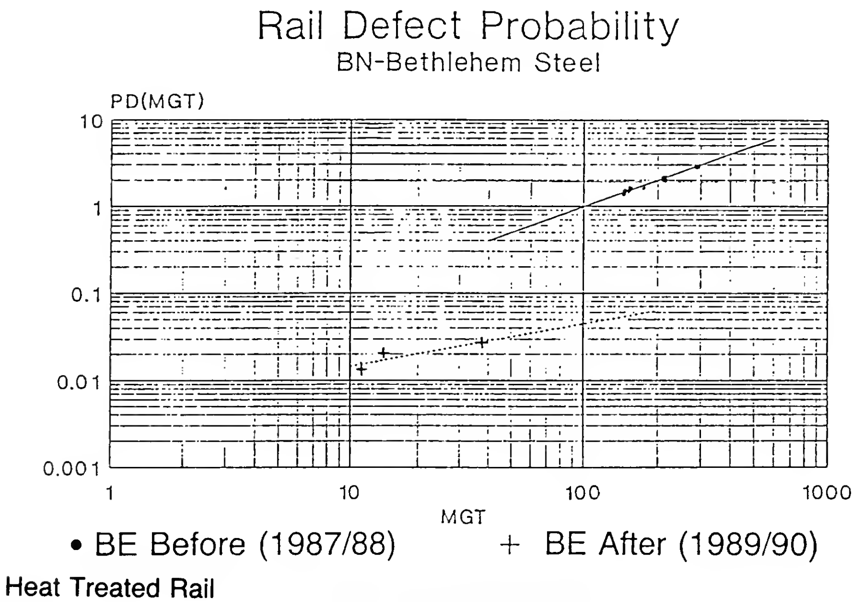

Figure 2. BN Heat Treated Rail

Examination of the CSX Standard Carbon Rail data in Figure 3 likewise showed an improvement in performance in the After data set. However, the difference was not as clear as in the case of the BN data. It should be noted that the tonnage levels for the CSX data was lower, with a maximum level of approximately 100 MGT (as compared to BN data with maximum tonnage levels approaching 300 MGT).

Finally, examination of CSX Heat Treated Rail data, Figure 4, shows that while sufficient data was available for the Before period to calculate a Weibull curve, there was not enough data available in the After data set. While this might lead to the general observation that rail defect behavior was less in the cleaner After steel, no direct data is available to fully support this observation.

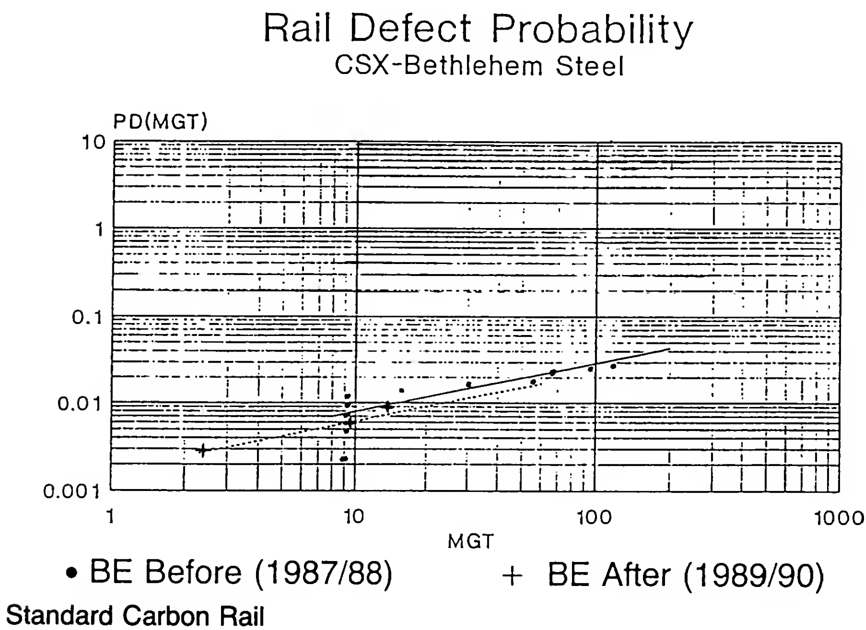

Figure 3. CSX Standard Carbon Rail

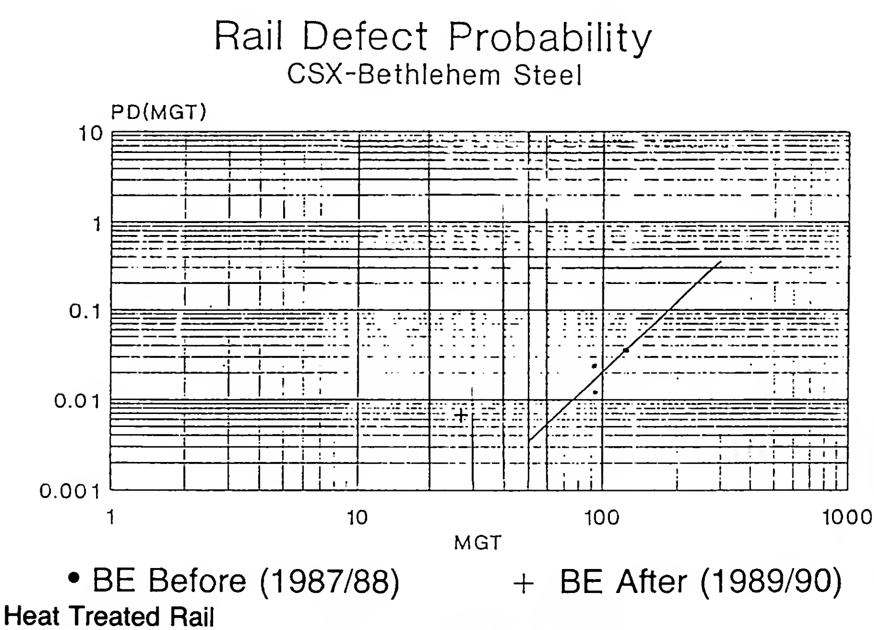

Figure 4. CSX Heat Treated Rail

Discussion of Results

Analysis of the defect data presented in Table 6 and in Figures 1 through 4 shows a distinct and measurable reduction in rail defect occurrence, associated with the change in manufacturing process occurring between the Before and After periods. This is particularly noticeable in the BN data (Figures 1 and 2) where there is a clear and distinct differentiation in the Before and After data trends. While this differentiation is also shown in the CSX data (Figure 3), it is not as distinct, probably due to the lower cumulative tonnages experienced by the study rails on CSX.

Noting that the Before and After rails were generally installed in similar types of locations, and thus experienced similar loadings, and that the maintenance practices on each railroad remained the same for the study periods, it can be inferred that there was a change, and specifically an improvement, in the performance of the rail steel itself, associated with the change in manufacturing process, (see Appendices A and B).

It should be noted here, that while the data set used in this study for the standard carbon rail was statistically significant, the number of defects found in the premium (heat treated) rails for both BN and CSX were relatively small, and as such these results should be treated as preliminary.

It was also observed in this study, that some of the rail defect data required to perform these types of analyses were not conveniently or readily available. In order to avoid inconsistencies in future data sets, a list of data requirements was put together to provide railroads with some guidance for the collection of data for future research. These "standardized" data requirements are presented in Table 7.

Table 7. Standardized Data Requirements

Defect Information	Location Type How Detected Date Found (day/mo/yr)
Track Geometry at Defect Location	Curvature Grade
Maintenance History	Grinding Lubrication
Traffic Information	Train Consist Speed Annual/Cumulative Tonnage
Rail Information	Manufacturer Date Rolled (mo/yr) Date Laid (mo/yr) Rail Section Metallurgy Heat Number Inspection History

Finally, it should be noted that the true goal of any improvement in rail manufacturing process is in the actual improved performance of the rail in service and an associated reduction in rail maintenance costs to the railroad. This becomes increasingly important as railroads look towards increasing traffic densities and axle loadings, as well as reducing their overall operating costs. To this end, any specification or standard should have, as its goal, an improvement in the "life" of the rail under actual service conditions, with such an improvement manifesting itself in terms of increased rail life, reduced level of defects, or reduced overall (life cycle) costs.

Acknowledgements

The authors would also like to acknowledge the contributions of the Burlington Northern Railroad and of CSX Transportation and for their permission to present the data and the results of the study.

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APPENDIX A

I. *Overview of Manufacturing Practice Changes That Have an Effect on Steel Cleanliness*

- Standard Operating and Quality Practices Established for Steel Production
- Improved Refining Practice in Electric Furnaces
  —Better Quality Scrap
  —Increase of Cold Iron in the Charge
  —Oxygen Blowing in the Furnace
  —Improved Tap Temperature Control Through Use of Computerized Model
- Improved Ladle Treatment at Argon Stirring Station
  —Closer Control of Chemical Analysis
  —Strict Compliance to Argon Stirring Practice for Optimum Inclusion Flotation
  —Strict Compliance to Departure Temperatures to the Caster
  —Strict Compliance to Departure Times to the Caster
  —Elimination of Aluminum Addition in Deoxidation Practice with Resultant Reduced Aluminates

I. *Overview of Manufacturing Practice Changes That Have An Effect on Steel Cleanliness (Continued)*

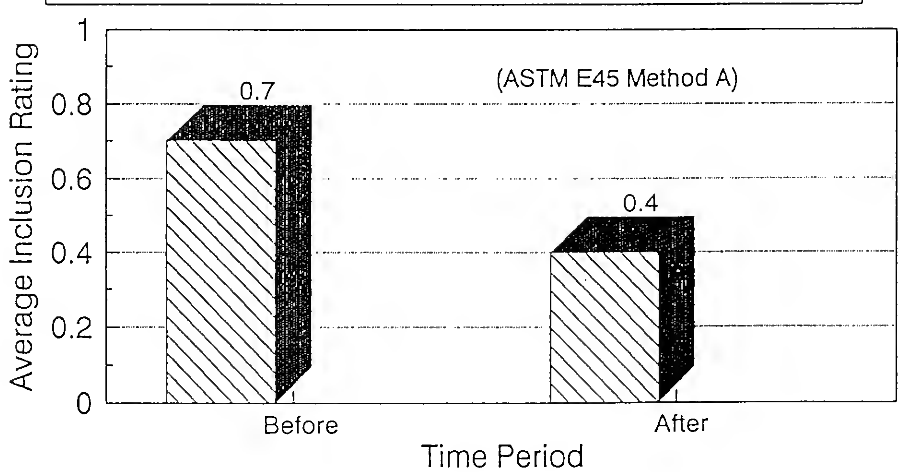
- Improved Continuous Caster Practices
  - —Improved and Excellent Ladle Free Opens
  - —Increase Tundish Volume
  - —Change to By-Pass Stopper Rods in Tundish
  - —Improved Steel Flow Through Tundish by Use of Baffled Walls. Uniform Residence Time and Improved Non-Metallic Inclusion Flotation
  - —Standard Operating and Quality Practices for Caster Operation to Optimize Solidification and Resultant Internal and External Quality

II. *Specific Windows—Steelmaking/Caster Practice Changes to Improve Rail Microcleanliness*

Change I: (Feb. 1989)	Modification of steel flow through tundish by use of baffled walls. Increased tundish capacity from working level of 22 to 28 tons (27.0% increase).
Change 2: (Sept. 1989)	Modification to tundish stopper rod design to minimize air aspiration (reoxidation).
Change 3: (Jan. 1990)	Modification to steel deoxidation practice during furnace tapping (no aluminum).

APPENDIX B

EXAMPLE OF MICROCLEANLINESS IMPROVEMENT FOR ALUMINA TYPE B INCLUSIONS



EXPERIENCE WITH TWO ULTRASONIC-BASED MEASUREMENT TECHNIQUES FOR RESIDUAL STRESS DETERMINATION IN RAILROAD RAILS

By: David Utrata*

Introduction

The need to measure residual stresses in rail is of concern to the railroad industry. The distribution of residual stresses in roller straightened rail, for example, is suspected to affect the degree to which a given rail will exhibit catastrophic web cracking in service [1], but no quantitative evidence has been presented to determine the extent of this relationship. The ability to measure quantitatively the level of residual stress in the component is essential to understanding the complex interaction of residual stress, mechanical strength and service performance in rail.

The goal of the project at hand was to determine the ability of various nondestructive methods to quantitatively document the distribution of residual stresses in roller-straightened rails. Two test methods were evaluated for this task. They consist of two nondestructive techniques based on generating and monitoring ultrasonic waves in the test sample. The two methods evaluated were a commercial device, the Debro-30 Ultrasonic Stress Meter, and a prototype system based on the use of electromagnetic acoustic transducers (EMATs).

The Debro-30, which has been developed by the Polish Academy of Sciences, was evaluated over several test periods. Work was performed in collaboration with researchers from Poland, as well as through intensive studies performed independently by the AAR during a leasing arrangement of the device. The use of EMAT-based ultrasonic testing was investigated through AAR-sponsored work at Magnasonics, Inc. of Albuquerque, New Mexico.

Use of the Debro-30 for Stress Measurements

As mentioned in the introduction, undesirable web cracking tendencies might be linked to the residual stress distribution in rail. In addressing the origin of those residual stress states the roller straightening operation merits scrutiny as a contributor to the development of residual stress. Domestic rail manufacturers were asked to monitor their rail production, and to provide the AAR with rails that had been straightened with different degrees of roller force.

One such rail metallurgy was identified as intermediate strength rail, and was received in several sections. Two of the rail lengths had been straightened in vertical and horizontal planes, and two had been straightened in the vertical plane only. Within these groupings, the rails were designated as having seen the extremes of the range of operating forces for the roller straightener. That is, two rails saw light force in two- and one-plane straightening and two saw heavy force under similar conditions.

A 1-foot length of rail was cut from the trailing end of one of the rails, and was stress-relieved by holding at a temperature of 650°C for about 2 hours, after which it was furnace-cooled. Reference transit times could therefore be obtained on this calibration sample. Polish research has shown that the acousto-elastic constant (the slope of the velocity versus load plot) remains fairly uniform for various rail metallurgies [2]. This alleviated the need to perform this portion of the calibration procedure.

Measurements were made along the running surfaces and base undersides of these rails starting at one foot from the original leading end, and then at two-foot intervals. Figures 1 and 2 show the results of the longitudinal traverses along the heads and bases of these rails, respectively. It is evident that lighter roller force, when applied in either one- or two-plane conditions, imparted a lower residual stress state along the running surface of the rails, but had little effect on the stress measured on the base underside.

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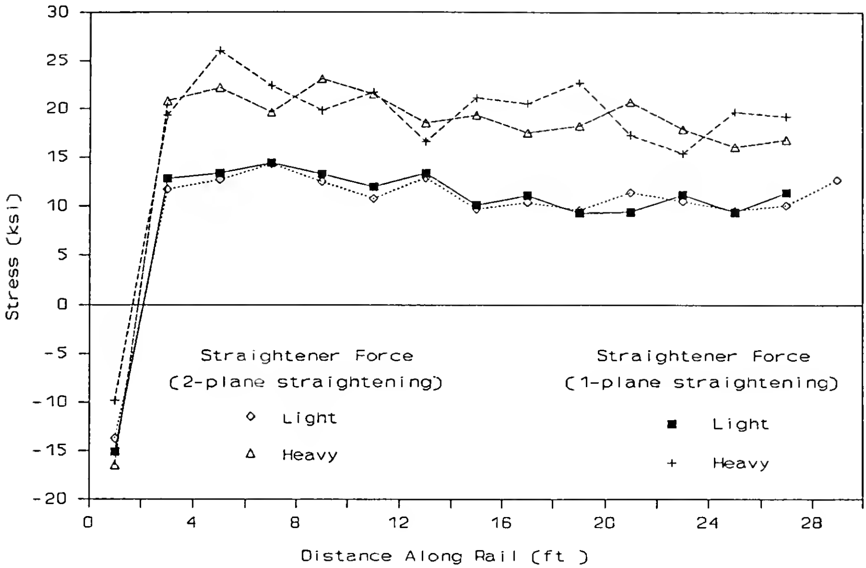

Figure 1. Results of Stress Measurement Along Running Surfaces of Intermediate Strength Rails, Using Debro-30.

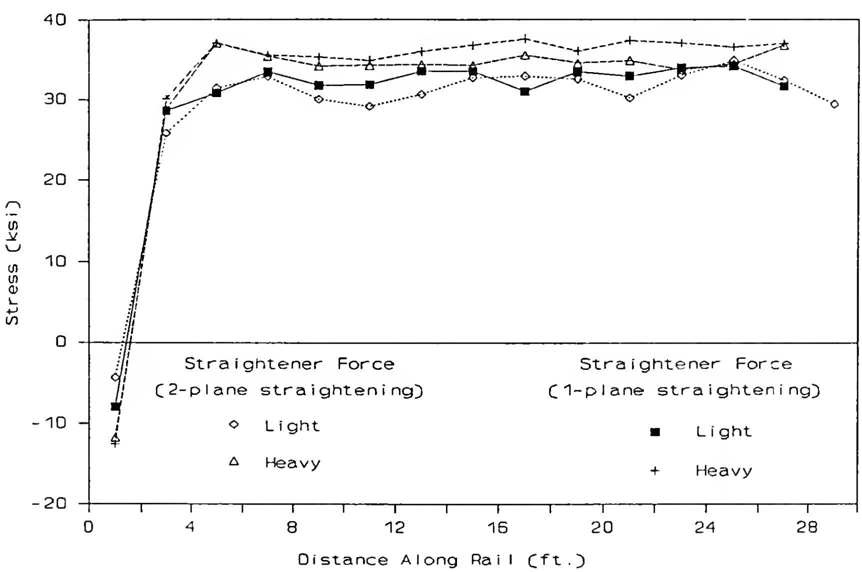

Figure 2. Results of Stress Measurement Along Base Undersides of Intermediate Strength Rails, Using Debro-30.

Also evident is a pronounced stress gradient at the leading end of all four rails. This is indicative of the operating conditions at this production mill. At this mill, the lead ends of the rails are cropped off prior to straightening. A gradient over several feet will occur in the region where the rail is first "pinched" between three offset rollers.

The magnitude of this gradient was seen to be quite steep, with the head region changing from an initial compressive stress state of about -10 ksi (-69 MPa) and levelling off at about 10 to 20 ksi (69 to 138 MPa) in tension. The gradient along the bases was even more severe; an initial stress reading of -10 ksi (-69 MPa) gave way to a reading of + 33 ksi (227 MPa) over a span of approximately 3 feet (1 meter).

The nature of this gradient was examined on a finer scale by repeating a traverse of one of the rails, moving the Debro-30 probehead in six-inch (15 cm) increments along the rail length. Figure 3 shows the results of this survey, and indicates a smooth transition along the stress gradient. The repeatability of the data obtained between the fine- and coarse-scale traverses is an encouraging appraisal of the Debro-30's measurement capabilities.

Various rail samples were assembled at the Chicago Technical Center to allow further studies with the Debro-30. These samples included sections of the intermediate strength rails just mentioned, as well as fully heat treated and standard rails from a second rail manufacturer. This material provided samples from two metallurgies, one of which came from two manufacturers. Further, this selection included rail sections with fairly uniform longitudinal stress distributions, as well as rail sections having pronounced stress gradients.

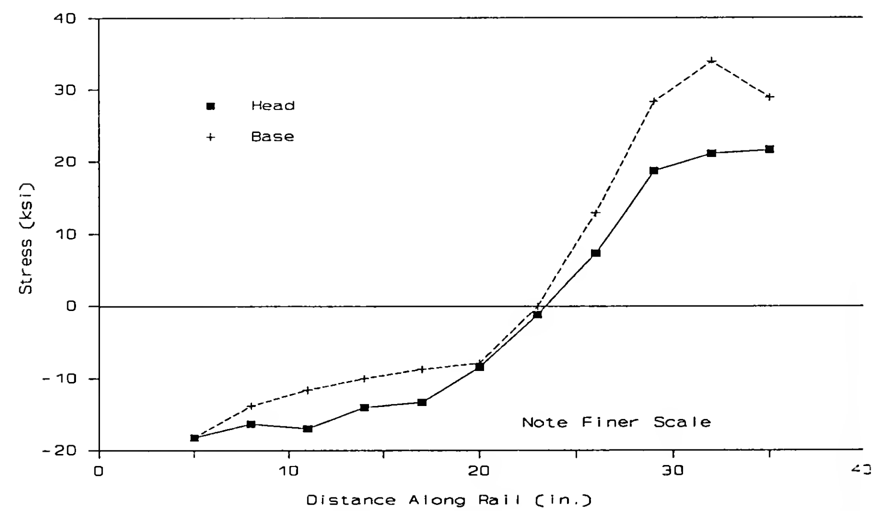

Figure 3. Results of Debro-30 Stress Measurement, Repeated for the Intermediate Strength Rail Straightened in a Single Plane Under Relatively High Pressure, Using Finer Scale.

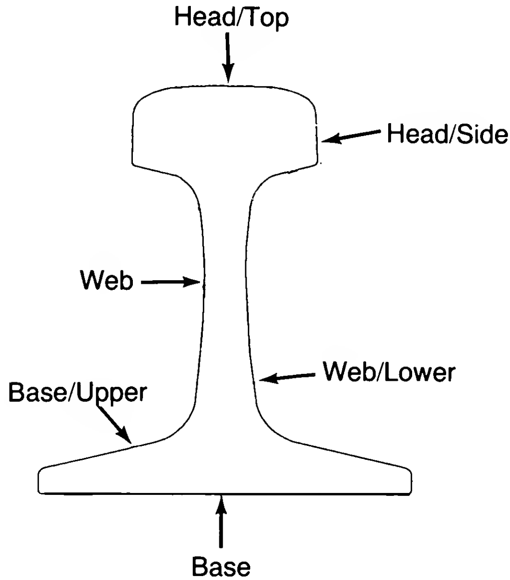

Figure 4. Drawing Indicating the Position of Longitudinal Rail Traverses for Stress Profile Determination with the Debro-30.

Accounting for residual stresses has been acknowledged as a hurdle to overcome in making absolute force (from stress) measurements on rail in track. Essentially, track measurement requires distinguishing residual stresses from stresses induced by thermal changes. The previous section revealed that the longitudinal distribution of stresses may vary considerably along a rail.

The distribution of residual stresses throughout the cross section of a rail has been documented by several researchers [3,4]. Typically, roller-straightened rails will exhibit a tensile longitudinal stress in the head and base, and a compressive stress in the web. This connotes that at two points on each side of the rail cross section, the residual stress must be zero. A stress profile survey was then undertaken to determine if such "null points" occurred at common sites on different rails, and how stress gradients throughout the rail would, in turn, affect stress measurements at such points.

An appropriate calibration was made for each of the rail types by subjecting a 1-foot piece from each section having uniform stress distribution to the thermal stress relief treatment. The six full sections were then inspected with the Debro-30 at six inch intervals, running along (a) the top of the head, (b) the side of the head, (c) at mid-height on the web, (d) on the lower web, just above the base fillet, and (f) on the underside of the base. These positions are indicated in Figure 4.

Figure 5 shows the stress profiles measured along one of these sections. This figure shows the results from the intermediate strength rail having a non-uniform stress gradient section. The stress measurement taken along the upper base, just below the base fillet, demonstrated the least amount of fluctuation. The traverses at this position on the six rail pieces are shown plotted together in Figure 6, and indicate a similar behavior on all of the rail sections examined.

The implications of such results are that it may be feasible to make thermal stress measurements at this region along rail in track, and be fairly confident that the results obtained were perhaps just slightly influenced skewed toward a more compressive reading. Taking this behavior into consideration, the field reading could then provide a slightly conservative reading of the actual thermally-induced or rail creep induced track force. Much work needs to be done to validate this statement. The effects of other metallurgies and of particular roller-straightening practices will need to be studied to determine the applicability of this behavior to all rails.

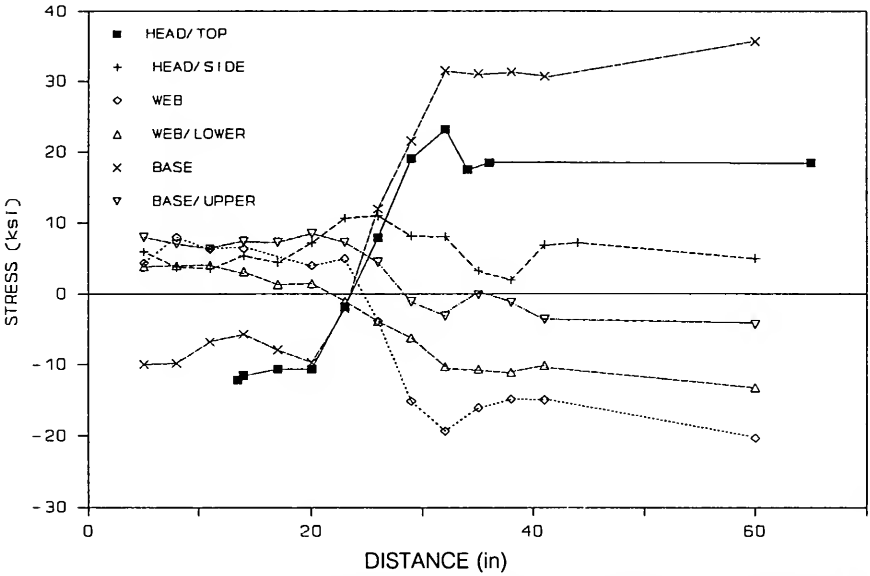

Figure 5. Stress Profile on Intermediate Strength Rail Along Upper Base Region, Using Debro-30.

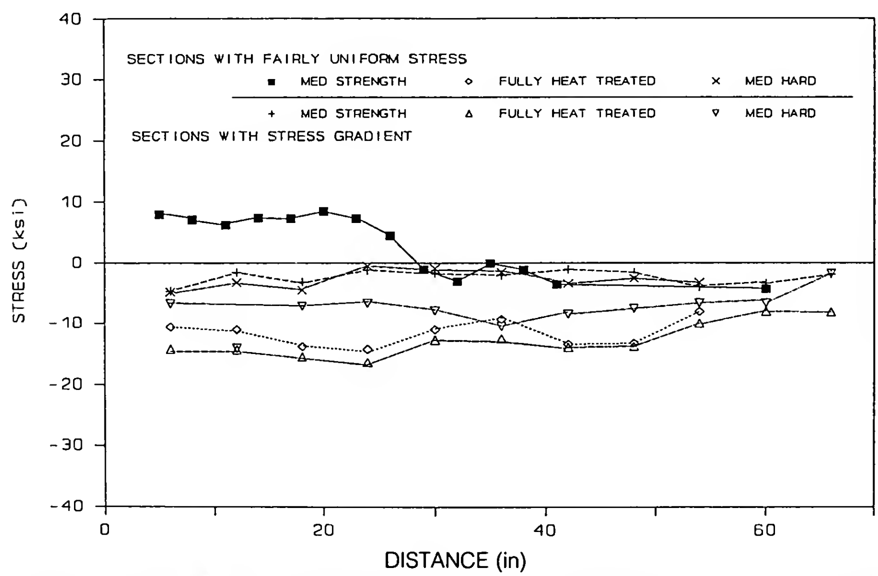

Figure 6. Stress Profiles for Various Rails Along the Upper Base Regions, Obtained with the Debro-30.

Testing with Electromagnetic Acoustic Transducers (EMATs)

The second major aspect of this investigation involved the evaluation of an EMAT-based system to measure stresses in rail. The use of EMATs is attractive primarily in two respects. First, these transducers do not require the use of a couplant, as ultrasound is induced in, rather than transmitted to, the surface of the test piece. Second, EMATs may be configured to generate ultrasonic wave modes that could not be easily achieved with piezoelectric transducers, such as surface-skimming shear horizontal (SH) waves [5,6].

Recent advances in the theory of wave propagation [7] have concluded that stress may be determined when the propagation and polarization directions of shear waves are interchanged, and their velocities measured.

If a transmitter/receiver EMAT pair is mounted on the sample surface to generate and detect such waves, a measurement of the transit time, required to traverse the separation distance between the transducers, will allow for calculation of the wave velocity. Rotation of such an arrangement about an axis perpendicular to the surface will effectively interchange the polarization and propagation directions of the shear wave. The exact theory for sound wave propagation in stressed and anisotropic media further relates the transit time to the angle between the line joining the transducers and the axis of the specimen. The major implication of such theory is that stress measurements may be made independent of texture and material considerations which would normally affect the results.

Selected sections of the rails that had been studied with the Debro-30 device were shipped to Albuquerque for analysis with the EMAT-based system. The results of the EMAT stress measurements on the portion of the intermediate strength rail that had exhibited a pronounced stress gradient are shown in Figure 7. Testing with the EMAT-based system was performed along the running surface and center of the base of the rail, as well as on both the brand and stamp sides of the web at mid height.

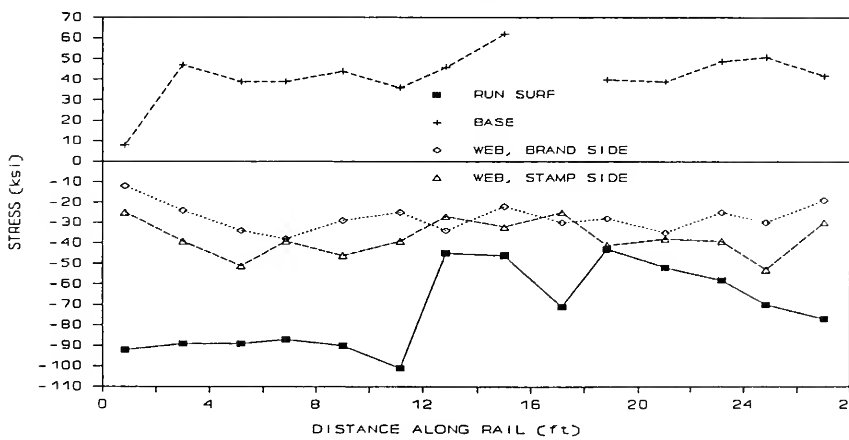

Figure 7. Stress Distribution Along an Intermediate Strength Rail, as Determined on an EMAT-Based System.

Quite high residual compressive stresses were reported along the running surface of the rail. This is in contradiction to experimental observations and stress analyses [3,4,5] that indicate roller-straightened rails typically exhibit a longitudinal residual tensile stress in the head and base regions, and longitudinal residual compression in the web region. Tensile stresses were reported to exist in the base region, and compressive stresses of somewhat differing magnitudes were noted across the web of the rail.

While both measurement techniques report the existence of a stress gradient of about 40 to 45 ksi (276-310 MPa) along the rail head in the first 30 inches or so of the rail, there exists a pronounced discrepancy in the two absolute stress values. The Debro-30 gave results that indicated a reversal of the sign of longitudinal stress in the rail and the EMAT technique indicated stress values only in the tensile regime.

The points of good agreement between the two techniques appear to be that, in both cases, residual tensile stresses were detected in the base regions and residual compression was detected in the web area. While the values reported for the level of compression in the web were in close agreement, the values for the base differed by about 20 ksi (138 MPa).

Discussion

The results that the two methods produced for the values of stress in various rail samples show similarities on a qualitative basis. However, stress readings obtained on the running surface of test rails, in particular, are obviously in significant disagreement. An unacceptable reading must be associated with the EMAT-based measurement. The origin of this discrepancy is currently unknown. New research suggests that spurious readings obtained with certain nondestructive methods may be susceptible to an outer layer of plastic deformation on the surface of test samples. Whether such surface effects are the mechanism responsible for the readings gathered on steel rail remains to be proven.

Given these, it is concluded that the Debro-30 has provided valid estimates of the residual stresses in various rail samples. Stress measurement using EMAT-based technology, at this point in time, seems hampered by surface effects that remain to be identified. It is obvious that further refinement in the manipulation and interpretation of this technology is required.

This observation is by no means to be construed as an outright endorsement by the AAR on behalf of the Debro-30, nor is it intended to be a condemnation of the use of EMATs for such measurements. As stated at the outset, this work was an exercise to evaluate two methodologies as possible candidates for stress measurement in the railroad industry.

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MEMOIR

FLOYD OTIS JOHNSON, JR.
1926-1991

Floyd O. Johnson, Jr., age 65, retired General Manager, Railroad Sales (Executive Dept.) of CF&I Steel Corp., died September 3, 1991 at a hospice in Colorado Springs after a protracted illness following surgery earlier this year.

Mr. Johnson was born July 18, 1926 in Greeley, Colorado to Floyd O. Johnson, Sr. and Fern (Elam) Johnson. After serving during WWII in the U.S. Navy 1944-1946, he received a B.S. in Civil Engineering from Iowa State University in 1949. He married Nancy Anne Malmborg in Minneapolis, Minnesota on April 15, 1950. She preceeded him in death in 1990.

Mr. Johnson began his railroad engineering career as a Junior Engineer in the Engineering Department of the former Pennsylvania Railroad in March of 1949 and was Assistant Supervisor of Track at Orrville, Ohio when he left the Pennsylvania Railroad in December of 1953 to join the Railroad Sales Department of The Colorado Fuel and Iron Corporation at Denver, Colorado. He was appointed Assistant to General Manager Railroad Sales in May 1960, Manager Railroad Sales in January 1962, and General Manager Railroad Sales in November 1976, which position he held until his retirement in March 1984. Subsequent to his retirement from CF&I Steel Corp., he continued his involvement in railroad industry activities as a Consultant in Railroad Marketing to the L. B. Foster Company and to the Association of American Railroads where he was engaged in marketing the Facilities of the AAR Transportation Test Center at Pueblo, Colorado.

He joined the American Railway Engineering Association in 1949 and became a Life Member in 1987. He served on Committee 3—Ties, Committee 24—Engineering Education, was a member of the Annual Technical Conference Arrangements Committee for many years, and actively supported and promoted the work of Committee 4—Rail. A proponent of professionalism in railroad engineering and an advocate of supply association support of the railroad industry, he was a Past President of the Railway Engineering and Maintenance Supply Association and served as Chairman of the Railway Progress Institute in 1976 at a time when the railroads were engaged in a battle to survive. He had been involved in community affairs in Denver and Colorado Springs, had been a member of the Denver and Pueblo Chambers of Commerce, and at the time of his death, an active member of the First Lutheran Church of Colorado Springs.

Mr. Johnson is survived by two daughters, Mrs. Denise Anne Nicholson of Littleton, Colorado, and Mrs. Stephanie Lyn Barron of Cascade, Colorado; four grandchildren; and his mother Mrs. Fern Johnson of Colorado Springs, Colorado.

Well known and respected in the industry, he will be missed both personally and professionally by his associates, colleagues, and friends and his advocacy and reasoned judgement will be sorely missed by the Association, the engineering profession, and the railroad industry.

Ralph G. Michael
Donald V. Sartore

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